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Design Analysis Report for the TN-WHC Cask and Transportation System

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Abstract: This document presents the evaluation of the Spent Nuclear Fuel Cask and Transportation System. The system design was developed by Transnuclear, Inc. and its team members NAC International, Nelson Manufacturing, Precision Components Corporation, and Numatec, Inc. The cask is designated the TN-WHC cask. This report describes the design features and presents preliminary analyses performed to size critical dimensions of the system while meeting the requirements of the performance specification.

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E-15166

DESIGN ANALYSIS REPORT

FOR THE

TN-WHC CASK

AND

TRANSPORTATION SYSTEM

PROJECT 3035

Item no. 8
WHC Specification no. WHC-S-0396
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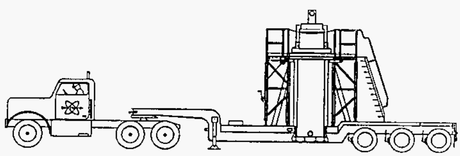

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E-15166

Final Design Analysis Report
for the
TN-WHC Cask and Transportation System

Initial Issue:

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PART A: DESCRIPTION AND OPERATIONS

A1.0 INTRODUCTION

A1.1 GENERAL INFORMATION

This Design Analysis Report (DAR) presents the evaluation of the design of the cask and transportation system (including a unique operations support system) to perform the on-site transfer of Type B, Highway Route Controlled Quantity (HRCQ) fissile spent fuel. The design of the system has been developed by Transnuclear, Inc. and its team members consisting of NAC International, Nelson Manufacturing, Precision Components Corporation and Numatec, Inc. The cask is designated the TN-WHC. This DAR describes design features and presents preliminary analyses performed to size critical dimensions of the system while meeting the requirements of the Specification for SNF Path Forward Cask and Transportation System, Hanford Specification[(1)].

The TN-WHC Cask and Transportation System will be used for safely packaging and transporting approximately 2,100 metric tons of unprocessed, spent nuclear fuel from the 105 K East and K West Basins to the 200 E Area Canister Storage Building (CSB). Portions of the system will also be used for drying the spent fuel under cold vacuum conditions prior to placement in interim storage.

The spent nuclear fuel is currently stored underwater in the two K-Basins. The fuel elements will be placed in special baskets and stacked in the Multiple Canister Overpacks (MCO) that have been previously placed in the cask. The MCO shield plug will be installed on the MCO. The cask will be removed from the K Basin load out area and taken to the cold vacuum drying station. Here the MCO shield plug retaining ring will be installed on the MCO, the water will be removed from the MCO and the cask prepared for transportation to the CSB. Shipments will occur exclusively on-site, specifically between the K-Basins and the CSB. Travel will be by road with one cask per trailer.

A1.2 SYSTEM DESCRIPTION

The Cask and Transportation System consists of a transport cask with a dedicated semi-trailer. It is designed to transport the cask in the vertical orientation. A single MCO loaded with spent fuel baskets will be transported from the K-Basins' Loadout Facility to the CSB. The System layout is shown on Figure A1.2-1. Unique operations equipment has been developed for the K-Basin

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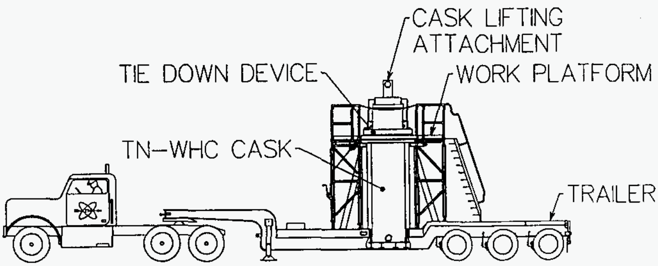
Figure A1.2-1 TN-WHC Cask and Conveyance System



Loadout pit. The equipment has been engineered to:

- minimize cycle times
- achieve excellent control of contamination
- provide high margins of safety
- minimize waste generation
- minimize personnel exposure
- support ease of operations by facility personnel.

Descriptions of the cask, conveyance (trailer), cask lifting attachment and the operations equipment are provided below. Detailed design drawings are provided in Section A9.1 (Appendix).

A1.2.1 Cask

The cask consists of a body fabricated from stainless steel forging(s) and a bolted-on stainless steel lid with two welded on trunnions. The cask incorporates features for ease of loading, decontamination and routine handling. The design is engineered to minimize cask maintenance and maximize in-service time and for ease of fabricability to enhance project completion goals.

The overall dimensions of the cask are 170.25 inches long and 39.81 inches in diameter. The cask cavity has a length of 160.50 inches and a cavity ID of 25.19 inches. The general arrangement of the cask is depicted in Figure A1.2-2. The cask is designed to be lifted and placed in a vertical orientation only. Component terminology used in this DAR is also identified on Figure A1.2-2. The closure lid end is referred to as the top with the cask in the vertical orientation.

A1.2.2 Cask Lifting Attachment

The cask is lifted from the trailer and from the Cask Operations Equipment, and maneuvered by two trunnions welded on the lid. The layout of the attachment is shown on Figure A1.2-3. The lifting attachment is used for loading and unloading the cask from the conveyance system, for movement to and from the load out pit and the CSB, and for any other cask handling operations. It is designed to lift the cask vertically and move with the cask in the vertical orientation only. The lifting attachment structural members are constructed of stainless steel.

The lifting attachment consists of two trunnions which are welded to the cask lid by a set of brackets and gussets. The geometry and dimensions are shown in Figure A1.2.3. All components are made of 304 stainless steel.

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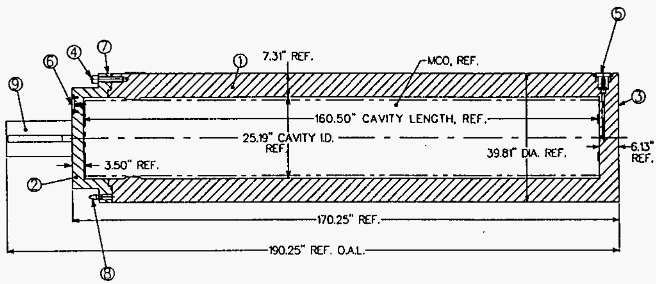
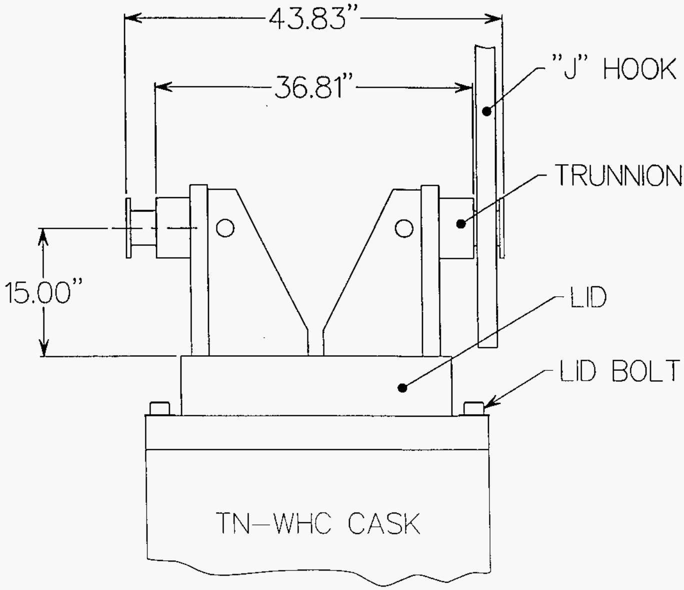
Figure A1.2-2 General Arrangement of the TN-WHC Cask



ITEM NO.	DESCRIPTION
1	Cask Body
2	Closure Lid
3	Bottom Plate
4	Lid Bolts
5	Drain Port
6	Vent Port
7	Bolting Flange
8	Lid Alignment Pin
9	Cask Lifting Attachment

Figure A1.2-3 TN-WHC Cask Lifting Attachment



A1.2.3 Conveyance

The conveyance system is a semi-trailer which can be attached to a standard tractor. The trailer provides the necessary supports and attachment points for securing the cask in the vertical orientation.

A1.2.4 Cask Operations Equipment

The K-Basin Loadout Pit Operations Equipment for the TN-WHC cask has been designed to support the concept of "start clean, stay clean". An immersion pail with a sealing lid encloses the cask in a clean demineralized water cavity. The entire enclosed immersion pail, cask, MCO, and seal lid assembly is then lowered into the K-Basin Loadout Pit for loading of the MCO. Pneumatic seal contact surfaces between the immersion pail seal lid and immersion pail, and between the seal lid and MCO, contain an internal immersion pail positive 2 psig relative pressure to external hydrostatic pressure during all in-pit operational sequences. Use of the sealed immersion pail precludes contamination of the exterior and interior surfaces of the cask.

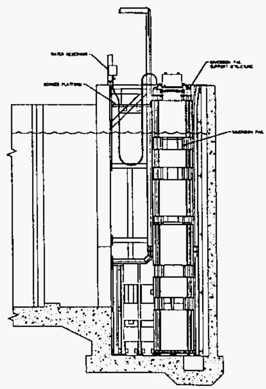
The immersion pail is supported by a steel frame support structure extending from the floor of the loadout pit to the top of the loadout pit shield wall, or from lift slings and the facility crane, depending on the system's operational configuration. During immersion pail cask loading and unloading activities, the immersion pail is supported by the immersion pail support structure. The facility crane with slings is used to lower and raise the immersion pail from the pit side support structure to the pit floor for MCO loading. Worker access is provided to the immersion pail seal lid and system connections in the area opposite the fuel transfer canal during pre and post MCO loading by two worker platforms supported from the loadout pit shield wall. This loadout pit worker platform is provided for operational flexibility and not intended to be a required access point for normal operations. Normal operation of the immersion pail system is intended to be performed by operators from the main operations floor without the use of special tooling. The immersion pail support structure and worker platform are passive structures that, once installed prior to initiation of operations, do not need to be removed during the normal cask operations. Compressed air and demineralized water supply are required to support the MCO loading operation. Figure A1.2-4 presents the K-Basin Loadout Pit Operations Equipment as supported by both the in pool support structure and facility crane.

The immersion pail lid is handled by the facility crane during installation and removal for each loading cycle. The pail lid is lowered in place, seals are pressurized, and deionized water flow established. Seal integrity verification occurs at this point in the operation.

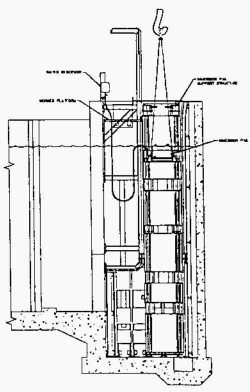
The immersion pail lid is fabricated of stainless steel to mitigate concerns about corrosion and abrasion. The lid is held in place through seal pressure, dead weight and four bolts to the main pail structure. The lid design limits seal crevasses and pool water entrapment. permits flushing of the seal surface prior to breaking the seal, and permits clean immersion pail water to flow from the seal boundary when seal pressure is removed. Each of these features supports ease of decontamination during the operation sequence.

Figure A1.2-4 K-Basin Loadout Pit Operations Equipment

A. Support Structure Configuration



B. Crane Support Configuration



References For Section A1.0

1. Performance Specification For TN-WHC Cask And Transportation System, WHC-S-0396, Rev. 1, September 1995.

A2.0 PACKAGING SYSTEM

The packaging system is the assembly of components necessary to ensure compliance with the materials containment and compliance requirements delineated in Hanford Specification[1]. The Cask and Transportation System consists of the cask with lifting attachment, the dedicated trailer with the tiedown system, and the operations equipment.

A2.1 CONFIGURATION AND DIMENSIONS

A2.1.1 Cask

The structure of the cask is a right circular cylinder with a bottom and a closure lid. The basic components of the cask are the cask body, closure lid and the lid bolts. The cask body consists of the cylindrical shell and the bottom plate. The closure lid is attached to the cask body with twelve 1.5 inch diameter bolts. Two lifting trunnions with brackets and gussets are welded to the top end of the lid and are a 180° apart. Two penetrations into the containment are provided to support cask operations. One is located at the lid and the other is located in the cask bottom. The maximum gross weight of the loaded cask is 57,910 pounds including a payload of 18,950 pounds. The cask is transported in the vertical orientation with the lid end facing upward. During transport, the cask is supported on the trailer by an upper tiedown device and a lower cup shaped retainer.

The following sections provide a physical and functional description of each major component. Detailed drawings showing dimensions are provided in Section A9.1. A complete materials list is provided in Section A2.2. Reference to these drawings is made in the following physical description sections and in general, throughout this DAR. Fabrication of the cask will be performed in accordance with the design drawings.

Cask Body

The cask body assembly is shown on drawing H-1-81535, sheet 1 of 5 and consists of a circular cylinder (shell) welded to a bottom plate. The stainless steel material for the shell and bottom plate is ASME SA-336 Type F304 or equivalent. The shell is 7.31 inches thick. The bottom plate is 6.13 inches thick. The overall length and diameter of the cask body is 170.25 inches and 40.57 inches respectively. The welds in the shell assembly (containment boundary welds) are full penetration welds.

Attachments and subassemblies associated with the cask body include:

- Lifting attachment on top of the lid.
- MCO standoffs on the inner surface of bottom plate.

- Cask drain penetration through the bottom plate.
- Cask vent penetration through the lid.
- Lid alignment pins.
- Lid bolts and washers

Closure Lid and Bolts

The design of the closure lid is shown on drawing H-1-81535, sheet 4 of 5. The closure lid is a 3.5 inch flanged plate made from ASME SA-336, Type F304 stainless steel or equivalent. This plate forms the lid portion of the containment boundary. The perimeter of the lid has 12 equally spaced holes for the closure bolts which are located on a 36.44 inch diameter bolt circle. The closure bolts are nominally 1.5 inch in diameter manufactured from ASME SA-479-XM19, hot rolled or equivalent material.

One dovetail seal groove is machined in the underside of the lid flange. A Butyl o-ring is installed in this seal groove. The o-ring provides the containment boundary function.

Two lid alignment pins are provided to ensure that the lid is properly aligned with respect to the cask body so that the lid bolts can be installed.

Cask Lifting Attachment

The lifting function is provided by a pair of lifting trunnions welded to the brackets and gussets. The brackets and gussets are welded to the top surface of the lid, 180° apart. Detailed dimensions of the lifting attachment are shown on drawing H-1-81535, sheet 4 of 5. This trunnion pair is sufficient for lifting a 30 ton loaded cask vertically.

Containment Penetrations

There are a total of two penetrations through the containment vessel, one located in the lid end (designated the Vent Port) and the other, in the cask bottom (designated the Drain Port). The penetrations are used to drain, dry, backfill and vent the containment boundary, or circulate warm water in the interspace between the cavity wall and the MCO. All penetrations are closed and sealed during transport. The configuration details of each penetration including seals, covers and bolts are shown on drawings H-1-81535, sheets 3 of 5, and 5 of 5.

Vent Port

The vent port is used for venting and back filling of the cask cavity. It is a direct penetration through the lid, 0.44 inch in diameter, with a threaded outer end to accept a quick-disconnect fitting.

The vent port is closed by a 6.0 inch diameter, 0.75 inch thick blind flange which is secured to the lid with four 0.5 inch diameter socket head cap screws. The penetration cover is recessed into the outer plate of the lid so that the outer surfaces are flush. A single Butyl o-ring is mounted in a dovetail groove machined in the underside of the penetration cover.

Drain Port

This penetration is located in the bottom of the cask body. Access to this penetration is located on the side of the cask body at the bottom plate. A 0.63 inch hole is drilled from the inside surface of the cavity bottom to the cask body side and includes a 90° bend as shown on drawing H-1-81535, sheet 3 of 5. The drain port permits draining of the cask cavity with the TN-WHC cask in a vertical orientation. A quick-disconnect coupling is provided at this penetration. As on the vent port, a blind flange which maintains the containment boundary at this point is secured over the drain port by four bolts. A single butyl o-ring is located in the dovetail groove machined in the penetration cover.

A2.1.2 Cask Lifting Attachment

The lifting attachment for the cask is used for loading and unloading the cask from the conveyance system, for movement at the loadout pit and the CSB, and for any other cask handling operations. It is designed to lift the cask vertically with the cask in the vertical orientation only.

The lifting assembly consists of two trunnions which are attached to the cask lid by a set of brackets and gussets. The overall dimension of the lifting attachment is 43.83 inches. The design details are provided on drawing H-1-81535, sheet 4 of 5.

A2.1.3 Conveyance

The design of the trailer is shown on drawings H-1-81555, H-1-81556, and H-1-81557. The basic components are:

- Main Beams
- Frame
- Deck
- Kingpin
- Landing Legs
- Axles
- Suspensions
- Wheels
- Tires
- Brakes

The major dimensions are as follow:

- Overall length 40', With the tractor approximately 54'
- Overall width 10'
- Overall height 17'-7" (loaded at top of the cask lifting attachment)
- Loaded deck height 3'
- Loaded ground clearance 12"

A2.1.4 Cask Operations Equipment

The K-Basin Loadout Pit Operations Equipment consists of an immersion pail, support structure and operator work platform. In addition to pit side equipment an MCO Cold Vacuum Drying (CVD) Lid is provided to support conditioning/drying of the MCO. Drawings of the individual equipment components and pail assembly showing dimensions and materials for the operations equipment, and drawings of the system general arrangement include the following:

H-1-81543	K-Basin Immersion Pail, Lift Beam Assembly
H-1-81544	K-Basin Immersion Pail
H-1-81545	K-Basin Immersion Pail Support Structure
H-1-81546	K-Basin Immersion Pail Seal Lid
H-1-81547	K-Basin Immersion Pail Assembly
H-1-81549	K-Basin MCO / Cask Cold Vacuum Drying Lid
H-1-81550	K-Basin Immersion Pail Ancillary Equipment
H-1-81551	K-Basin Immersion Pail Interface Control Drawing
H-1-81552	K-Basin Immersion Pail Lock Pin Guide Assembly
H-1-81553	K-Basin Immersion Pail Support Structure Assembly
H-1-81554	K-Basin Immersion Pail Support Equipment

The immersion pail is a thin walled circular cylinder 165.5 inches long with a sealed foam filled floatation cavity. Use of the floatation cavity in the immersion pail design permits the existing crane hardware to lift the pail, cask and filled MCO to the top of the loadout pit shield wall without challenging the crane load capacity. Locating the top of the immersion pail at the top of the loadout pit shield wall for operator access reduces cumulative operator dose supporting project ALARA objectives.

The immersion pail base plate carries the cask load to the pail wall which uniformly transmits the cask load in tension to the top shell ring structure and four immersion pail lifting lugs. The immersion pail lift lugs interface with the loadout pit immersion pail support structure or the crane lift slings. During system operation when the immersion pail is moving between support points the immersion pail lift lugs travel within a captured tracking provided by the support structure tub steel columns. The cross section envelop of the immersion pail is 42.75 inches x 53.5 inches which transmits the cask load to the immersion pail structure base plate in bearing when the immersion pail and cask is located on the floor of the loadout pit for the MCO loading operation. The immersion pail support structure base plate is 48.06 inches x 56.87 inches. These envelope dimensions permit pail operation without removal of existing rail structures mounted to the side of the loadout pit. Location control and guidance of the cask during insertion into the immersion pail is provided by a series of beveled, stepped concentric landings. Initial pail opening of 42 inches reduces to 40 inches over approximately 18 inches of axial cask travel.

The immersion pail loadout pit support structure is a steel frame two part structure approximately 320 inches high. Leveling feet are provided between each set of corner column tube steel supports for initial structure installation into the loadout pit. Solid foundation for the support structure is provided during the equipment installation process. Following initial location of the immersion pail, pit support structure grout is installed beneath the support structure base plate providing a solid load path from the support structure to the loadout pit floor. The immersion pail loadout pit support structure provides support for the empty MCO, cask and immersion pail during the task activities performed for maintaining a contamination free boundary prior to lowering the cask to the pit floor. Also, this structure provides support for the loaded system following fuel loading while performing activities for moving the contamination free cask to the cask transport trailer. Manually operated lock pin assemblies are mounted to the top of each of the immersion pail support structure corner columns. The lock pins are designed to be locked in the full open or full closed position.

Two worker platforms are suspended from opposite sides of the loadout pit shield wall to form a slotted work surface, permitting operator access to the immersion pail lid opposite the fuel transfer canal without the use of special tooling. Slotted access is maintained to provide MCO loading system flexibility permitting monorail cable access from the pool to the loadout pit during fuel loading of the MCO. Providing the slotted access permits system operation without movement of the work platform.

The immersion pail seal lid is a stainless steel weldment fitted with inflatable seals on the pail and MCO interface surfaces. The lid is sized to provide approximately 0.5 inch nominal clearance between the MCO and inside diameter of the seal lid. The seal lid and immersion pail boundary provides approximately 0.1 inch nominal clearance. Seal pressure of 45 psig activates the silicone seals which have been rated to withstand radiation environments of 150 Rem/hr. Three lifting lugs are provided for moving the immersion pail lid to and from the immersion pail using slings and the facility crane. Vent port design captures the highest fluid elevation in the inner radius of the lid cavity and is located in the outboard section of the lid to permit easier access during operation.

A2.2 MATERIALS OF CONSTRUCTION

A2.2.1 Cask

The materials of construction are summarized in the following table:

Component	Material
Cask Shell	ASME SA-336, Type F304 or equivalent
Bottom Plate	ASME SA-336, Type F304 or equivalent
Closure Lid	ASME SA-336, Type F304 or equivalent
Closure Bolts	ASME SA-479-XM19, hot rolled or equivalent
O-Ring	Butyl, Parker B612-70 or equivalent

Materials for other miscellaneous components are listed on drawings H-1-81535, sheets 1 to 5. (Section A9.1).

A2.2.2 Cask Lifting Attachment

The lifting attachment structural members are constructed of stainless steel, ASME SA-182, Grade F304. Materials for other miscellaneous components are listed on drawing H-1-81535, sheet 4 of 5.

A2.2.3 Conveyance

The materials of construction are summarized in the following table:

Component	Material
Main Beams	A514 (T1)
Frame	A-36
Kingpin	SAE-J700

Materials for other miscellaneous components are indicated on drawings H-1-81555, H-1-81556, and H-1-81557.

A2.2.4 Cask Operations Equipment

The K-Basin Loadout Pit Operations Equipment consists of an immersion pail, loadout pit mounted support structure and loadout pit shield wall suspended work platform. In addition to the loadout pit operations equipment an MCO Cold Vacuum Drying Lid is provided to support conditioning/drying of the MCO. Materials of construction are listed on each component drawing for the respective component item number. The primary immersion pail structure is constructed from Type 304 stainless steel. The immersion pail support structure and loadout pit work platform are fabricated from Type A36 and Type A500 series carbon steel and coated to protect it against corrosion over the life of the system. The immersion pail lift beam is fabricated from Type 516 carbon steel and the sling storage box and the immersion pail positive pressure reservoir are made from Type 304 stainless steel. The lock pin is Type 17-4PH stainless steel in order to provide significant margin of safety when postulating a two support configuration with ANSI 14.6 load factors.

The immersion pail seal lid and the MCO conditioning lid are fabricated from Type 304 stainless steel.

A2.3 MECHANICAL PROPERTIES OF MATERIALS

A2.3.1 Cask

The mechanical properties of the structural materials used in the cask is shown on following table as a function of temperature. The materials are identified and procured by reference to ASME or corresponding ASTM specifications. The yield and ultimate strengths of the structural steels shown on table are the minimum values specified in the material specifications. The ASME[(2)] design stress intensity values (S_m) for Class 1 components are used to establish allowable stresses for the elastic analyses performed for the cask. Stress intensity limits for the various stress categories are discussed in Sections B4.3 and B4.4.

Temperature Dependent Material Properties

Component	Material	Temp. °F	Ultimate S_u(ksi)	Yield S_y(ksi)	Allow. S_m(ksi)	E (E^6 psi)	α^* (E^{-6})
Cask Body and Lid	SA-336 Type F304	70	70	30	20	28.3	8.55
		200	66.2	25	20	27.6	8.79
		300	61.5	22.5	20	27.0	9.0
		400	60.0	20.7	18.7	26.5	9.19
Lid Bolt	SA-479 XM19 Hot Rolled	70	135	105		28.34	8.87
		200				27.6	9.02
		300				27.0	9.10
		400				26.5	9.14

* Mean Coefficient of Thermal Expansion (in/in-°F) from 70°F to the Indicated Temperature.

A2.3.2 Cask Lifting Attachment

Mechanical properties of the material used in the cask lifting attachment are listed in the following table.

Component	Material	Temp. °F	Ultimate S_u(ksi)	Yield S_y(ksi)
Trunnion	SA-182 F304	70^0	75	30
Bracket	Type 304 SS	70^0	75	30
Gusset	Type 304 SS	70^0	75	30

The lifting attachment will be designed per ANSI N14.6[3] with a factor of safety of three to yield or five to ultimate, whichever is most restrictive.

A2.3.3 Conveyance

Mechanical properties of the material used in the trailer are listed in the following table.

Component	Material	Temp. °F	Ultimate S_u(ksi)	Yield S_y(ksi)
Main Beams	A-514 (T1)	70^0	110	100
Frame	A-36	70^0	58	36

A2.3.4 Cask Operations Equipment

Cask operational equipment load path structures are fabricated from 500 series carbon steel, 17-4 PH stainless steel or Type 304 stainless steel. Yield strength and material ultimate strength for these materials at service temperatures equal to or less than 150°F are as follows:

Material	Yield Strength (ksi)	Ultimate Strength (ksi)
Carbon Steel, ASTM A500, GR B	46.0	58.0
Type 304 Stainless Steel	30.0	75.0
17-4PH Stainless Steel	100.1	135.0

A2.4 DESIGN AND FABRICATION METHODS

A2.4.1 Cask

A2.4.1.1 Design

The cask is designed to comply with all the requirements of Hanford Specification[1] for normal and accident conditions. Part B of this DAR provides the details of the design analyses. The structural material selected is ASME/ASTM certified stainless steel (See design drawings, Section A9.1). Stainless steel has adequate resistance to the corrosive effects of materials (liquids, vapors, gases and solids) that it could come in contact with the cask during the cask's life cycle at the Hanford Nuclear Reservation site. The stainless steel material also minimizes contamination adhesion and chemical-galvanic reactions between the payload components and the cask. The material also complies with the material requirements identified in NUREG/CR-3854[4]. A minimum wall thickness of at least 3-in. (7.62-cm) of stainless steel has been provided as required by Hanford Specification[1]. The design considers avoiding potential contamination traps to the greatest extent practicable.

A2.4.1.2 Fabrication Methods

Fabrication criteria for a Category I packaging, as delineated in NUREG/CR-3854 will be followed. Fabrication of the packaging will be performed in accordance with the ASME Code, Section III as required by NUREG/CR-3854.

The cask will be fabricated from stainless steel using proven manufacturing techniques for spent fuel transportation casks. The cask body will consist of one or more forged cylinders welded with a complete penetration weld to a bottom closure head forging. It is anticipated that the cask body welds will be narrow groove welds made primary by Gas Tungsten Arc Automatic Welding (GTAW) and the Submerged Arc Automatic Welding (SAW) process and welded from the outer diameter.

All welds and weld joints will be examined per the ASME Code, Section III. Welds will be inspected per ASME Section V by welders qualified to ASME Section IX. All containment welds will be radiographed per ASME requirements.

A2.4.2 Cask Lifting Attachment

The lifting Attachment is designed per ANSI N14.6 with a factor of safety of three to yield or five to ultimate, whichever is most restrictive. Fabrication of the lifting attachment will also be performed in accordance with the requirements of ANSI N14.6.

A2.4.3 Conveyance

The trailer will be designed per Hanford Specification(1) with a factor of safety of two to yield. All welding will be in accordance with AWS D1.1.

A2.4.4 Cask Operations Equipment

The K-Basin Loadout Pit Operations Equipment consists of an immersion pail, immersion pail support structure, and loadout pit operations work platform. Safety related load path components are designed in accordance with ANSI N14.6(3).

To supplement the requirements of ANSI N14.6, applicable design criteria from the American Institute of Steel Construction (AISC) and ASME Boiler and Pressure Vessel Code have been adopted for evaluation of support structures for loads other than tension loading.

A2.5 WEIGHTS AND CENTER OF GRAVITY

A2.5.1 Cask

The calculated gross weight of the cask (including contents) is 57,910 pounds. Approximate weights of major individual components or subassemblies are tabulated below:

Weight of Lid:	1,890 lbs
Weight of Shell:	34,300 lbs
Weight of Bottom:	2,270 lbs
Weight of Lifting Attachment:	500 lbs
Weight of Dry MCO:	18,950 lbs
Gross Cask Weight (Dry):	57,910 lbs

The center of gravity of the unloaded packaging is located on the cylindrical axis at 82.29 inches from the outer bottom surface.

The center of gravity for a loaded packaging (Dry) is located on the cylindrical axis at approximately 83.6 inches from the outer bottom surface.

A2.5.2 Cask Lifting Attachment

The calculated gross weight of the lifting attachment is 500 pounds. Approximate weights of major individual components are tabulated below:

Trunnions:	120 lbs
Brackets:	250 lbs
Gussets:	130 lbs

A2.5.3 Conveyance

The calculated gross weight of the trailer is 19,500 lbs. Approximate weights of the major individual components used for trailer design are tabulated below:

Tractor:	18,500#
Trailer:	19,500#
Cask & Loaded MCO:	57,910# (Dry), 59,370# (Wet)
Platform:	2,500#
Tie Down System:	5,000#
Total gross weight	103,410# (Dry), 104,870# (Wet)

The center of gravity of the loaded cask on the trailer is 104.27" above the ground and is not exceed 120% of the axle track (axle track is 95").

A2.5.4 Cask Operations Equipment

The K-Basin operations equipment components of interest relative to weight considerations include the immersion pail and immersion pail seal lid. These components represent the operational equipment which influence loading on the crane and loadout pit immersion pail support structure. Although the weight of these structures influence total load path loading, the design for the in-pit equipment incorporates buoyancy force of the submerged pail volume and retains full crane capacity for the loaded cask.

Summary of component and system weight loading:

Component	Pounds
Pail	5,700 (#)
Pail Lid	600 (#)
Cask	36,570 (#)
Cask Lid	1,890 (#)
Cask Lifting Attachment	500 (#)
MCO	1,900 (#)
MCO Contents	15,685 (#)
MCO Water	1,210 (#)
MCO Shield	1,360 (#)
MCO Loaded (wet)	20,160 (#)
Pail Slings	400 (#)
Pail Lift Beam	550 (#)
Pail Water w/cask	850 (#)
MCO/Cask Annulus Water	250 (#)

A2.6 CONTAINMENT BOUNDARY

The containment boundary consists of the cask body cylindrical shell, bottom plate and the lid. The lid bolts and seals are also part of the containment boundary as is the drain and vent cover plates, bolts and seals. The containment boundary is designed to be an ASME Section III, Subsection NB Class I component as applicable. The Subsection NB rules for materials, design, fabrication and examination are applied to all of the above components to the maximum practical extent. The containment boundary is shown on Figure A2.6-1.

The acceptability of the containment boundary under the applied loads is based on the following criteria:

- ASME Code Design Stress Intensities
- Fatigue Failure to be Precluded
- Brittle Fracture to be Precluded
- Buckling to be Prevented

The values for material properties, design stress intensities (S_m) and design fatigue curves for Class 1 components given in Part D of Section II of the ASME B&PV Code shall be used for the containment boundary materials. Allowable stress levels for containment components are outlined in Table B4.3-4.

The design properties of other materials are based on industry-recognized specifications, or standards, or on appropriate test data.

A2.7 CAVITY SIZE

The basic structure of the cask cavity is a right circular cylinder. The cask cavity has a length of 160.50 inches and an internal diameter of 25.19 inches. A 4.0 inch land is located towards the top of the cavity. This land has an internal diameter of 24.25 inches. The cavity of the TN-WHC cask is depicted in Figure A2.6-1.

A2.8 HEAT DISSIPATION

The cask is designed to dissipate the design basis heat load of the payload while maintaining cask component temperatures within acceptable ranges. The thermal evaluation is provided in Section B5.0. The following is a summary of the heat to be dissipated during normal and accident conditions:

Normal Conditions

Payload	Surface Heat Flux At MCO Sidewalls	Surface Heat Flux At MCO Top	Surface Heat Flux At MCO Bottom	Total Watts Per MCO
Maximum	12.7 Watts/ft^2	6.0 Watts/ft^2	0	950
Minimum	0	0	0	0

(The defined sidewall surface heat flux occurs over the lower 11.7 ft. of the MCO)

Accident Conditions

Payload	Surface Heat Flux at Center 28 in Section of MCO Sidewall	Surface Heat Flux at Remainder of MCO Sidewall	Total Watts Per MCO
Maximum	30 Watts/ft^2	12.7 Watts/ft^2	1200
Minimum	0	0	0

A2.9 SHIELDING

The most significant shielding design features of the cask are the thick walled forged stainless steel cask body and lid. The cask body has a minimum wall thickness of 7.25 inches and a minimum bottom thickness of 6.13 inches. Additional shielding is provided by the fuel assemblies, the baskets, and the MCO. The cask design does not included separate neutron shielding because of the relatively low neutron source term in the spent fuel.

The shielding analysis of the cask is performed using industry standard codes and conservative modeling assumptions. An evaluation of the shielding performance of the cask was performed assuming dry cask conditions. This evaluation is based on the maximum source term payload.

The bounding source term used for the shielding evaluation is the Mark IV fuel elements, 0.95 U-235 irradiation to 16% Pu-240, thirteen years after discharge from the N reactor.

The gamma and neutron analyses are performed using the one dimensional SAS1 module of SCALE-4, with the 27n-18g coupled cross-section library. This uses the codes XSDRNPM and

XSDOSE to calculate surface flux and translate the flux into dose rates away from the cask surface. ANSI standard flux-to-dose factors, within SCALE-4, are used for the dose calculation at the selected points.

The method in which the cask and its contents are modeled for the shielding analysis and the shielding analysis results are described in the Section B3.0.

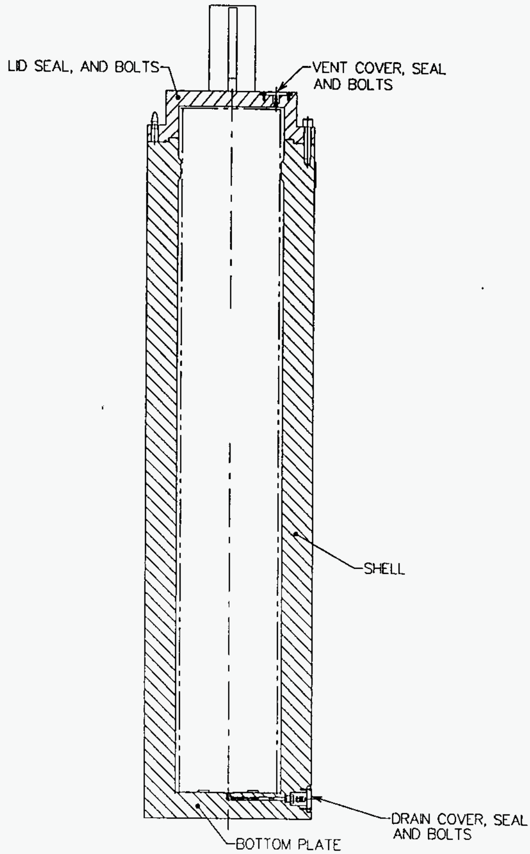
A2.10 CASK LIFTING ATTACHMENT

The lifting attachment for the cask are the two lifting trunnions, two brackets and two gussets. The trunnions, brackets and gussets are designed per ANSI N14.6 with a factor of safety of three to yield or five to ultimate, whichever is most restrictive.

A2.11 TIEDOWN ATTACHMENTS

The cask is held down by the cask hold down device which is part of the tiedown system. There are no tiedown attachments required at the cask. The tiedown system is designed to withstand the tiedown vertical 2g loads. The cask tiedown system design and load evaluations are provided in Section B7.0. Detailed dimensions of the tiedown system are shown on drawings H-1-81539, sheets 1 to 3.

Figure A2.6-1 TN-WHC Cask Containment Boundary



References For Section A2.0

1. Performance Specification For TN-WHC Cask And Transportation System, WHC-S-0396, Rev. 1, September 1995.

2. ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, American Society of Mechanical Engineers, NY, 1992. (1992 Revision).

3. Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds or More, ANSI N14.6, American National Standards Institute Inc., NY, 1993,

4. Fischer, L. E. and Lai, W., 1985, Fabrication Criteria for Shipping Containers, NUREG/CR-3854 UCRL-53544, Lawrence Livermore National Laboratory, Livermore, California.

A3.0 PACKAGE CONTENTS

A3.1 GENERAL DESCRIPTION

A3.1.1 Physical Form

The Cask contents consist of a Multiple Canister Overpack (MCO) which is the primary containment for the fuel elements. MCOs are 24 in. (0.61 m) outside diameter, stainless steel pipe slightly over 13 ft (4 m) long, with the metallic uranium fuel elements in baskets stacked inside (Figure A3.1-1). Approximately 400 of these fuel containers (MCOs) will be handled.

A3.1.2 MCO Weights and Dimensions

The approximate weights of the MCO components and some dimensions are supplied in Table A3.1-1.

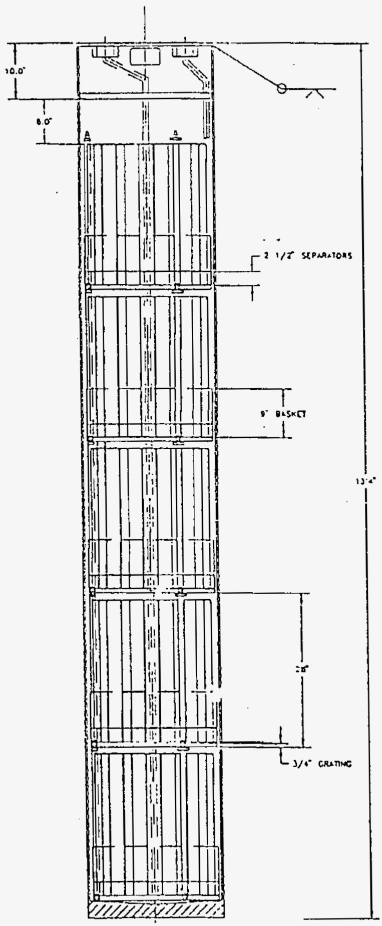
References For Section A3.0

1. Performance Specification For TN-WHC Cask And Transportation System, WHC-S-0396, Rev. 1, September 1995.

Table A3.1-1 Weights and Dimensions of MCO Components

Payload configuration	Figure 14 of Ref. 1
MCO length	Figure 15 of Ref. 1
MCO outer diameter	Figure 15 of Ref. 1
MCO wall thickness	Figure 15 of Ref. 1
Water - Kg (lb)	551 (1,210)
MCO w/o shield plug & empty Kg (lb)	862 (1,900)
MCO shield plug (30.5 cm thick) Fully assembled - Kg (lb)	616 (1,360)
Zr Clad - Kg (lb)	445 (980)
Fuel and Clad - Kg (lb)	6,835 (15,050)
5 MK IV Baskets w/54 Mk IV Elements per basket - Kg (lb)	7,115 (15,685)
Total flooded maximum MCO weight Wet - Kg (lb)	9,144 (20,160)

Figure A3.1-1 Typical Arrangement of Spent Fuel in the MCO



A4.0 TRANSPORT SYSTEM

A4.1 TRANSPORTER

System Components

The design of the trailer is shown on drawings H-1-81555, H-1-81556, and H-1-81557. The basic components are:

- Main Beams
- Frame
- Deck
- Kingpin
- Landing Legs
- Axles
- Suspensions
- Wheels
- Tires
- Brakes

The major dimensions are as follow:

- Overall length 40', With the tractor approximately 54'
- Overall width 10'
- Overall height 17' 7" (loaded at top of cask lifting attachment)
- Loaded deck height 3'
- Loaded ground clearance 12"

The trailer has three axles. The axles have a nominal capacity of 22,000 lbs per axle. The axle track is 95". The trailer has three air ride suspensions. Each suspension has a rated capacity of 25,000#. The tri-axle assembly will be controlled by a single automatic height control valve. A manual override system will also be provided to raise or lower the rear of the trailer as needed.

Landing legs is adequately braced to the frame of the trailer. A 38" square bearing pad is provided for each landing leg to accommodate the soil bearing restrictions. The pad will be placed under the legs on an as needed basis and not permanently attached to the legs.

275/R x 22.5 - Load Range H Bridgestone Tires stated rating on the side wall shall be 6,175# per tire. Actual load on the tire will not exceed 90% of the stated rating or exceed 600# per inch of the tire width. The loaded section for this tire is 11.9".

Design Load Factor

The trailer is designed to meet the requirements of the Hanford Specification. The trailer system is capable of resisting the forces for road, as described below.

Design load requirements:

2.5 G down vertical
2.0 G up vertical
1.5 G lateral both directions
2.0 G fore
1.5 G aft

Parked
1.5 G down vertical

The weight distribution (1G down) for the six axle combination shall be approximately 10,000 lbs on the steering axle, 37,250 lbs on the tractor drive axles, and 57,620 lbs on the trailer tri-axle assembly.

A4.2 TIEDOWN SYSTEM

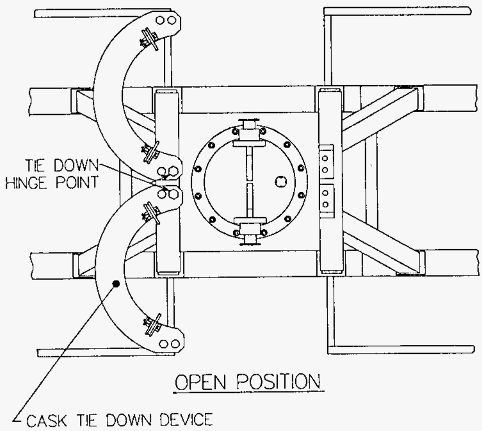
The basic components of the system are:

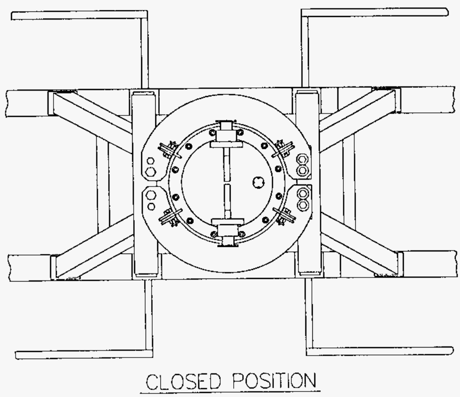
- Frames and Beams
- Cask Tiedown Device
- Cask Hold Down Device
- Cask Support Device

The eight frames, two cross beams and four support braces (including the weld attachments of the vertical support frames to the support pads of the trailer) are the major components of the tiedown system. The loads from the cask are transmitted by the frames to the trailer. The cask tiedown device consists of two rotating flanges, six tiedown bolts, and two hold down pins. The cask hold down device consists of four hold down arms which bolted to the brackets of the cask tiedown device. The cask support device consists of one cylindrical cup, bottom plate, and fourteen (14) attachment bolts. A detailed design drawing for the cask tiedown system is provided in Section A9.1.

The cask is supported by the support device (cylindrical cup) at the bottom and secured by the tiedown device (two rotating flanges) at the top. The two rotating flanges can be opened and closed (by removing the six tiedown bolts and rotated from the hold down pins) for loading and unloading the cask. Figure A4.2-1 shows the opened and closed positions of the rotating flanges of the cask tiedown device. The cask is transported in the vertical orientation with the lid end facing up.

Figure A4.2-1 TN-WHC Cask Tiedown System - Opened and Closed Positions





A4.3 SPECIAL TRANSFER REQUIREMENTS

None.

A4.4 APPENDIX

Structural Analysis of the Trailer

TABLE OF CONTENTS

Section **Page**

1. INTRODUCTION

This report contains a very detailed computer analysis made of this trailer. A computer model which is virtually identical with the actual trailer construction has been developed and the various loading conditions applied. There were seven separate computer analyses made. See Section 4.5 of this report for a listing of the load cases and their corresponding data. The computer output for all load cases is given in Appendix C.

All analyses were made in a conservative manner. Thus, the results and conclusions contained in this report will give a safe view of the trailer's ability to withstand the specified loading.

The computer model used is shown in considerable detail in Figures 1, 2, 3, and 4. The properties of the members are given in Appendix A.

The allowable stresses used are 50% of the yield stress for all loading cases. All allowables are in accordance with the specification.

ALABAMA REGISTERED No. 9586 PROFESSIONAL ENGINEER CLAUDIE KENNETH McDONALD

C.K. McDonald

C.K. McDonald, Ph.D., P.E.

Alabama Registration No. 9586

2. SUMMARY OF RESULTS

The maximum stresses are compared to the allowables below. See Appendix C for the computer output for all loading conditions. The actual and allowable stresses are in psi.

Components	Actual	Allowable
Maximum Main Beam Stress, psi	43,384	50,000
Maximum Cross Beam and Other Structural Stress, Psi	16,828	18,000

The main beam is T1 steel with a minimum yield stress of 100,000 psi. All other structural is A-36 steel.

3. COMPUTER MODEL AND ANALYSIS

The computer model for the trailer is shown in Figures 1, 2, 3,and 4. The model contains approximately 5,000 nodes and 6,000 elements/members. The units used in this analysis are lbs. and inches.

The analysis was made utilizing the computer code ANSYS 5.3 operating on a Pentium 100 Megaherz computer.

See Appendix C for the computer output all load cases.

Modeling a trailer, although appearing deceptively simple, presents some special modeling problems. This is because you are modeling an assemblege of plates and beams with a relatively course mesh. The purpose is to ascertain the overall structural integrity of the trailer, thus a coarse mesh is adequate. However, for a trailer, most of the beam type elements can only bend in one direction, the other direction is restrained by a continuous weld or closely spaced bolts. In some case, such as corners of the trailer, both directions are restrained from localized bending. Since the beams are only attached to the plates at nodes in the computer model, unrealistic bending stresses are sometimes predicted by the computer.

In this model, in order to eliminate these unrealistic bending stresses in some beam elements, the computer input is adjusted such that it does this without affecting the integrity and results of the model. This is done by setting the distance from the nuetral axis to near zero in the real constants for that element that cannot bend. This eliminates the stress without affecting the model. The reason that the value is set to near zero but not zero is because the computer will stop each time and question the zero and this is cumbersome in performing the analysis.

The localized bending of the beams does not affect the overall structural integrity of the trailer which is maintained by the web plates and the floor deck.

1

ANSYS 5.3
OCT 22 1996
09:24:23
PLOT NO. 1
ELEMENTS
TYPE NUM
U
F
CP

XV =1
YV =1
ZV =1
DIST=416.528
*ZF =-28.5
Z-BUFFER

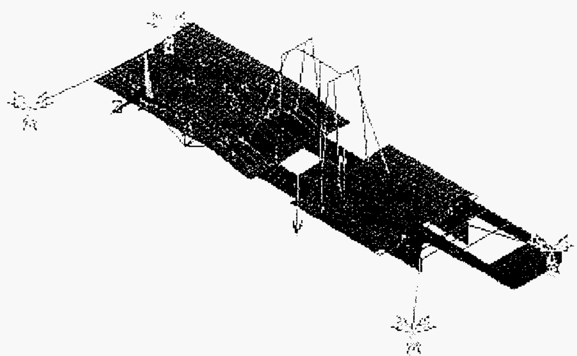


Figure 1 - Isometric View

computer model of trailer and cask

1

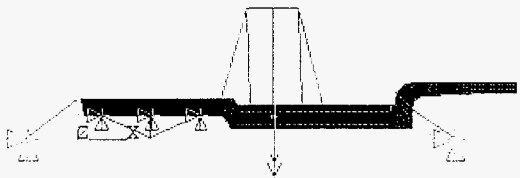


Figure 2 - Side View

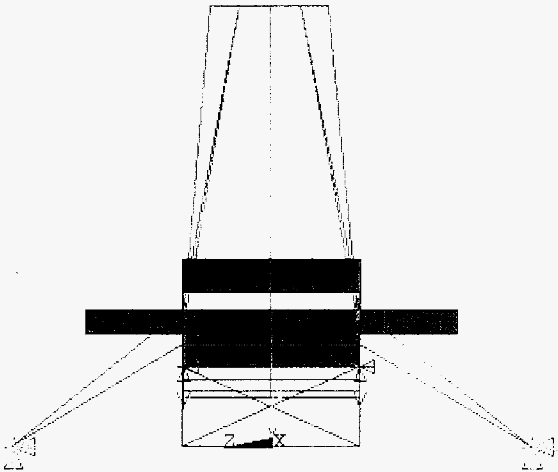
computer model of trailer and cask

A4.4-6

ANSYS 5.3
OCT 22 1996
09:24:36
PLOT NO. 2
ELEMENTS
TYPE NUM
U
F
CP

ZV =1
DIST=528
*ZF =-28.5
Z-BUFFER

1



ANSYS 5.3
OCT 22 1996
09:24:52
PLOT NO. 3
ELEMENTS
TYPE NUM
U
F
CP

XV =1
DIST=156.332
*ZF =-28.5
Z-BUFFER

Figure 3 - End View

computer model of trailer and cask

E-15166

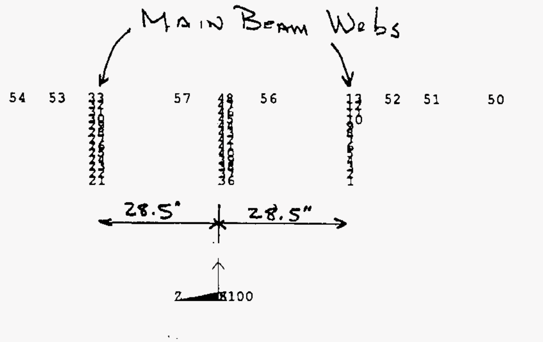


Figure 4 - Nodal Plot at X = 0 (Rear End of Trailer)

Note: This pattern in increments of 100 is generated for the length of the beam. All nodes are not used at ever station on the trailer.

ANSYS 5.3
OCT 22, 1996
12:14:46
PLOT NO. 1
NODES
NODE NUM
CP
ACEL

XV=1
DIST=97.35
*ZF=-28.5
Z-BUFFER

4. LOADING CRITERIA

4.1 Trailer Weight

The total trailer weight used in the analysis is 86,100 lbs, including the cask and tie down system.

4.2 Shock Loads

The shock loads applied are 2.5 g downward, 2 g upward, 2g fore, and 1.5g aft. A load of 1.5 g lateral is specified but a load of 0.5g lateral overturns the trailer when loaded, see reactions for the lateral load analysis, page C-25, to confirm this. The seismic loads also includes a lateral load when the trailer is tied down with the seismic struts. See Section 4.4 below for a detailed discussion of the computer loading.

4.4 Parked Loading

The parked shock factor is 1.5 g vertical.

4.5 Computer Load Cases

The above loadings are imposed by computer in the following load cases.

A) 2.5g Vertical Down

The trailer is supported at the kingpin and on the rear axles.

B) 2.0g Vertical Up + Deadweight

The entire trailer will never see this load because it would leave the ground. However, an individual component could see it. Thus, to be conservative, the entire trailer is loaded with 2g upward plus deadweight and the trailer is supported at the seismic struts, which is conservative.

C) 2.0g Fore + Deadweight

The trailer is supported by the kingpin in the fore direction and by the kingpin and wheels in the vertical direction.

D) 1.5g Aft + Deadweight

The trailer is supported in the aft direction on the kingpin and vertically by the wheels and kingpin.

E) 1.5g Parked (File PARK.DAT)

The trailer is supported by the wheels and landing gear.

F) Seismic + Deadweight

The trailer is supported entirely by the four seismic struts. This is conservative because the trailer is also supported vertical by a pad directly under the cask. The trailer is also supported laterally by friction on the pad and on the tires and landing gear (or tractor).

G) 1.5 Lateral + Deadweight

The maximum load that can be applied laterally without overturning the trailer is 0.5g. An additional lateral load is applied by seismic, as noted above.

5. SUPPLEMENTAL HAND CALCULATIONS

5.1 Maximum Main Beam Stress

The main beam structal stresses are given on pages C-1 through C-7. The maximum stress is:

S = 43,384 psi (page C-4)

The allowable stress for T1 steel which has a minimum yield of 100,000 psi, is 50,000 psi. In additional to the conventional structural stresses, which are maximum in the beam flanges by well known beam theory, the concentrated stresses in the beam were calculated by use of finite elements in the web. These stresses are given on pages C-15 through C-21. The maximum concentrated stress is given on page C-17 and is 75,325 psi. This concentrated stress is only 75% of the yield stress and occurs at the 90 degree turn at the start of the gooseneck. Note that the plots on pages C-15 through 21 are of such scale that the location of the maximum cannot be seen. Therefore, to confirm the location of the maximum and to check the stresses at other locations.

5.2 Maximum Stress in Cross Beams and Other Structural

These stresses are given on pages C-8 through C-14. The maximum is:

S = 16,828 psi (page C-14)

The allowable for A-36 steel is .5(36000) = 18,000 psi

5.3 Loads on Seismic Strut Lugs

The loads on the seismic struts are shown on page C-28. The maximum loads for which the lugs on the trailer should be designed are:

Fx = 43,982 lbs (Longitudinal load on lug)

Fy = 35,185 lbs (Vertical load on lug)

Fz = 53,066 lbs (Lateral load on lug)

5.4 Deflections

The deflections of the main beam along the 24" deep span are given on pages C-22 through C-28. For convenience in determining the locations of these deflections the coordinates of the nodes are given on page C-29. The x dimension on the coordinates is the location rear to front, measured from the rear of the trailer.

APPENDIX A

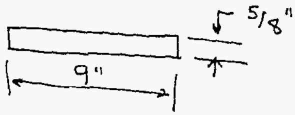
MEMBER PROPERTIES

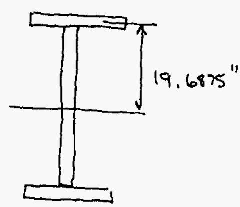
Appendix A - Member Properties

Real 1 Main Beam Web

$t = 1/2''$

Real 2 Main Beam Flange Modeled As A Beam. Area is Adjusted to Account for Distance to Outer Fiber of Beam.





$$I_1 = \frac{.625(9)^3}{12} = 37.97 \text{ in}^4$$

$$I_2 = \frac{9(.625)^3}{12} = .183 \text{ in}^4$$

$$I_{\text{TOTAL of Beam}} = \frac{.5(18.75)^3}{12} + 2(.625)(9)(19.6875)^2 = 4635 \text{ in}^4$$

Using Computer Model of Web,

$$I = 4635 = \frac{.5(20)^3}{12} + A'(20)^2(2)$$

$$A' = \frac{4635 - 333}{800} = 5.378 \text{ in}^2 \quad (\text{instead of } .625(9) = 5.625 \text{ in}^2)$$

A-2

Real 3 Main Beam Flg

$t = 5/8"$ Width = 7.25"

$A = 7.25(.625) = 4.77\ in^2$

$I_1 = \frac{7.25(.625)^3}{12} = .147\ in^4$

$I_2 = \frac{.625(7.25)^3}{12} = 19.85\ in^4$

Real 4 Channels $15\ 3/8 \times 2 \times 1/4$

$t = 1/4"$ Web

Real 5 – $2 \times 1/4$ Flange

$A = .5\ in^2$ $I_1 = .167\ in^4$ $I_2 = .0026\ in^4$

Real 6 – $4 \times 3 \times 1/4$ Tube

$A = 3.09\ in^2$

$I_1 = 6.45\ in^4$

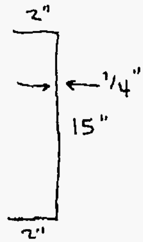
$I_2 = 4.10\ in^4$

Real 7 – C8 x 8.5 Channel

$A = 2.50$ $I_1 = 23.3\ in^4$ $I_2 = .628\ in^4$

A-3

Real 8



$$A = 14.75(.25) + .25(1.875)(2) = 4.63 \text{ in}^2$$

$$I_1 = \frac{.25(14.5)^3}{12} + 2(2)(.25)(7.375)^2 = 117.9 \text{ in}^4$$

$$\bar{y} = \frac{4(.25)(.875)}{4.63} = .189''$$

$$I_2 = \frac{2(.25)(2)^3}{12} + 14.5(.25)(.189)^2 = .46 \text{ in}^4$$

Real 9 W6x25 Beam

$A = 7.34 \text{ in}^2$ $I_1 = 53.4 \text{ in}^4$ $I_2 = 17.1 \text{ in}^4$

Real 10 PLATE

$t = 1/2''$

A-4

Real 11 4 x 8 x 3/16 Tubing

$A = 4.27\ in^2$ $I_1 = 35.3\ in^4$ $I_2 = 12.0\ in^4$

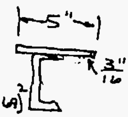
Real 12 5 x 3 x 5/16 Angle

$A = 2.40\ in^2$ $I_1 = 6.26$ $I_2 = 1.75\ in^4$

Real 13 C5 x 6.7

$A = 1.97\ in^2$. $I_1 = 7.49\ in^4$ $I_2 = .479$

+ 3"+2" TREAD PL. $A = 2.90$ $I_1 = 7.49 + 1.97(.81)^2 + .94(1.69)^2 = 11.47\ in^4$



Real 14 C10 x 15.3

$A = 4.49\ in^2$ $I_1 = 67.4\ in^4$ $I_2 = 2.28\ in^4$

Real 15 2 x 2 x 1/4 Angle

$A = .938\ in^2$ $I_1 = I_2 = .348\ in^4$

Real 16 TREAD PLATE

$t = 3/16"$

Real 17 W8 x 18

$A = 5.26\ in^2$ $I_1 = 61.9\ in^4$ $I_2 = 7.97\ in^4$

Real 18 Dummy Members to simulate Axles and Kingpin

A-5

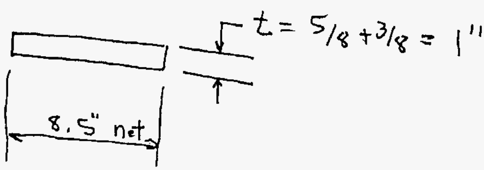
REAL 19 Web Stiffeners

$t = 3/8''$

REAL 20 Web + Stiffener

$t = 1/2'' + 3/8'' = 7/8''$

REAL 21 Flg + Stiffener



$A = 8.5 \quad I_1 = \frac{8.5(1)^3}{12} = .708 \text{ in}^4 \quad I_2 = \frac{1(8.5)^3}{12} = 51.17 \text{ in}^4$

REAL 22 Web Stiffener

2 - 3/8" x 4" PLATES

$A = 2(.375)(4) = 3 \text{ in}^2$

$I_1 = \frac{2(.375)(4)^3}{12} = 4 \text{ in}^4 \quad I_2 = \frac{2(4)(.375)^3}{12} = .035 \text{ in}^4$

A-6

Real 23

6 x 6 x 1/2 Cask Suppts

$A = 10.4\ in^2$ $I = 50.5\ in^4$

Real 24

8 x 8 x 1/2 Cask Suppts

$A = 14.4\ in^2$

$I = 32.9\ in^4$

Real 25 Dummy Member to Represent Cask

Real 26 Dummy Member to Represent Hold Down Device.

APPENDIX B

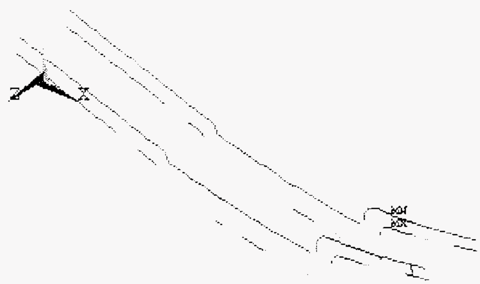
(deleted)

APPENDIX C

COMPUTER OUTPUT DATA

1

Pages C-1 thru C-7 are
Maximum Main Beam Stresses.
Max occurs in Beam Flanges



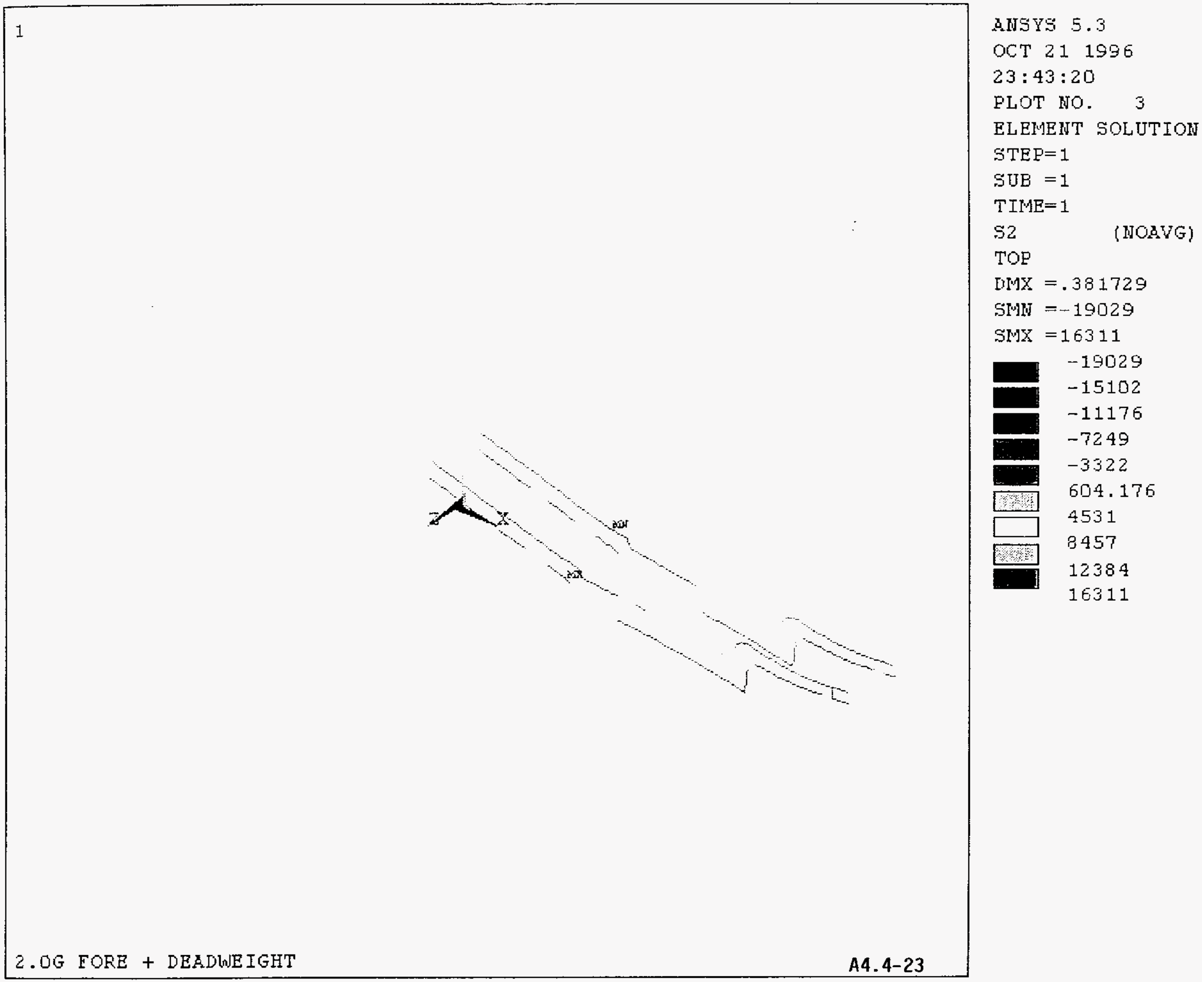
2.5G VERTICAL

A4.4-22

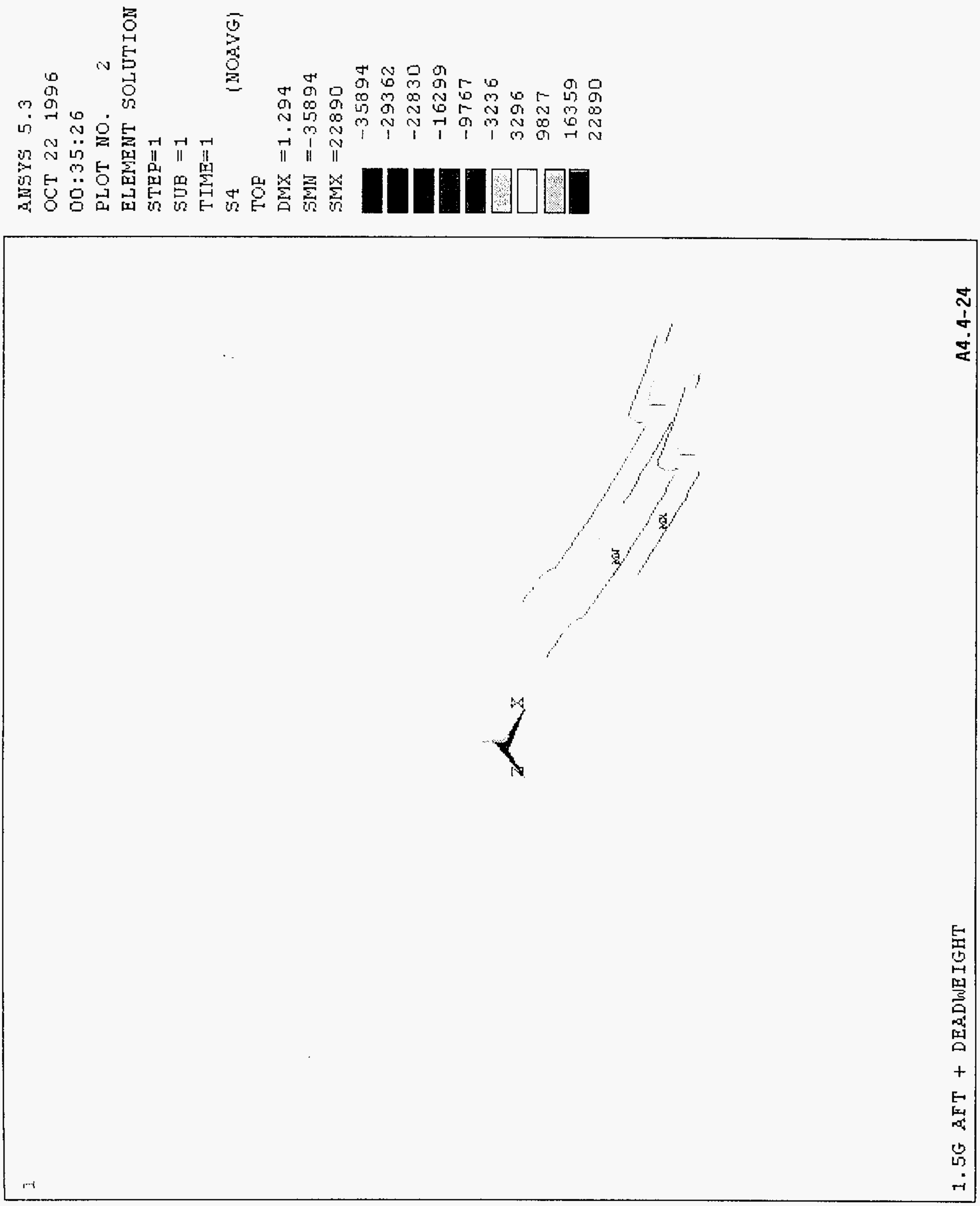
ANSYS 5.3
OCT 21 1996
23:25:19
PLOT NO. 1
ELEMENT SOLUTION
STEP=1
SUB =1
TIME=1
S3 (NOAVG)
TOP
DMX =1.731
SMN =-36351
SMX =37922

	-36351
	-28098
	-19846
	-11593
	-3341
	4912
	13164
	21417
	29669
	37922

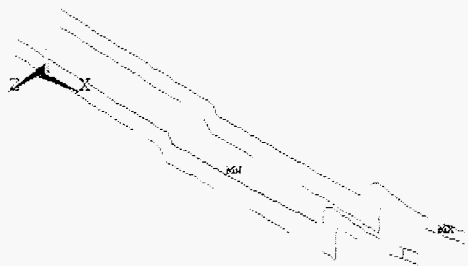
APPENDIX C - COMPUTER OUTPUT DATA


1
ANSYS 5.3
OCT 21 1996
23:43:20
PLOT NO. 3
ELEMENT SOLUTION
STEP=1
SUB =1
TIME=1
S2 (NOAVG)
TOP
DMX =.381729
SMN =-19029
SMX =16311
-19029
-15102
-11176
-7249
-3322
604.176
4531
8457
12384
16311
Z
X
2.0G FORE + DEADWEIGHT

A4.4-23


ANSYS 5.3
OCT 22 1996
00:35:26
PLOT NO. 2
ELEMENT SOLUTION
STEP=1
SUB =1
TIME=1
S4 (NOAVG)
TOP
DMX =1.294
SMN =-35894
SMX =22890
-35894
-29362
-22830
-16299
-9767
-3236
3296
9827
16359
22890
1.5G AFT + DEADWEIGHT

1

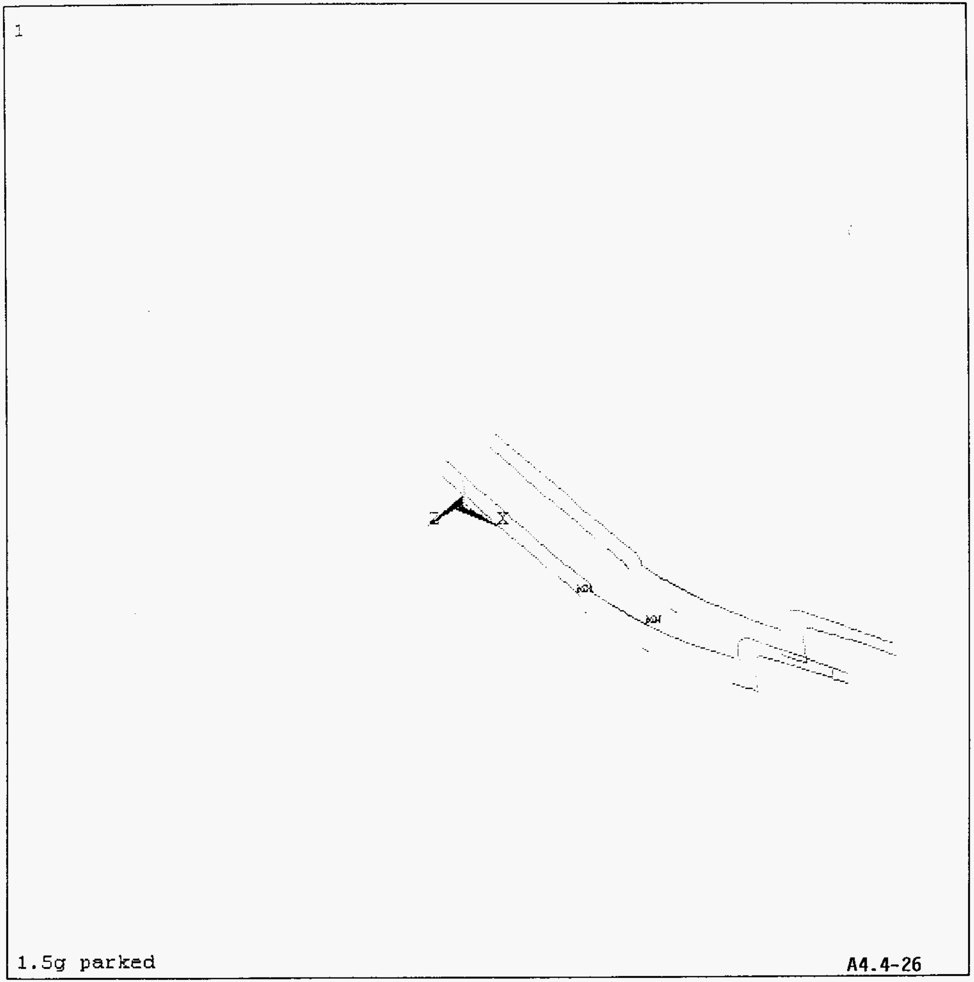


LATERAL G LOAD + DEADWEIGHT

A4.4-25

ANSYS 5.3
OCT 22 1996
05:23:14
PLOT NO. 2
ELEMENT SOLUTION
STEP=1
SUB =1
TIME=1
S1 (NOAVG)
TOP
DMX =1.073
SMN =-19110
SMX =43384

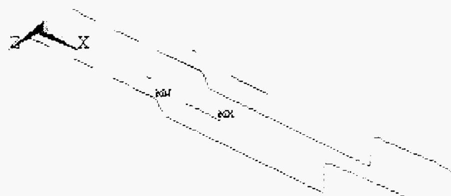
-19110
-12166
-5222
1721
8665
15609
22553
29497
36440
43384



ANSYS 5.3
OCT 22 1996
10:09:09
PLOT NO. 2
ELEMENT SOLUTION
STEP=1
SUB =1
TIME=1
S1 (NOAVG)
TOP
DMX =.308347
SMN =-13139
SMX =15802

-13139
-9923
-6707
-3492
-276.221
2939
6155
9371
12586
15802

1



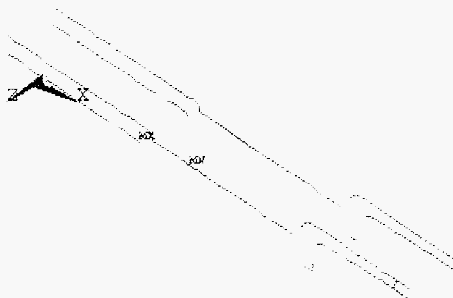
ANSYS 5.3
OCT 22 1996
11:49:16
PLOT NO. 2
ELEMENT SOLUTION
STEP=1
SUB =1
TIME=1
S2 (NOAVG)
TOP
DMX =278003
SMN =-19938
SMX =15628

-19938
-15986
-12034
-8082
-4131
-178.943
3773
7725
11676
15628

2.0G UPWARD + DEADWEIGHT

A4.4-27

1



ANSYS 5.3
OCT 22 1996
06:46:14
PLOT NO. 1
ELEMENT SOLUTION
STEP=1
SUB =1
TIME=1
S1 (NOAVG)
TOP
DMX =562395
SMN =-29112
SMX =32882

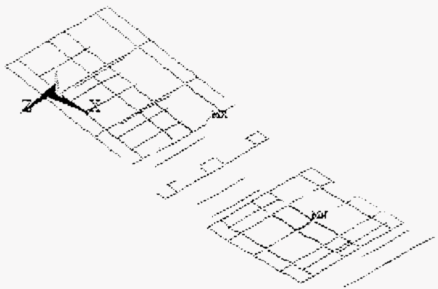
-29112
-22224
-15335
-8447
-1559
5329
12218
19106
25994
32882

SEISMIC LOADS

A4.4-28

1

Pages C-8 Thru C-14 Are Max Stresses In All Beams Except Main Beam

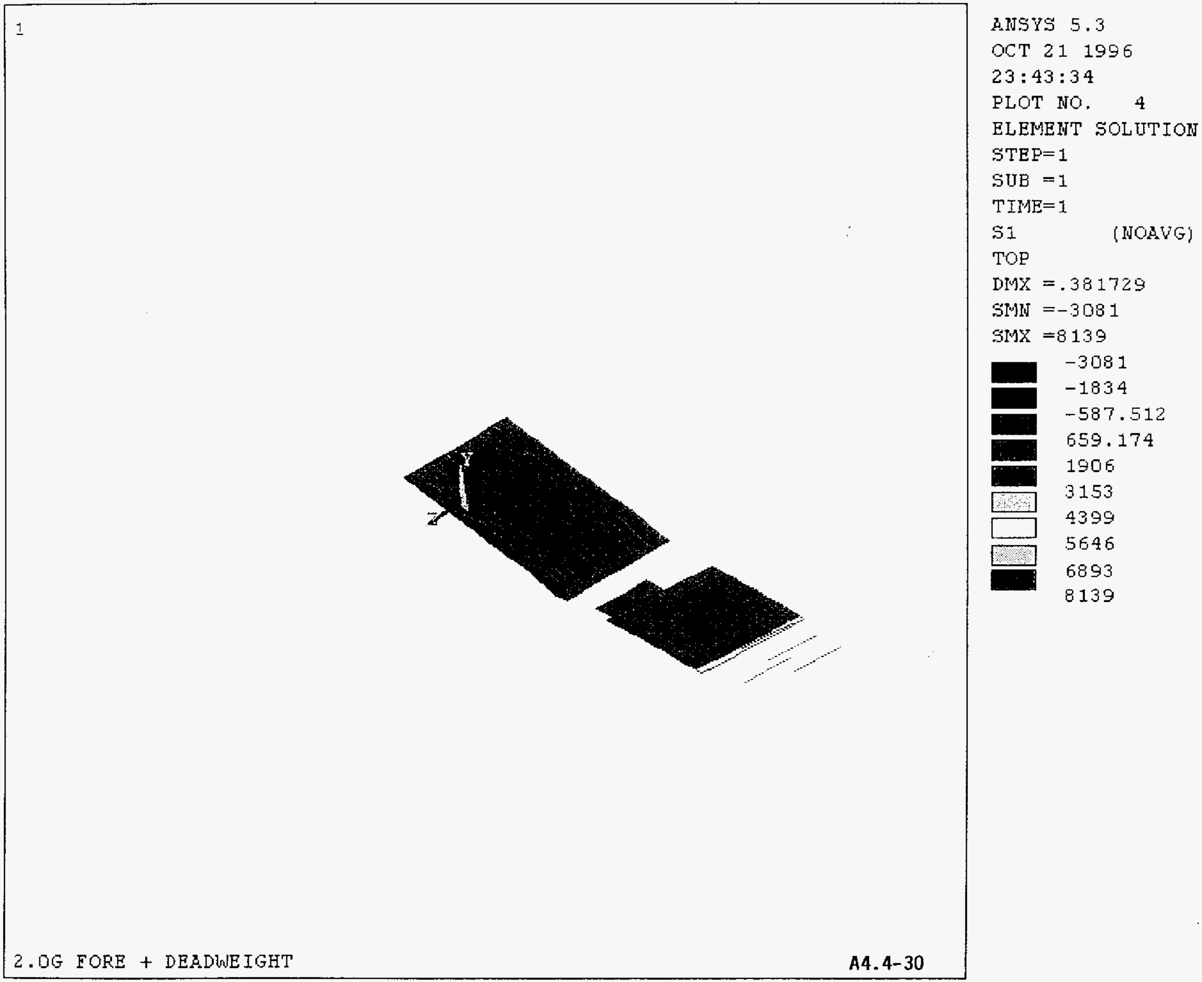


ANSYS 5.3
OCT 21 1996
22:59:40
PLOT NO. 1
ELEMENT SOLUTION
STEP=1
SUB =1
TIME=1
S3 (NOAVG)
TOP
DMX =1.731
SMN =-7807
SMX =16692

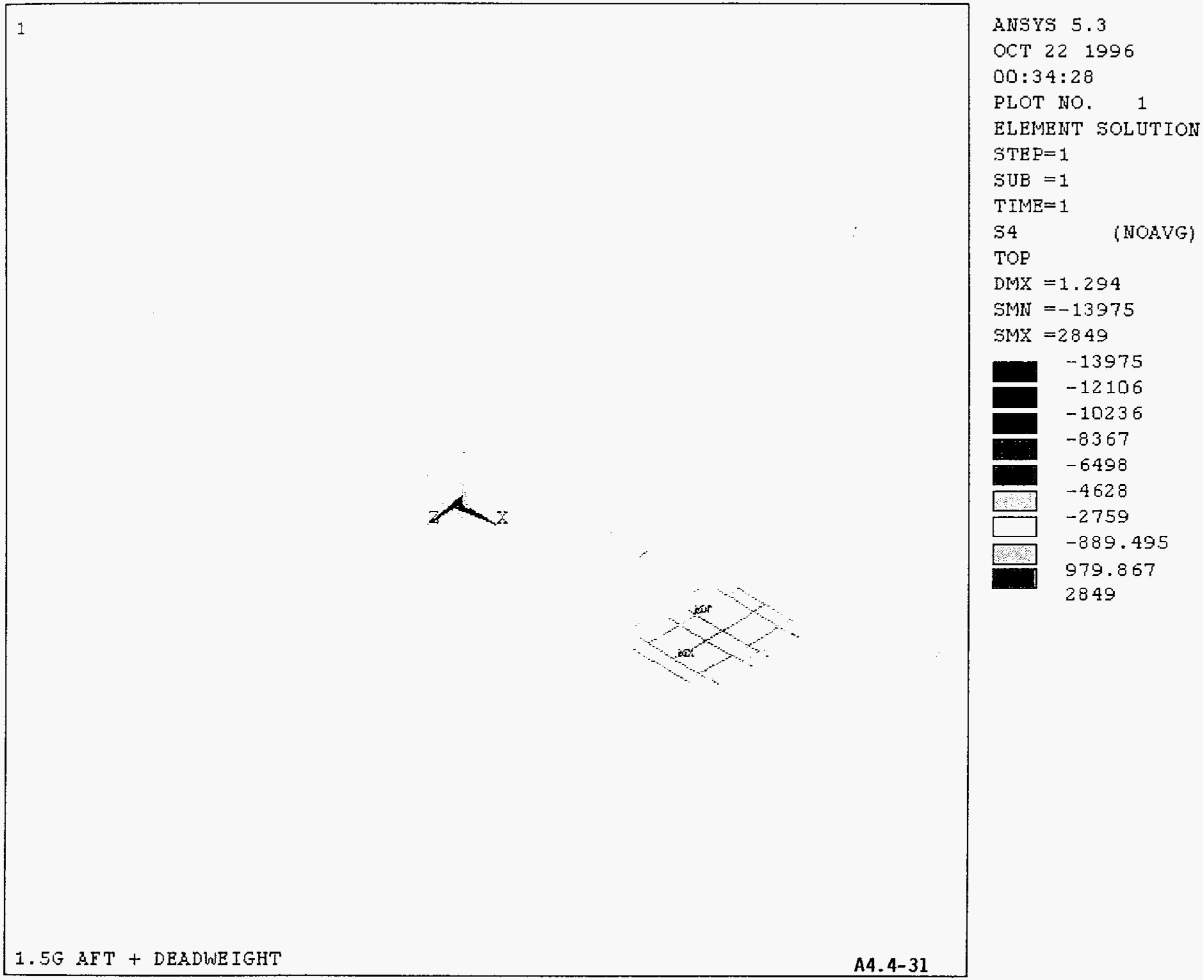
-7807
-5085
-2363
359.182
3081
5804
8526
11248
13970
16692

2.5G VERTICAL

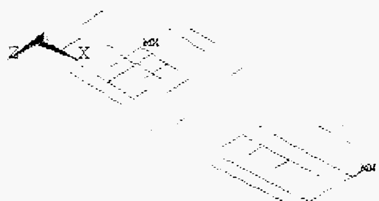
A4.4-29


1
ANSYS 5.3
OCT 21 1996
23:43:34
PLOT NO. 4
ELEMENT SOLUTION
STEP=1
SUB =1
TIME=1
S1 (NOAVG)
TOP
DMX =.381729
SMN =-3081
SMX =8139
-3081
-1834
-587.512
659.174
1906
3153
4399
5646
6893
8139
2.0G FORE + DEADWEIGHT

A4.4-30


1
ANSYS 5.3
OCT 22 1996
00:34:28
PLOT NO. 1
ELEMENT SOLUTION
STEP=1
SUB =1
TIME=1
S4 (NOAVG)
TOP
DMX =1.294
SMN =-13975
SMX =2849
-13975
-12106
-10236
-8367
-6498
-4628
-2759
-889.495
979.867
2849
Z
X
1.5G AFT + DEADWEIGHT

A4.4-31



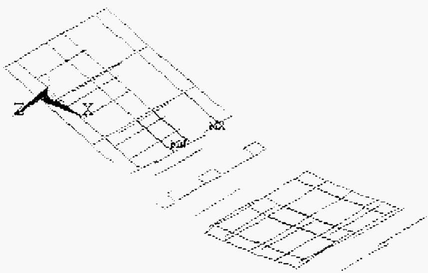
ANSYS 5.3
OCT 22 1996
05:22:08
PLOT NO. 1
ELEMENT SOLUTION
STEP=1
SUB =1
TIME=1
S2 (NOAVG)
TOP
DMX =1.073
SMN =-8553
SMX =2696

-8553
-7303
-6054
-4804
-3554
-2304
-1054
195.894
1446
2696

LATERAL G LOAD + DEADWEIGHT

A4.4-32

1

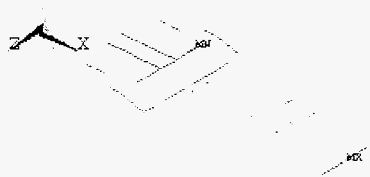


ANSYS 5.3
OCT 22 1996
10:02:58
PLOT NO. 1
ELEMENT SOLUTION
STEP=1
SUB =1
TIME=1
S3 (NOAVG)
TOP
DMX =.308347
SMN =-2880
SMX =7600

-2880
-1715
-550.854
613.567
1778
2942
4107
5271
6436
7600

1.5g parked

A4.4-33



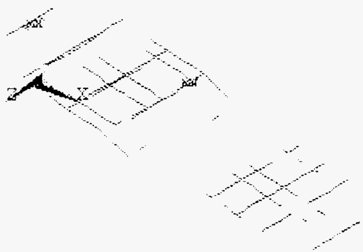
2.0G UPWARD + DEADWEIGHT

A4.4-34

ANSYS 5.3
OCT 22 1996
11:48:13
PLOT NO. 1
ELEMENT SOLUTION
STEP=1
SUB =1
TIME=1
S4 (NOAVG)
TOP
DMX =278003
SMN =-13231
SMX =5411

-13231
-11160
-9089
-7017
-4946
-2875
-803.358
1268
3339
5411

1

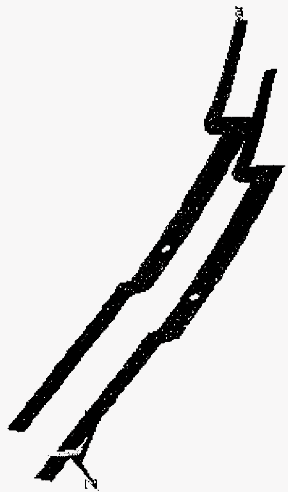


SEISMIC LOADS

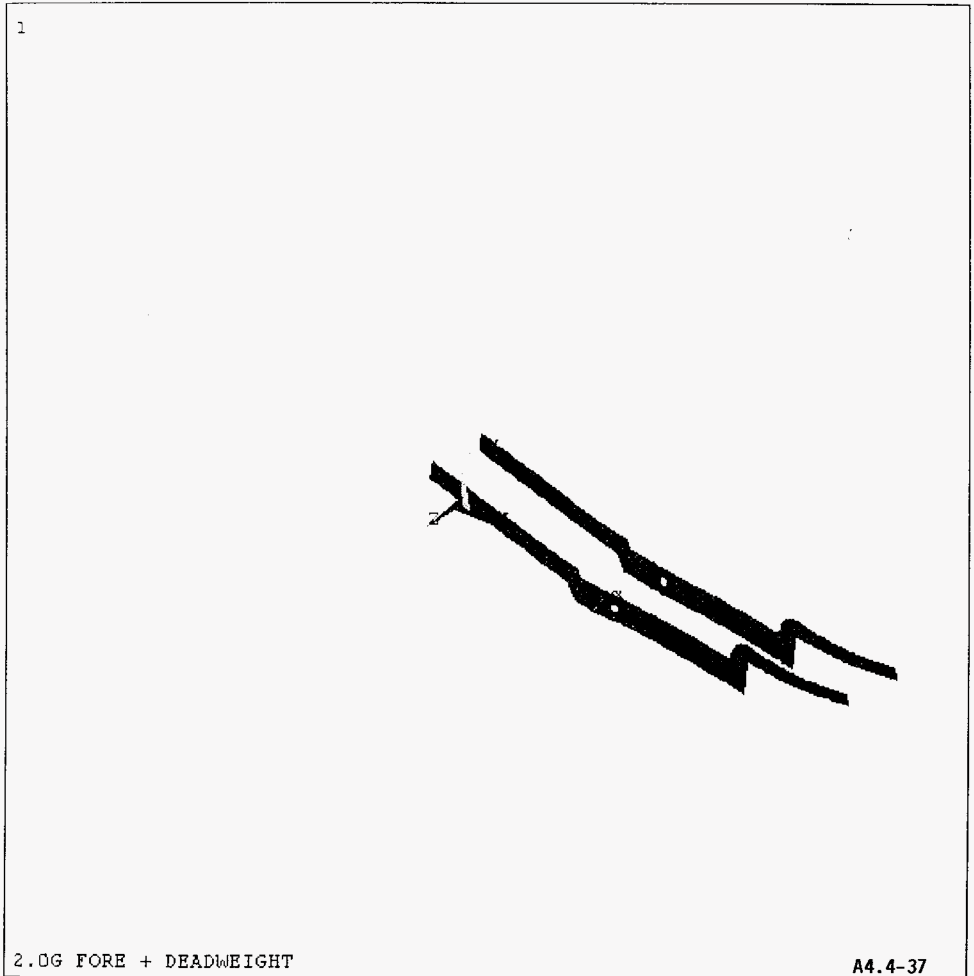
A4.4-35

ANSYS 5.3
OCT 22 1996
06:46:34
PLOT NO. 2
ELEMENT SOLUTION
STEP=1
SUB =1
TIME=1
S4 (NOAVG)
TOP
DMX =562395
SMN =-16828
SMX =2226

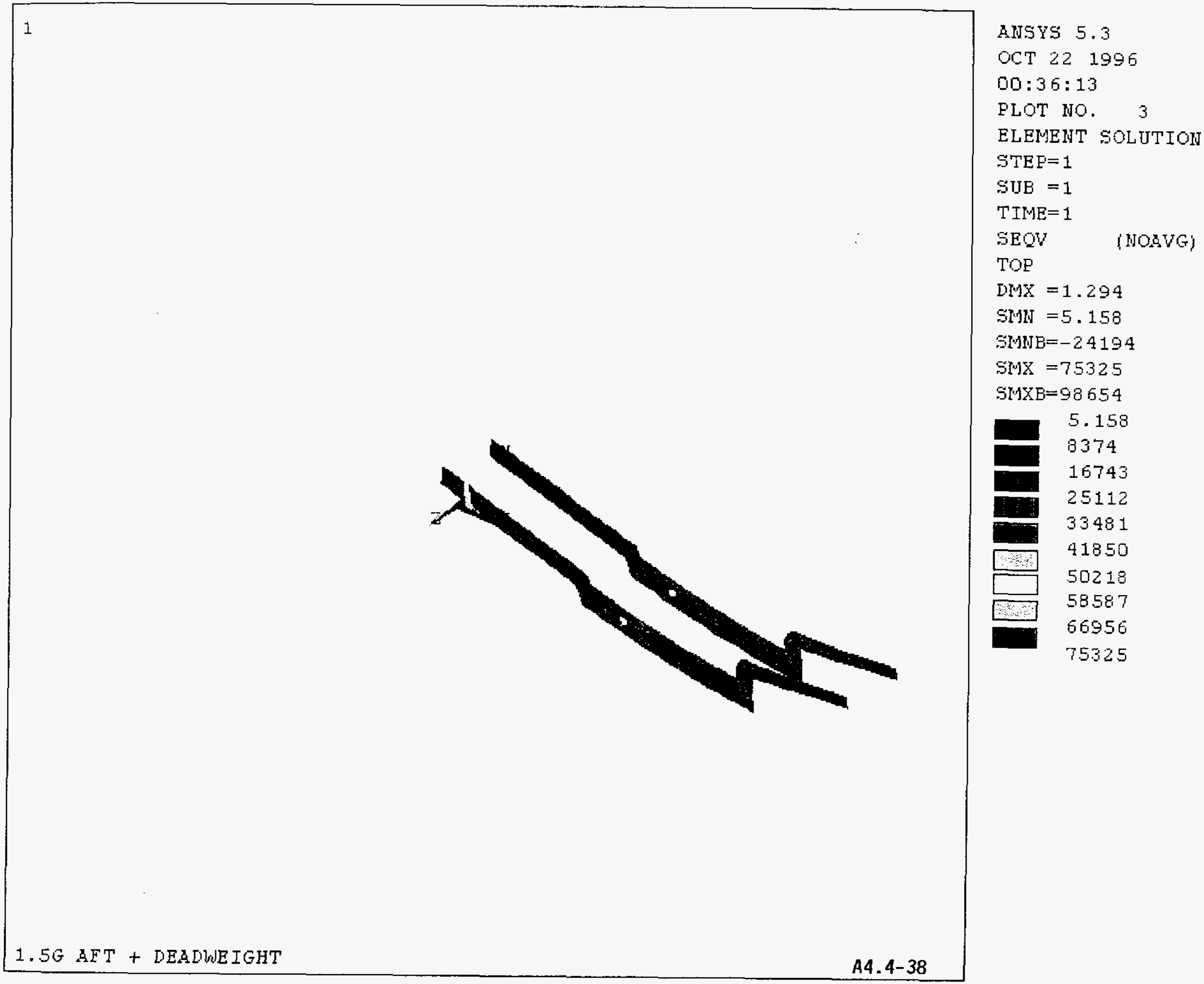
-16828
-14711
-12594
-10477
-8359
-6242
-4125
-2008
109.039
2226

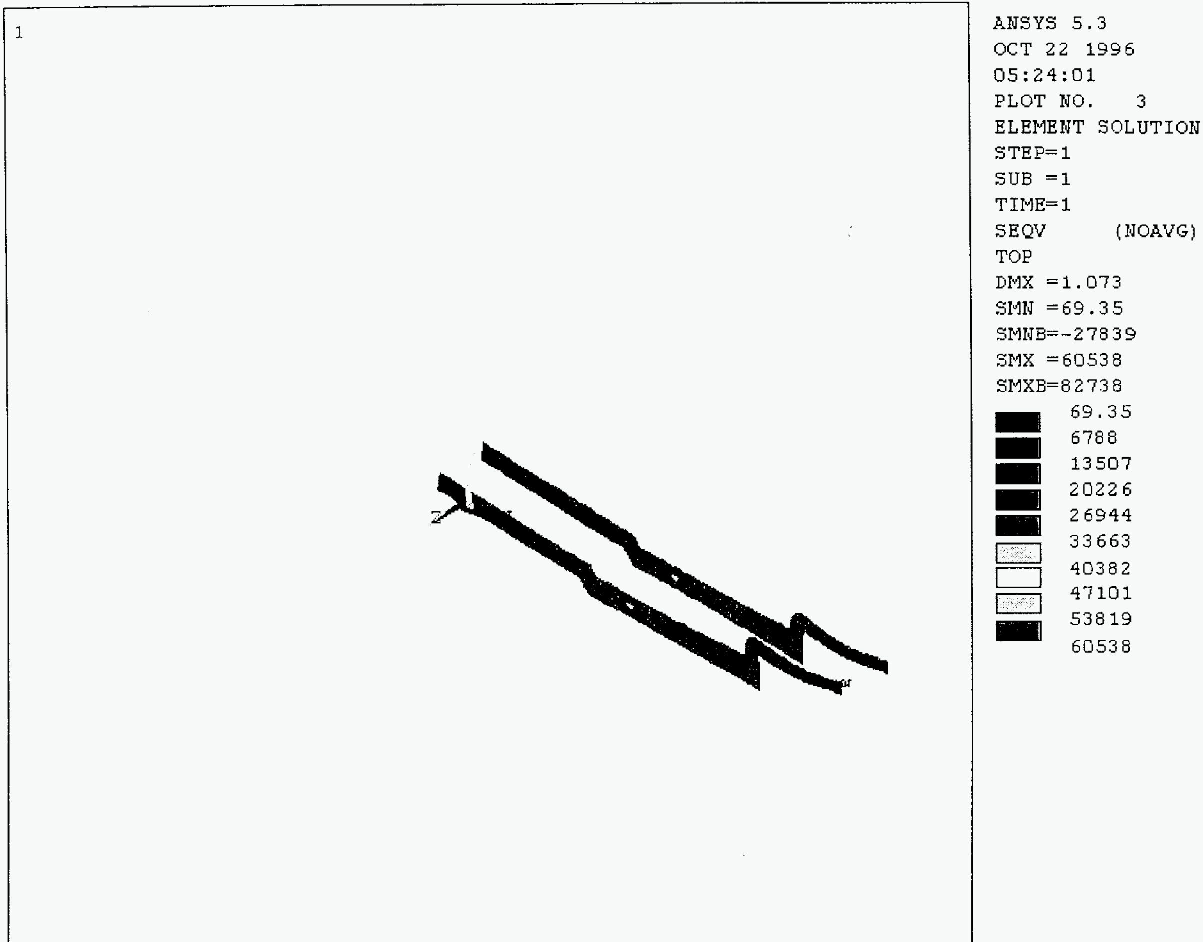


Pages C-15 thru C-21 Are Maximum Stress Concentrations at Sharp Corners in Main Beam Web.


1
ANSYS 5.3
OCT 21 1996
23:44:14
PLOT NO. 5
ELEMENT SOLUTION
STEP=1
SUB =1
TIME=1
SEQV (NOAVG)
TOP
DMX =.381729
SMN =6.785
SMNB=-18275
SMX =45913
SMXB=78342
6.785
5108
10208
15309
20410
25510
30611
35712
40813
45913
2.0G FORE + DEADWEIGHT

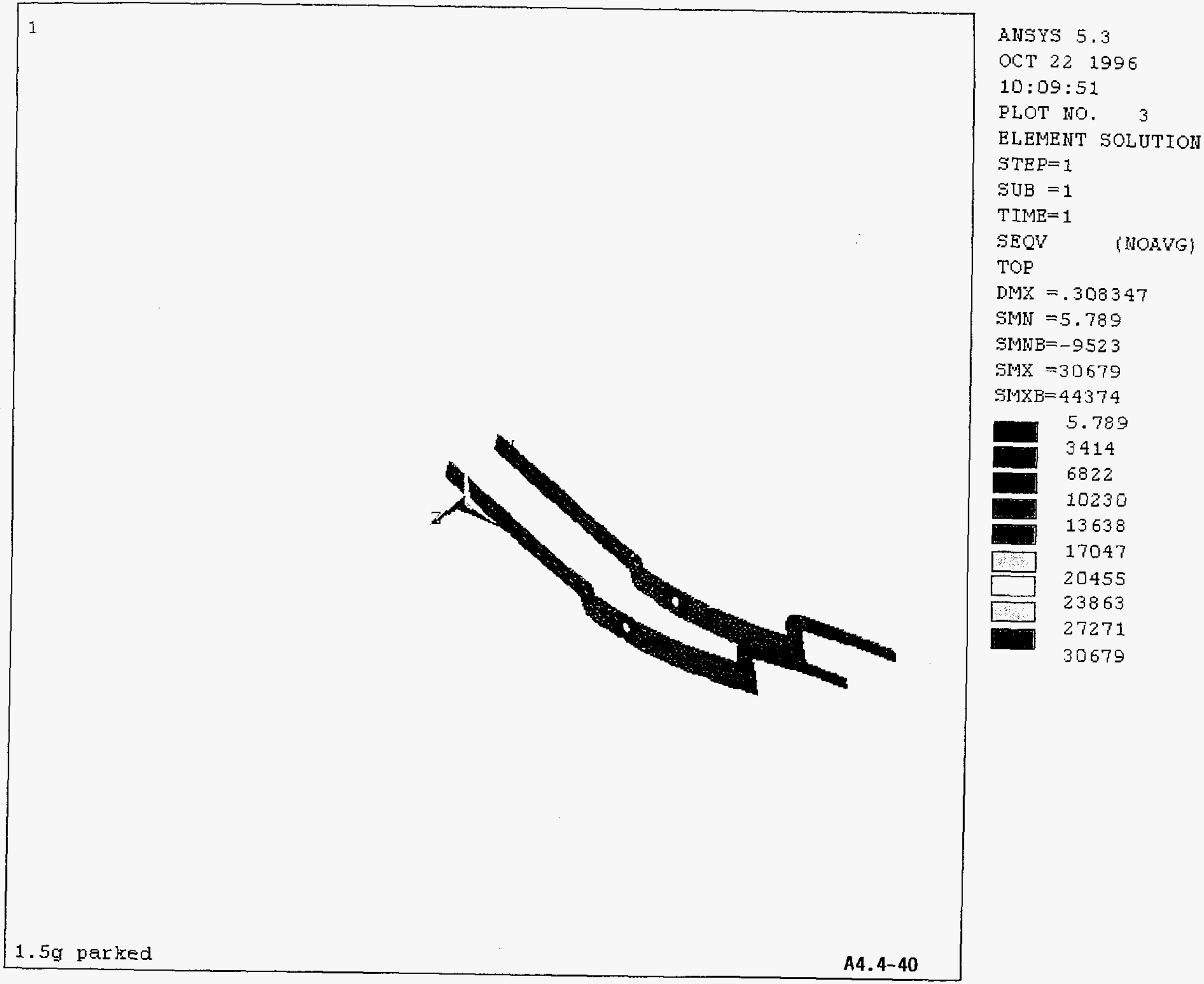
A4.4-37


1
ANSYS 5.3
OCT 22 1996
00:36:13
PLOT NO. 3
ELEMENT SOLUTION
STEP=1
SUB =1
TIME=1
SEQV (NOAVG)
TOP
DMX =1.294
SMN =5.158
SMNB=-24194
SMX =75325
SMXB=98654
5.158
8374
16743
25112
33481
41850
50218
58587
66956
75325
1.5G AFT + DEADWEIGHT



LATERAL G LOAD + DEADWEIGHT

A4.4-39

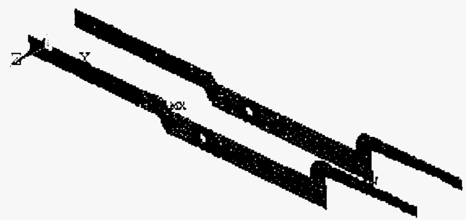


A4.4-40

HNF-SD-SNF-FDR-003 Rev. 0

E-15166

1



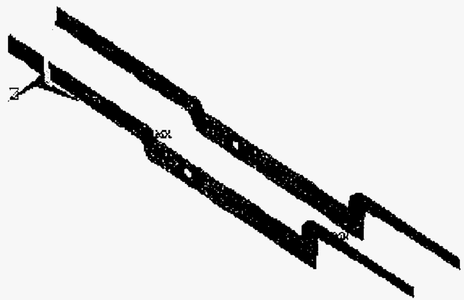
ANSYS 5.3
OCT 22 1996
11:50:01
PLOT NO. 3
ELEMENT SOLUTION
STEP=1
SUB =1
TIME=1
SEQV (NOAVG)
TOP
DMX =278003
SMN =48.5
SMNB=-8336
SMX =32181
SMXB=42851

48.5
3619
7189
10759
14330
17900
21470
25041
28611
32181

2.0G UPWARD + DEADWEIGHT

A4.4-41

1



SEISMIC LOADS

A4.4-42

ANSYS 5.3
OCT 22 1996
06:47:20
PLOT NO. 3
ELEMENT SOLUTION
STEP=1
SUB =1
TIME=1
SEQV (NOAVG)
TOP
DMX =562395
SMN =280.698
SMNB=-15378
SMX =53312
SMXB=73654

280.698
6173
12065
17958
23850
29742
35635
41527
47419
53312

C-22

```
PRINT F    REACTION SOLUTIONS PER NODE

 ***** POST1 TOTAL REACTION SOLUTION LISTING *****

 LOAD STEP=     1  SUBSTEP=     1
  TIME=    1.0000      LOAD CASE=   0

 THE FOLLOWING X,Y,Z SOLUTIONS ARE IN GLOBAL COORDINATES

   NODE       FX           FY           FZ
   1315                  71584.
   1335                  71626.      -.99503E-04
   8391  -.10515E-05   72064.       .99605E-04

TOTAL VALUES
VALUE   -.10515E-05  .21527E+06  .10190E-06

/OUTPUT FILE= JOKE.DAT

NRSE  FOR LABEL= Y     BETWEEN  36.000     AND  36.000      KABS=  0.
 TOLERANCE=  .180000

 THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

   NODE      UY
   3211   -1.1053
   3413   -1.1393
   3513   -1.1525
   3613   -1.1593
   3713   -1.1996
   3813   -1.2430
   3913   -1.2872
   4013   -1.3309
   4113   -1.4887
   4213   -1.5165
   4313   -1.5388
   4413   -1.5602
   4513   -1.5826
   4613   -1.6061
   4713   -1.6269
   4813   -1.6408
   4913   -1.6535
   5013   -1.6589
   5113   -1.6640
   5213   -1.6668
   5313   -1.6675
   5413   -1.6659
   5513   -1.6621
   5613   -1.6562
   5713   -1.6482
   5813   -1.6382
   5913   -1.6263
   6013   -1.6131
   6192   -1.4155
   6193   -1.3483
   6194   -1.3655
   6195   -1.3825
   6196   -1.3992
   6270   -1.4313




   6271   -1.4466
   6272   -1.4613
   6273   -1.4754

 ***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

 LOAD STEP=     1  SUBSTEP=     1
  TIME=    1.0000      LOAD CASE=   0

 THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

   NODE      UY
   6461   -1.6019
   6462   -1.6085
   6463   -1.6055

MAXIMUM ABSOLUTE VALUES
NODE         5313
VALUE     -1.6675
```

2.5 Vert

C-23

2g Fore + Aft

```
***** POST1 TOTAL REACTION SOLUTION LISTING *****

LOAD STEP=     1  SUBSTEP=     1
 TIME=    1.0000      LOAD CASE=   0

THE FOLLOWING X,Y,Z SOLUTIONS ARE IN GLOBAL COORDINATES

  NODE        FX           FY           FZ
  3315                    37402.
  3335                    37415.       2.5113
  8391    .17222E+06     11293.       -2.5113

TOTAL VALUES
VALUE     .17222E+06   86110.        .41582E-07

/OUTPUT FILE= JOKE.DAT

NRSE  FOR LABEL= Y      BETWEEN  36.000     AND  36.000       KABS=  0.
 TOLERANCE=   .180000

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

  NODE       UY
  3211   -.16813
  3413   -.16838
  3513   -.16626
  3613   -.16537
  3713   -.15876
  3813   -.15517
  3913   -.15235
  4013   -.15172
  4113   -.13644
  4213   -.13288
  4313   -.12964
  4413   -.12491
  4513   -.11976
  4613   -.11307
  4713   -.10626
  4813   -.10178
  4913   -.97915E-01
  5013   -.96556E-01
  5113   -.94537E-01
  5213   -.92896E-01
  5313   -.91615E-01
  5413   -.90837E-01
  5513   -.90562E-01
  5613   -.90823E-01
  5713   -.91638E-01
  5813   -.92965E-01
  5913   -.94902E-01
  6013   -.97351E-01
  6192   -.14438
  6193   -.15053
  6194   -.14913
  6195   -.14753
  6196   -.14603
  6270   -.14271
  6271   -.14105




  6272   -.13945
  6273   -.13793

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP=     1  SUBSTEP=     1
 TIME=    1.0000      LOAD CASE=   0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

  NODE       UY
  6481   -.99392E-01
  6482   -.98226E-01
  6483   -.92731E-01

MAXIMUM ABSOLUTE VALUES
NODE        3113
VALUE     -.16938
```

THE FOLLOWING X,Y,Z SOLUTIONS ARE IN GLOBAL COORDINATES

NODE	FX	FY	FZ
1315		22057.	
1335		22077.	-1.8836
8391	-.12916E+06	41975.	1.8836

1.5 g AFT + DWT

TOTAL VALUES			
VALUE	-.12916E+06	86110.	.40609E-07

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UY
3211	-.64758
3413	-.67125
3513	-.68208
3613	-.68747
3713	-.72063
3813	-.75374
3913	-.78677
4013	-.81784
4113	-.93976
4213	-.96188
4313	-.97993
4413	-.99848
4513	-1.0180
4613	-1.0394
4713	-1.0591
4813	-1.0723
4913	-1.0840
5013	-1.0888
5113	-1.0939
5213	-1.0971
5313	-1.0986
5413	-1.0980
5513	-1.0956
5613	-1.0912
5713	-1.0850
5813	-1.0770
5913	-1.0672
6013	-1.0561
6192	-.88257
6193	-.83094
6194	-.84403
6195	-.85706
6196	-.86994
6270	-.89450
6271	-.90685
6272	-.91835
6273	-.92933

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

6273 -.92933

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UY
[illegible]	-1.0455
[illegible]	-1.0523
6461	-1.0198

MAXIMUM ABSOLUTE VALUES
NODE 5313
VALUE -1.0986

C-25

TIME= 1.0000 LOAD CASE= 0 LAT + Dwt

THE FOLLOWING X,Y,Z SOLUTIONS ARE IN GLOBAL COORDINATES

NODE	FX	FY	FZ
1315		83133.	
1335		-25849.	28642.
8391	.69122E-06	28826.	14413.

TOTAL VALUES

VALUE	.69122E-06	86110.	43055.

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UY
3211	-.45252
3413	-.46556
3513	-.47050
3613	-.47309
3713	-.48894
3813	-.50602
3913	-.52341
4013	-.54115
4113	-.60859
4213	-.62166
4313	-.63329
4413	-.64464
4513	-.65638
4613	-.66859
4713	-.68023
4813	-.68886
4913	-.69691
5013	-.70184
5113	-.70692
5213	-.71121
5313	-.71479
5413	-.71755
5513	-.71955
5613	-.72081
5713	-.72132
5813	-.72132
5913	-.72067
6013	-.71962
6192	-.57668
6193	-.54842
6194	-.55562
6195	-.56275
6196	-.56978
6270	-.58344
6271	-.59002
6272	-.59642
6273	-.60261

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UY
6461	-.71959
6462	-.71933
6463	-.71962

MAXIMUM ABSOLUTE VALUES

NODE	5813
VALUE	-.72132

THE FOLLOWING X,Y,Z SOLUTIONS ARE IN GLOBAL COORDINATES

NODE	FX	FY	FZ
1315		35300.	
1335	-.57881E-06	34236.	-.78444E-04
6538		29269.	.78479E-04
6984		30359.	

TOTAL VALUES

VALUE	-.57881E-06	.12916E+06	.34632E-07

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UY
3211	-.25608
3413	-.26173
3513	-.26220
3613	-.26250
3713	-.26420
3813	-.26738
3913	-.27088
4013	-.27399
4113	-.27133
4213	-.26723
4313	-.26064
4413	-.25372
4513	-.24721
4613	-.24124
4713	-.23438
4813	-.22473
4913	-.21452
5013	-.20147
5113	-.18853
5213	-.17497
5313	-.16077
5413	-.14597
5513	-.13063
5613	-.11482
5713	-.98614E-01
5813	-.82047E-01
5913	-.65168E-01
6013	-.47974E-01
6192	-.27501
6193	-.27452
6194	-.27486
6195	-.27508
6196	-.27513
6270	-.27470
6271	-.27419
6272	-.27348
6273	-.27254

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UY
6461	-.27085E-01
6462	-.41094E-01
6463	-.34013E-01

MAXIMUM ABSOLUTE VALUES

NODE	6196
VALUE	-.27513

THE FOLLOWING X,Y,Z SOLUTIONS ARE IN GLOBAL COORDINATES

NODE	FX	FY	FZ
3903			-3072.6
4203			3216.0
9100	28567.	-20494.	-34467.
9101	28182.	-20217.	34002.
9102	-28214.	-22571.	-28471.
9103	-28533.	-22827.	28793.

TOTAL VALUES			
VALUE	1.3722	-86109.	.22757E-01

/OUTPUT FILE= JOKE.DAT

TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UY
3211	3798.4
3413	6738.5
3513	8379.5
3613	9200.0
3713	14123.
3813	19046.
3913	23969.
4013	28892.
4113	50225.
4213	55147.
4313	60070.
4413	64993.
4513	69916.
4613	74839.
4713	79762.
4813	84685.
4913	89608.
5013	94531.
5113	99454.
5213	.10438E+06
5313	.10930E+06
5413	.11422E+06
5513	.11915E+06
5613	.12407E+06
5713	.12899E+06
5813	.13391E+06
5913	.13884E+06
6013	.14376E+06
6192	39558.
6193	31025.
6194	33158.
6195	35292.
6196	37425.
6270	41691.
6271	43825.
6272	45958.
6273	48091.

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UY
6461	.14950E+06
6462	.14567E+06
6463	.14759E+06

MAXIMUM ABSOLUTE VALUES
NODE 6461
VALUE .14950E+06

C-28

THE FOLLOWING X,Y,Z SOLUTIONS ARE IN GLOBAL COORDINATES

NODE	FX	FY	FZ
9100	-43982.	31553.	53066.
9101	-43982.	31553.	-53066.
9102	43981.	35185.	44381.
9103	43981.	35185.	-44381.

SEISMIC

TOTAL VALUES

VALUE	-2.5872	.13347E+06	.87420E-03

.ALL SELECTED NODES. DSYS= 0

)DE	X	Y	Z	THXY	THYZ	THZX
:211	170.42	36.023	-28.500	.00	.00	.00
.413	174.00	36.000	-28.500	.00	.00	.00
.513	176.00	36.000	-28.500	.00	.00	.00
:613	177.00	36.000	-28.500	.00	.00	.00
;713	183.00	36.000	-28.500	.00	.00	.00
(813	189.00	36.000	-28.500	.00	.00	.00
;913	195.00	36.000	-28.500	.00	.00	.00
.013	201.00	36.000	-28.500	.00	.00	.00
.113	227.00	36.000	-28.500	.00	.00	.00
.213	233.00	36.000	-28.500	.00	.00	.00
.313	239.00	36.000	-28.500	.00	.00	.00
413	245.00	36.000	-28.500	.00	.00	.00
.513	251.00	36.000	-28.500	.00	.00	.00
.613	257.00	36.000	-28.500	.00	.00	.00
713	263.00	36.000	-28.500	.00	.00	.00
.813	269.00	36.000	-28.500	.00	.00	.00
913	275.00	36.000	-28.500	.00	.00	.00
013	281.00	36.000	-28.500	.00	.00	.00
113	287.00	36.000	-28.500	.00	.00	.00
213	293.00	36.000	-28.500	.00	.00	.00

ᴰE	X	Y	Z	THXY	THYZ	THZX
.3	299.00	36.000	-28.500	.00	.00	.00
413	305.00	36.000	-28.500	.00	.00	.00
513	311.00	36.000	-28.500	.00	.00	.00
613	317.00	36.000	-28.500	.00	.00	.00
713	323.00	36.000	-28.500	.00	.00	.00
813	329.00	36.000	-28.500	.00	.00	.00
913	335.00	36.000	-28.500	.00	.00	.00
013	341.00	36.000	-28.500	.00	.00	.00
192	214.00	36.000	-28.500	.00	.00	.00
193	203.60	36.000	-28.500	.00	.00	.00
194	206.20	36.000	-28.500	.00	.00	.00
195	208.80	36.000	-28.500	.00	.00	.00
196	211.40	36.000	-28.500	.00	.00	.00
270	216.60	36.000	-28.500	.00	.00	.00
271	219.20	36.000	-28.500	.00	.00	.00
272	221.80	36.000	-28.500	.00	.00	.00
273	224.40	36.000	-28.500	.00	.00	.00
461	348.00	36.000	-28.500	.00	.00	.00
462	343.33	36.000	-28.500	.00	.00	.00
463	345.67	36.000	-28.500	.00	.00	.00

APPENDIX D

SEISMIC ANALYSIS DATA

APPENDIX D - SEISMIC ANALYSIS DATA

10 21 96 13:12 FAX 419 523 6247 NELSON MFG
07/17/96 12:58 509 376 8986 ICF KAISER ENGRS → SNF ENGINEERING 003 001

Andy Key

Post-it Fax Note 7671

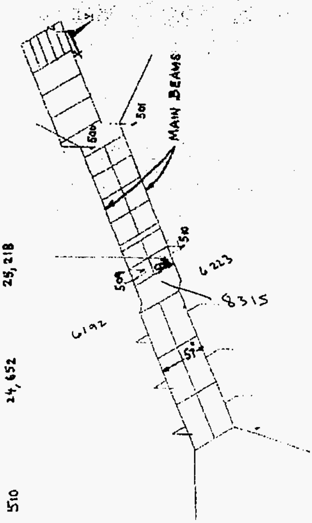
To DOUG CHENAULT	Date 7/17/96 # of pages ▸ 1
Co./Dept. WHC	From HARRY SHRIVASTAVA
Phone # 376-6230	Co. ICF KAISER
Fax # 373-9774	Phone # 376-3636
	Fax # 376-8986

ANSYS 5.2
JUL 17 1996
10:14:05
PLOT NO.
ELEMENTS
TYPE NUM

XV =1
YV =2
ZV =3
DIST=303.524
XF =266.5
ZF =95
VUP =Z
Z-BUFFER

REACTIONS AT JACKS & BLOCKS (RESPONSE SPECTRUM ANALYSIS)

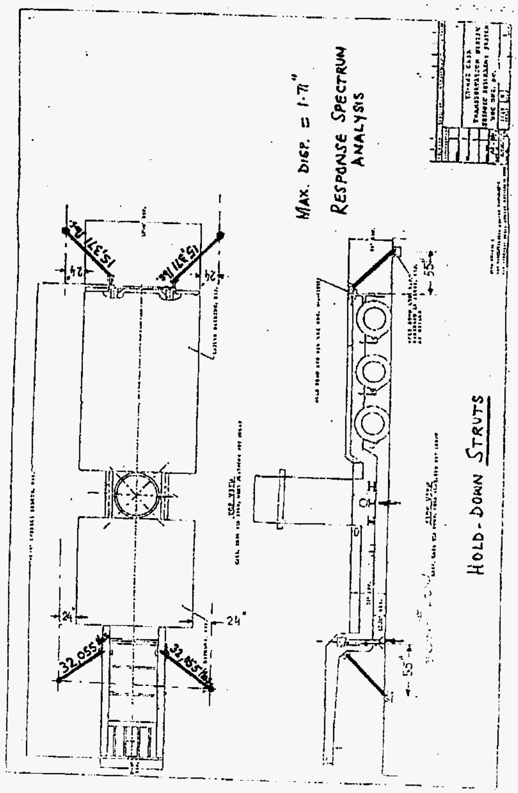
NODE NO.	VERTICAL LOAD, LBS. DEAD LOAD	SEISMIC LOAD
500	543	2,992
501	543	2,992
508	24,658	2,004
509	24,653	25,218
510	24,652	25,218



trailer analysis, response spectra analysis

D-2

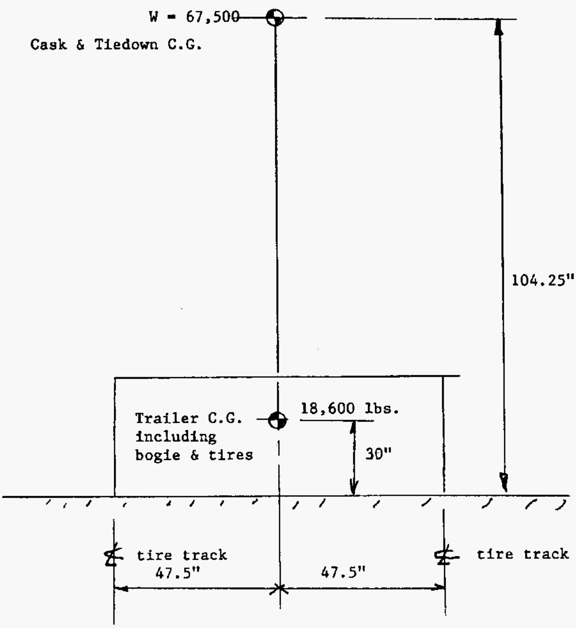
10 21 96 13:12 FAX 419 523 6217 NELSON MFG



APPENDIX E

CALCULATION OF OVERTURNING G LOAD

APPENDIX E - CALCULATION OF OVERTURNING G LOAD



$$G\ load = \frac{86100(47.5)}{18600(30) + 67500(104.25)} = .54$$

At .54 g the tires on one side will have lifted off the ground, thus to avoid damage to trailer and cask, the G load used is .5 for overturn impending but no damage done.

APPENDIX F

FATIGUE ANALYSIS

APPENDIX F - FATIGUE ANALYSIS

A fatigue analysis is made, using 400 events for all loading cases except the deadload case, which can have an infinite number of occurances as shown in the following. Figure I-9.1 from ASME Section III Boiler and Pressure Vessel Code is used for the analysis.

The deadweight peak stress can be obtained by linear ratio from the 2.5 g vertical stress, page C-15. Thus, S = (1/2.5)(66610) = 26,644 psi. One half of the total stress is the alternating stress, thus Salt = 13,322 psi. From Fig I-9.1, the allowable cycles are infinite and the usage factor is zero for deadweight. The peak stress for all load cases given on pages C-16 through C-21 is conservatively assumed to be the alternating stress. The peak stress for 2.5 g vertical down is halved for the alternating stress since it is known that this is one directional stress.

The usage factors are:

U1 = 0 (Deadweight calculated above)
U2 = 400/19000 = .02 (page C-15)
U3 = 400/6000 = .07 (page C-16)
U4 = 400/1050 = .38 (page C-17)
U5 = 400/2000 = .20 (page C-18)
U6 = 400/12000 = .03 (page C-19)
U7 = 400/11500 = .04 (page C-20)
U8 = 400/3000 = .13 (page C-21)

U = U1 + U2 + U3 + U4 + U5 + U6 + U7 + U8

= 0 + .02 + .07 + .38 + .20 + .03 + .04 + .13 = .87 < 1.0, thus adequate.

A5.0 ACCEPTANCE OF PACKAGING FOR USE

A5.1 NEW PACKAGING

A5.1.1 Acceptance Requirements

Acceptance of the Cask and Transportation System will based on inspection and tests that will be performed by the fabricators prior to shipment to the Hanford Nuclear Reservation site. These tests will be performed in accordance with written procedures prepared by the fabricators and approved by Transnuclear. In addition documentation packages will be submitted for acceptance. The documentation will be unit specific and demonstrate that the unit fulfills the final material, welding and dimensional requirements of the approved design drawings and the procurement specification, as required by the Hanford Specification.

A5.1.2 Inspection and Testing

A5.1.2.1 Cask

The inspection and testing requirements will satisfy the requirements of the Hanford Specification. All cask containment boundary welds will be radiographically inspected. The final surface of all welds will be liquid penetrant inspected. The fabrication drawings will show cask regions that require the following inspections:

a. Liquid Penetrant Inspection: This inspection will be performed in accordance with ASME[(1)] Section V based upon the acceptance criteria from ASME Section III. Any indication of a defect will be removed, repaired and reinspected as required by the Hanford Specification.

b. Radiographic Inspection: Welds that require radiographic inspection will performed in accordance with the ASME Code, Section III. Any indication of a defect will be removed, repaired and reinspected as required by the Hanford Specification.

The following tests will be performed to satisfy the requirements of the Hanford Specification:

a. Leakage Rate Testing: Helium leakage rate tests will be performed to verify the leak tightness of the seals of the containment boundary of the cask. Leakage shall not exceed 1×10^{-7} scc/sec, air.

b. Pressure Testing: Each unit will be hydrostatically tested in accordance with the requirements of the Hanford Specification. The acceptance criteria is no evidence of leakage.

After fabrication and prior to first use, a visual inspection shall be performed to verify that all accessible cask surfaces have no damage (cracks, surface discontinuities with depth exceeding minimum wall thickness requirements, etc.), and are free of grease, oil or other contamination. The sealing surfaces will be examined for cracks or scratches that may result in acceptable leakage. In general, a confirmation will be made that all cask components are in acceptable condition for use.

A5.1.2.2 Cask Lifting Attachment

The lifting attachment will be subjected to a load test of 150% of the maximum service load. A confirmation will be made that all components of the lifting attachment are in acceptable condition for use.

A5.1.2.3 Conveyance

Standard pre trip inspection shall be performed by the driver in accordance with CDL requirements. Annual inspection shall be performed in accordance with standard DOT specification.

Upon completion of the trailer fabrication and prior to the installation of the upper tiedown system, the trailer will have a static load test. It will be tested at 120% of the expected concentrated load.

A5.1.2.4 Cask Operations Equipment

The immersion pail and loadout pit support structure are both designed to meet the criteria of ANSI 14.6[(2)]. These structures will be subjected to a load test of 150% of the maximum service load, which is testing to 90,000 pounds.

Assembly testing will be performed at the fabricators facility for each of the component interface boundaries permitted to be evaluated prior to shipment.

A5.2 ANNUAL INSPECTION REQUIREMENTS

The annual inspection and testing requirements will be provided in the Installation, Operation, Repair, and Maintenance Manuals (IORM) for the System. Included in the manuals will be the inspection and testing to be performed, and the acceptance requirements.

A5.2.1 Acceptance Requirements

The annual inspection requirements for the cask is the visual inspection of the cask components including seals and sealing surfaces. Typically the replacement of the seal and bolts (depending on usage) occur at this time. The Containment Verification Leak Test is performed after the change of the seals using approved procedures. Acceptance requirements is the leakage rate of 1 x 10^{-7} scc/sec, air.

A5.2.2 Inspection and Testing

Load testing of the cask operational equipment will be required following any major maintenance or alteration to the load path structure, or if an incident occurred in which any of the load-bearing components may have been subjected to stresses substantially in excess of those for which the structure has been qualified by previous testing, or following an incident that may have caused permanent distortion of the load-bearing parts.

Inspection of the equipment including the cask lifting attachment and the cask will be performed by operating personnel for indications of damage or deformation prior to each use. Maintenance personnel, or other non-operating personnel, will be required to visually inspect load path components at intervals not to exceed three months in length for indications of damage or deformation.

The annual Containment System Verification Test is required to be performed on the cask in accordance with ANSI N14.5[(3)].

References For Section A5.0

1. ASME Boiler and Pressure Vessel Code, American Society of Mechanical Engineers, NY, 1992.

2. Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds or More, ANSI N14.6, American National Standards Institute Inc., NY, 1993.

3. Leakage Tests on Packages for Shipment of Radioactive Materials, ANSI N14.5, American National Standards Institute Inc., NY, 1987.

A6.0 OPERATING REQUIREMENTS

A6.1 GENERAL REQUIREMENTS

The TN-WHC Transport Cask and the K-Basin Operational Equipment have been designed to facilitate the loading of fuel from the K-Basins into the Multi-Canister Overpacks (MCOs). The procedures provided in this Section provide the necessary steps associated with the operation of the TN-WHC Transport Cask and the K-Basin Operational Equipment. Integration of these procedures into site specific procedures will form the bases for system facility operation.

The Operational Equipment and procedures are based on the concept of "start clean, stay clean". This concept has been incorporated into the design of the K-Basin immersion pail, support structure and loadout pit work platform.

The immersion pail support structure is a welded steel structure which provides an operations guide system and support for the TN-WHC cask during loadout pit MCO loading operations. When loaded into the support structure at the operator access level, the cask is lowered into and sealed with the immersion pail system which precludes contamination of the cask's surfaces. This "start clean, stay clean" operational system thereby improves turnaround time and reduces operator dose rates by eliminating the need for extensive cask decontamination efforts following MCO loading operations.

As part of the operational procedures development, a radiation dose evaluation has been performed for the MCO loading operations. This evaluation provides a baseline for the development of site specific operating procedures which incorporate As Low As Reasonably Achievable (ALARA) principles to minimize the dose to operators during the MCO loading operations.

A6.2 TN-WHC MCO LOADING OPERATIONS

The following operating procedures are provided to permit understanding of operations sequencing and generic task identification. Detailed system operating procedures are provided in the "Installation, Operation, Repair and Maintenance Manual, (IORM)".

A6.2.1 Receiving Cask in K Basin

1. Prepare cask receiving area for TN-WHC cask and trailer receipt.

2. Open door and back loaded cask trailer into facility.

3. Set tractor brakes, shut off tractor engine, change trailer override valve to manual, lower the rear of the trailer, set trailer brakes and install wheel chocks. Connect building air supply to the landing leg air supply glad hand, lower the landing legs until the trailer is lifted off the tractor.

4. Disconnect tractor electrical and air connections from trailer, release the fifth wheel and remove tractor from facility. Lower the front of the trailer until the trailer becomes relatively level.

5. Remove the four quick release locking pins from the vertical hold down devices and disengage the arms. Place the pins in the unlock position.

6. Align crane hooks with cask lifting trunnions and raise crane hoist to apply slight load on crane.

7. Remove the six tie-down bolts from the cask tie-down device. Place the bolts in the storage positions provided on the work platform.

8. Lower the removable trailer work platform from the working side of the trailer and disconnect cable. Relocate the safety chain.

9. Swing both sides of the tie-down device to the open position.

10. Raise the cask to clear the trailer.

11. Move the cask over the safe load path to the load out pit.

12. Align the cask with the immersion pail and lower into the pail until weight of cask is removed from crane hook.

A6.2.2 In-Pool Loading Operations

1. Detorque the cask lid bolts in sequence indicated. Ensure all bolts have disengaged from cask. Note: Bolts are captive on the cask lid.

2. Slowly raise crane hoist to remove cask lid. Position cask lid in area where lid o-ring can be visually inspected for feathering, crack, etc.. If damage is noted reject cask and send for maintenance. If no damage is noted place cask lid in storage position. Take care to protect cask and lid sealing surfaces.

3. Retrieve immersion pail lid from storage location with crane and lifting slings, and place in position on top of immersion pail structure. Check alignment of bolt holes. (Note: Immersion pail lid sealing surfaces will now be mated to the external surface of the MCO and the inner edge of the immersion pail structure.) Release immersion pail lid and remove slings from crane. Store immersion pail slings.

4. Engage the four immersion pail lid fasteners and inflate the immersion pail seal.

5. Tighten the pail lid fasteners "hand tight" and inflate the MCO seal.

6. Connect immersion pail water vent line.

7. Fill MCO with processed water until within one inch of top of pail structure.

8. Fill pail with clean deionized water through the fill connection while venting from the pail lid vent line. When fill water discharges from vent line, disconnect vent line from valve quick disconnect, and configure water fill line to the immersion pail water control box. Observe pail and MCO seals for any water leakage, correct as required.

9. Install the immersion pail lift beam on the crane hooks. Retrieve pail system slings from storage location and connect pail system slings to crane.

10. Slowly raise pail system until the alignment lines on the immersion pail lifting lugs are exposed at the lock pin housing. Lift lock pin gate and retract lock pins until the pin gate can close again. This ensures full retraction.

11. Using the crane, slowly lower the immersion pail system to the bottom of the loadout pit. Remove slings from master link and secure sling hooks to the sling storage boxes. Position immersion pail lift beam and crane for MCO loading.

12. Perform MCO loading operations per MCO loading procedures.

13. Position the crane with immersion pail lift beam and reattach pail lifting slings to the master link. Lift the immersion pail to the water surface using the lifting slings.

14. Rinse all surfaces free of possible fuel particulate with water at a hold point where the immersion pail lid is approximately 6 inches above the water surface. Continue raising the immersion pail while rinsing the MCO and pail lid surfaces with clean deionized water to remove any residual contamination.

15. Slowly raise pail into the support structure guides until the pin engagement point is reached. Stop crane and engage immersion pail locking pins.

16. Slowly lower immersion pail until resting on locking pins.

17. Remove immersion pail lifting slings and lift beam from crane.

18. Complete MCO closure and transport preparation using MCO operations procedures.

A6.2.3 Preparation of Loaded Cask for Transport

1. Decontaminate MCO shield plug top surfaces and immersion pail lid, as required. Vent air from MCO and pail seals. Permit water to flow past seals to flush contamination. Isolate deionized water supply.

2. Survey the pail lid prior to removing the lid.

3. Disengage four pail lid fasteners and attach lifting slings from immersion pail lid to crane.

4. Lift immersion pail lid, place it in storage and disengage the lift beam from crane.

5. Inspect lid end of cask body for cleanliness. Attach the cask lid to the crane and align with alignment pins and slowly lower the lid onto the cask body. Remove any weight from crane hoist.

6. Disengage crane hook from cask lid. Torque cask lid bolts in appropriate sequence.

7. Raise cask from the immersion pail.

8. Verify cask surfaces are free of contamination. Monitor surface radiation dose rates. (Note: Take pail water sample to verify water cleanliness prior to next MCO loading cycle.)

9. Transfer the cask to the trailer. Lower cask on to the trailer. Reposition cask operations platform on trailer and engage cask tie-down system.

10. Disengage crane from the trunnions and move free of trailer.

11. Perform cask and trailer final radiation and contamination surveys. Decontaminate as required.

12. Connect building air supply to the landing leg air supply glad hand. Open door and back tractor to front of trailer. Raise the front of the trailer to match the tractor fifth wheel and lock in place. Set tractor brake and shut off tractor engine.

13. Retract landing legs, change building air supply from landing leg to trailer air glad hand. Raise the rear of the trailer to defined location. Change the override valve to automatic, disconnect the building air supply and connect tractor air lines and electrical cable. Remove wheel chocks.

14. Release cask for transfer to CVD.

A6.3 CASK UNLOADING PROCEDURES

Transfer of the MCO to the Cold Vacuum Drying facility and subsequent transfer to the Canister Storage Building dose not require movement of the transfer cask from the transfer trailer. Site specific operating procedures will be developed using trailer and cask general operating procedures outlined in Section 6.2 of this report and the Systems "Installation, Operation, Repair and Maintenance Manuals". MCO unloading procedures will be provided with supply of the MCO.

A6.4 EMPTY PACKAGING PROCEDURES

Similar to the discussion provided in Section 6.3 the transfer cask is not intended to be moved from the transfer trailer during Cold Vacuum Drying, unloading the MCO in the Canister Storage Building and reloading the transfer cask with an empty MCO for the return to 105 K East and 105 K West Basins. Site specific operating procedures will be developed using trailer and cask general operating procedures outlined in Section 6.2 of this report and the Systems "Installation, Operation, Repair and Maintenance Manuals". Empty MCO loading procedures will be provided with supply of the MCO.

A6.5 CASK LOADING RADIATION DOSE ESTIMATES

Table 6.5-1 provides the estimated total dose for operators loading the MCO at the K-Basins. These dose estimates have been prepared based on the cask loading procedures described in Section 6.2 and estimates of the number of operators and time required to perform specific cask loading operations. The background dose rates were provided by WHC. The cask dose rate estimates were provided by TN based on the limiting MCO source terms. Cask dose rates were adjusted to reflect average source for integrated dose assessment. The factor representative of the average source has been defined as 42 % of the design bases maximum source.

Table A6.5-1 Estimated Total Dose

Activity	Number of People	Time (hr)	Total Man Hours	Backround (mrem/hr)	Avg. Source (1) (mrem/hr)	Background Dose (man-mrem)	Cask Field Dose (man-mrem)	Total Dose (man-mrem)
Receiving Cask in K-Basin								
1) Prepare receiving area	2	1	2	2	0	4	0	4
2) Back trailer into facility	1	0.25	0.25	2	0	0.5	0	0.5
3) Prepare trailer for tractor disconnect	2	0.25	0.5	2	0	1	0	1
4) Disconnect trailer	1	0.25	0.25	2	0	0.5	0	0.5
5) Release tie down lock pins	1	0.1	0.1	2	0	0.2	0	0.2
6) Attach crane	2	0.25	0.5	2	0	1	0	1
7) Remove tie-down bolts	2	0.4	0.8	2	0	1.6	0	1.6
8) Open trailer platform	1	0.1	0.1	2	0	0.2	0	0.2
9) Open cask tie downs	2	0.1	0.2	2	0	0.4	0	0.4
10) Raise cask free of trailer	2	0.2	0.4	2	0	0.8	0	0.8
11) Move cask to loadout pit	1	0.2	0.2	5	0	1	0	1
12) Lower cask into immersion pail	1	0.2	0.2	5	0	1	0	1
6.2.1 Total						12.2	0	12.2
: In Pool Loading Operations								
1) Detorque cask lid bolts and disengage	2	0.5	1	10	0	10	0	10
2) Remove cask lid	1	0.3	0.3	10	0	3	0	3
3) Install immersion pail lid	2	0.5	1	10	0	10	0	10
4) Engage immersion pail lid fasteners	1	0.3	0.3	10	0	3	0	3
5) Tighten pail lid fasteners and inflate MCO seal	1	0.2	0.2	10	0	2	0	2
6) Attach water vent lines	1	0.1	0.1	10	0	1	0	1
7) Fill MCO with water	1	0.4	0.4	10	0	4	0	4
8) Fill pail and cask with water	1	0.4	0.4	10	0	4	0	4
9) Install pail lift beam and slings	2	0.2	0.4	5	0	2	0	2
10) Raise pail and release lock pins	2	0.2	0.4	10	0	4	0	4
11) Lower pail, release slings and move crane / beam	2	0.2	0.4	10	0	4	0	4
12) Load MCO with fuel baskets (2)	2	4	8	2	0	16	0	16
13) Position lift beam, attach slings, lift to surface	2	0.4	0.8	10	0	8	0	8
14) Rinse lid free of residual contamination	1	0.2	0.2	10	0.084	2	0.0168	2.017
15) Lift pail and engage lock pins	2	0.2	0.4	10	0.252	4	0.1008	4.101
16) Lower pail onto lock pins	1	0.1	0.1	10	0.252	1	0.0252	1.025
17) Remove slings and lift beam	2	0.2	0.4	5	0.252	2	0.1008	2.101
18) Complete MCO transport preparation (3)	0	0	0	0	0	0	0	0
6.2.2 Total						80	0.2436	80.24

Activity	Number of People	Time (hr)	Total Man Hours	Backround (mrem/hr)	Avg. Source (1) (mrem/hr)	Background Dose (man-mrem)	Cask Field Dose (man-mrem)	Total Dose (man-mrem)
6.2.3 Preparation for Cask Departure								
1) Decon lid, vent seal, isolate water supply	2	0.5	1	10	0.252	10	0.252	10.25
2) Servey lid	1	0.1	0.1	10	1.302	1	0.1302	1.13
3) Remove pail lid fasteners and attach slings	2	0.1	0.2	10	0.252	2	0.0504	2.05
4) Remove pail lid and place in storage	1	0.2	0.2	10	0.252	2	0.0504	2.05
5) Attach and install cask lid	2	0.2	0.4	10	0.588	4	0.2352	4.235
6) Disengage crane hooks and torque lid bolts	2	0.5	1	10	0.588	10	0.588	10.59
7) Raise cask from pail	1	0.1	0.1	10	3.864	1	0.3864	1.388
8) Survey cask surface and pail water (4)	1	0.1	0.1	10	7.224	1	0.7224	1.722
9) Move cask and position/tiedown on trailer	2	0.3	0.6	5	3.864	3	2.3184	5.318
10) Release cask and move crane free of trailer	2	0.2	0.4	2	2.184	0.8	0.8736	1.674
11) Perform final radiation survey	1	0.2	0.2	2	7.224	0.4	1.4448	1.845
12) Connect tractor to trailer	1	0.2	0.2	2	0.84	0.4	0.168	0.568
13) Retract landing gear	1	0.1	0.1	2	0.84	0.2	0.084	0.284
14) Release cask for transfer to CVD								
6.2.3 Total						35.8	7.3036	43.1
Summary								
6.2.1 Total Dose						12.2	0	12.2
6.2.2 Total Dose						80	0.2436	80.24
6.2.3 Total Dose						35.8	7.3036	43.1
						128	7.5474	135.5

Total Indgrated Time for MCO Loading Operation 14.5 hours
Total Dose for MCO Loading Operation 135.55 man-mrem

(1) Average Source is 42% of Maximum
(2) Time and Dose are based on MCO Loading Specification
(3) Time and Dose To Be Determined by Others
(4) System Design Precludes Contamination

A6.6 LEAK TESTING TN-WHC CASK

A6.6.1 Containment System Periodic Verification Test

Method: Helium Mass Spectrometer Envelope, Pressurized Envelope Method (ANSI 14.5, A3.10.2)

Equipment required: Helium Mass Spectrometer Leak Detector
Vacuum Pump

Inspection of the Vent Port and Lid Seals

a. Verify that the cask is dry.
b. Remove quick-disconnect from Vent Port and install cover.
c. Connect the vacuum pump/helium mass spectrometer to the Drain Port quick-disconnect. Evacuate the cask cavity.
d. Install plastic hood around the top of the cask to cover the lid and the Vent Port.
e. The plastic hood is purged and pressurized with helium to slightly above atmospheric pressure.
f. Perform leak test using the leak detector.
g. Acceptance criteria is 1×10^{-7} std cc/sec, air.

Inspection of Drain Port Seal

a. Install quick-disconnect in Vent Port.
b. Remove quick-disconnect from Drain Port and install cover.
c. Connect the vacuum pump/helium mass spectrometer to the Drain Port quick-disconnect. Evacuate the cask cavity.
d. Install plastic bag to cover the Drain Port cover.
e. Purge bag with helium and pressurize to slightly above atmospheric pressure.
f. Perform leak test using the leak detector.
g. Acceptance criteria is 1×10^{-7} std cc/sec, air.

A6.6.2 Containment System Assembly Verification Test

Method: Pressure Rise (ANSI 14.5, A3.5)

Equipment required: Vacuum pump
Vacuum bell

Inspection of the Lid Seal

a. Verify that the cask is dry.
b. Evacuate the cask cavity using the Vent Port quick-disconnect.
c. Perform leak test.

d. Test sensitivity is 1 x 10^{-3} std cc/sec, air.
e. Install Vent Port cover.
f. Backfill with the appropriate fill gas.

Inspection of Vent and Drain Port Seals

a. Place vacuum bell over Vent Port cover.
b. Evacuate the vacuum bell.
c. Perform leak test
d. Test sensitivity is 1 x 10^{-3} std cc/sec, air.
e. Place vacuum bell over Drain Port cover.
f. Repeat steps b-d.

A7.0 QUALITY ASSURANCE REQUIREMENTS

A7.1 INTRODUCTION

Transnuclear's Quality Assurance Program is applicable to the safety related items (WHC Safety Class I) and activities performed on this project.

TN's QA Program Manual, " Quality Assurance Program for Design, Fabrication, Assembly, Testing, Maintenance, Repair, Modification and Use of Packaging for Transport of Radioactive Materials, E-1473", was prepared and implemented to satisfy the criteria of Subpart H to 10CFR71. This QA Program has been approved by the USNRC. In addition, WHC has reviewed the program and concluded that it is acceptable for use on this project.

All Transnuclear cask components are designated as "safety-related" except quick-disconnects and associated seals, lubricants, and nameplates. Lifting attachments and other hardware associated with lifting the cask at the K-Basin sites are designated "safety-related". All other equipment (e.g. trailer, platform, pail) of the cask transportation system and operational equipment are non-safety related.

A7.2 GENERAL REQUIREMENTS

A7.2.1 Organization

The organizational line relationships within TN and between TN, WHC and a Major Participating Organization are identified in Figure A7.2-1. Dotted lines on the organization chart (Figure A7.2-1) indicate communication and solid lines indicate direction, as appropriate.

A7.2.2 Quality Assurance Program

Transnuclear will follow the requirements of their QA Program, E-1473 for all components that are designated safety-related. Major Participating Organizations, whose services are used during the course of this project, will develop and implement their own Quality Assurance programs, as approved by Transnuclear.

A7.2.3 Design Control

TN has established measures to assure that regulatory requirements and packaging design have been or are correctly translated into drawings, specifications, procedures and instructions. Design inputs are documented and approved in accordance with QA procedures. Changes to design shall be identified, reviewed, approved and incorporated into the appropriate revision of design documents. These changes require the same review and approval as the original.

A7.2.4 Procurement Control

TN's safety related procurement documents shall identify which documents are to be prepared by a major participating organization and which documents are to be submitted to TN for review, information and/or approval. The procurement documents shall also specify which documents are to be retained, controlled and maintained by the major participating organizations for specified periods and which records shall be transmitted to TN prior to use of the packaging.

A7.2.5 Instructions, Procedures and Drawings

Instructions, procedures and drawings shall include quantitative and/or qualitative acceptance criteria to verify that activities affecting quality have been satisfactorily accomplished.

A7.2.6 Document Control

TN has established and implemented procedures to control the issuance of TN documents which prescribe activities affecting quality. These procedures define document control measures to assure adequate review, approval, release and distribution of original documents and subsequent revisions. Major participating organizations shall establish and implement document control procedures in accord with their approved QA program.

A7.2.7 Control of Purchased Material, Equipment and Services

Measures have been established and implemented to assure that all purchased material, equipment, and services conform to procurement documents. Major participating organizations shall provide objective evidence that safety-related components meet all quality requirements.

A7.2.8 Identification and Control of Materials, Parts and Components

Measures have been established and implemented to identify and control materials, parts and components. These measures shall assure identification and control by appropriate means during the fabrication, installation and use of the material/part/component. This shall prevent the inadvertent use of incorrect or defective items. The identification and control of safety-related items shall be traceable through procurement, fabrication, inspection and test records.

A7.2.9 Control of Special Processes

Measures have been established and implemented for the control of special processes used in the fabrication, modification and repair of safety-related components. Special processes shall be performed in accordance with approved written procedures. Personnel who perform special processes shall be formally trained and qualified in accordance with applicable codes, standards or specifications.

A7.2.10 Inspection

Measures shall be established and implemented to inspect materials, parts, processes or other activities affecting quality to verify conformance with documented instructions, procedures, specifications, drawings, or other procurement documents. These inspections shall be performed by personnel other than those who performed the activity being inspected. Modifications and/or repairs to and replacement of safety related components shall be inspected in accordance with the original design and inspection requirements or approved alternatives.

A7.2.11 Test Control

A program has been established and implemented to perform required acceptance and operational tests, as identified in procurement documents and the application for component approval. The tests shall be performed by qualified personnel in accordance with approved written instructions, procedures, and/or checklists. Test results shall be documented and evaluated to demonstrate that the acceptance criteria has been met.

A7.2.12 Control of Measuring and Test Equipment

Major participating organizations are responsible for appropriate selection, calibration and control of measuring and test equipment. Measuring and test equipment used for verifying safety related characteristics shall have documented, valid relationships to nationally recognized standards. Instrumentation and test equipment supplied by TN for testing following loading operations shall be calibrated and controlled in accordance with QA procedures.

A7.2.13 Handling, Storage and Shipping

TN documents shall identify handling, storage and shipping requirements. These shall include instructions for marking, special lift points, orientation for storage, shipping and preservation. Based on this, the major participating organizations shall invoke all required handling, storage and shipping requirements in accordance with their approved, written procedures.

A7.2.14 Inspection, Test and Operating Status

Major participating organizations shall implement their established systems for determining and identifying the acceptability of safety-related components regarding inspections and tests to be performed. Only those safety-related components which have met the required acceptance criteria shall be used. Nonconforming components shall be clearly identified to prevent inadvertent use.

A7.2.15 Nonconforming Material, Parts or Components

Measures shall be established and implemented to control materials, parts and components which do not conform to requirements to prevent their inadvertent use in subsequent manufacturing operations or during service. Nonconformance reports will be utilized for the procedural control of nonconformances.

A7.2.16 Corrective Action

TN personnel shall assess the need for corrective action based on audit findings, inspection reports, test reports, nonconformance reports, etc. as required by our QA procedures.

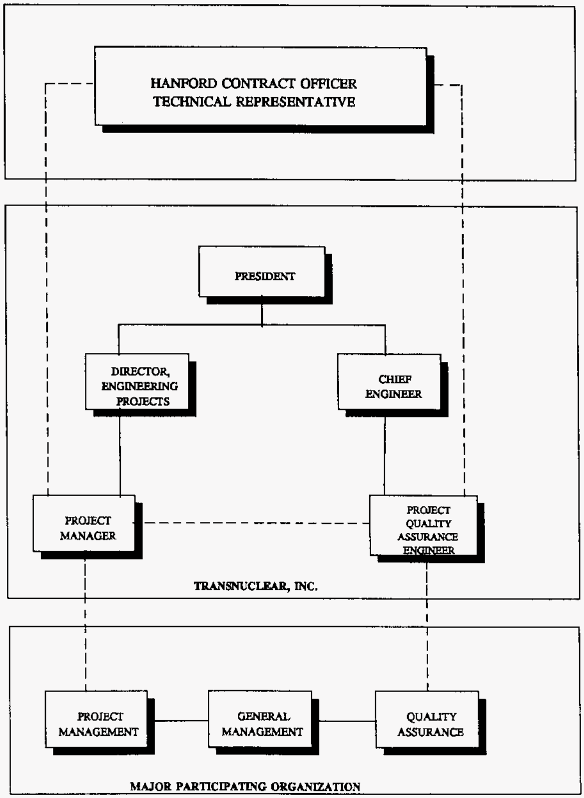
A7.2.17 Records

For each safety related component a program shall be established and implemented to assure that sufficient written records are maintained to furnish evidence of activities affecting quality.

A7.2.18 Audits

TN internal audits and audits of major participating organizations' activities shall be planned and conducted by the TN Project QA Engineer as required by QA procedures. Major participating organizations shall perform audits as required by their QA programs.

Figure A7.2-1 Chart Showing Organization



A8.0 MAINTENANCE

A8.1 GENERAL REQUIREMENTS

All manuals necessary for the operation and maintenance of the Cask and Transportation System will be provide at the time of delivery.

The general requirements for the cask would be the replacement of the seals on an annual basis. In addition, a visual inspection of all bolt holes is required to detect damage or galling. Replacement of damaged helicoils would occur at this time. A Containment System Verification Leak Test is required whenever the seals are replaced.

The cask operations equipment for the K-Basin loadout pit includes few mechanical systems and requires little maintenance activity. Maintenance support is limited to that required as a result of system operations inspections performed prior to each cask loading cycle and other system inspections performed monthly, tri-monthly and annually. Components which may require maintenance include immersion pail seal lid seals; immersion pail seal lid fasteners; support structure lock pins; demineralized water reservoir seals, hoses, and connectors; air lines and connectors; and lift slings and pail attachments. Due to the integrity of the design and limited operational components maintenance support is minimal.

A8.2 INSPECTION AND VERIFICATION SCHEDULES

Installation, Operation, Repair, and Maintenance Manuals (IORM) will be provided with the delivery of the Cask and Transportation System. These manuals will contain the required inspection and verification schedules.

Periodic inspection requirements for the operational system are minimal and include the following:

> Support inspection - Prior to each submersion cycle, the pail lifting slings and clevis pins are to be visually inspected for wear, frayed slings, or other signs of deterioration. If detected, part replacement is performed with the pail supported by the immersion pail support structure.
>
> Immersion pail seal verification - When the immersion pail lid is in place between the pail and the MCO and seals are inflated, a positive pressure head of deionized water is applied to the contained space between the two seal boundaries. Loss of air pressure in the seal or evidence of water leakage around the seal provides evidence of seal failure. The immersion pail lid is removed to contaminated equipment repair and the spare immersion pail seal lid is substituted.
>
> Immersion pail integrity - Visual inspection for leakage when the pail is supported by

the immersion pail support structure can be performed by observing a lowering of the water elevation when the reservoir is isolated from the immersion pail. While such failure is highly unlikely, the inspection process is capable of detecting this condition so that repairs can be affected prior to significant deterioration.

Miscellaneous - Monthly inspection of painted surfaces, air fittings and water fittings is performed in addition to the normal daily observation by operating personnel.

A9.0 APPENDIX

A9.1 TN-WHC CASK AND TRANSPORTATION SYSTEM DRAWINGS

A9.2 CASK OPERATIONS EQUIPMENT ANALYSES

A9.1 TN-WHC CASK AND TRANSPORTATION SYSTEM DRAWINGS

DRAWING/DOCUMENT NO.	TITLE
WHC Dwg. No. H-1-81533	TN-WHC Cask Transportation System, Arrangement Drawing
WHC Dwg. No. H-1-81534	TN-WHC Cask Transportation System, Assembly Drawing
WHC Dwg. No. H-1-81535	
Sheet 1	TN-WHC Cask Transportation System, Assembly and Parts List
Sheet 2	TN-WHC Cask Transportation System, Cask Body and Parts List
Sheet 3	TN-WHC Cask Transportation System, Cask Body Details
Sheet 4	TN-WHC Cask Transportation System, Lid
Sheet 5	TN-WHC Cask Transportation System, Lid
WHC Dwg. No. H-1-81536	TN-WHC Cask Name Plate
WHC Dwg. No. H-1-81537	TN-WHC Cask Transportation System, Seismic Restraint System
WHC Dwg. No. H-1-81539	
Sheet 1	TN-WHC Cask Transportation System, Tiedown System
Sheet 2	TN-WHC Cask Transportation System, Tiedown System Details
Sheet 3	TN-WHC Cask Transportation System, Tiedown System Details
WHC Dwg. No. H-1-81543	K Basin Immersion Pail, Lift Beam assembly (2 Sheets)
WHC Dwg. No. H-1-81544	K Basin Immersion Pail, TN-WHC Transport Cask
WHC Dwg. No. H-1-81545	K Basin Immersion Pail Support Structure (2 Sheets)
WHC Dwg. No. H-1-81546	K-Basin Immersion Pail Seal Lid (2 Sheets)
WHC Dwg. No. H-1-81547	K Basin Immersion Pail Assembly
WHC Dwg. No. H-1-8148	K Basin Transport Trailer Work Platform (7 Sheets)
WHC Dwg. No. H-1-81549	K Basin MCO/Cask CVD Lid (2 Sheets)

WHC Dwg. No. H-1-81550	K Basin Immersion Pail Ancillary Equipment
WHC Dwg. No. H-1-81551	K Basin Immersion Pail Interface Control Drawing (2 Sheets)
WHC Dwg. No. H-1-81552	K Basin Immersion Pail Lock Pin Guide Assembly
WHC Dwg. No. H-1-81553	K Basin Immersion Pail Support Structure Assembly
WHC Dwg. No. H-1-81554	K Basin Immersion Pail Support Equipment (3 Sheets)
WHC Dwg. No. H-1-81555	Transport Trailer Design (3 Sheets)

A9.2 CASK OPERATION EQUIPMENT ANALYSES

Structural analyses of the cask operation equipment has been performed relative to ANSI 14.6 criteria for safety related components in the immersion pail and loadout pit support structure. AISC criteria has been employed for structural evaluations of the steel support structure in combination with the ANSI N14.6 load factors. In addition to analyses of the safety related load path cask operational equipment, the cold vacuum drying lid is evaluated to assure the MCO is contained during cold vacuum drying operations. Table A9.2-1 summarizes results for each of the safety related system operational load path components.

Component analyses performed for non-safety related components include evaluation of the system support structures, including the immersion pail lid, the loadout pit work platform and the trailer work platform. Structural analyses results for these components are summarized in Table A9.2.2.

The following discussion provides a brief description of each calculation package documenting structural evaluations of the operation equipment components.

<u>Immersion Pail - Safety Related Support Load Path (Calculations 457-2003.2 and 2003.3)</u>

Calculation Package 457-2003.2 evaluates the immersion pail against the lifting requirements defined in ANSI N14.6. The calculation includes a determination of the pail weight and buoyancy force, along with evaluations of the bottom plate, lifting lug, lug to shell welds, and primary shell. The design is based on a two (2) point lift load.

Two analysis calculation packages encompass the evaluation of the pail under stand resting conditions. Both calculation packages invoke the load factor requirements defined in ANSI N14.6. The calculation package scopes are delineated as follows:

- Calculation 457-2003.2 evaluates the immersion pail upper flange forging subjected to support structure loading conditions. The design is based on a normal condition four (4) point support load.

- Calculation 457-2003.3 analyzes the immersion pail upper flange forging subjected to support structure loading conditions. The analyses considers a two (2) point support load. A general purpose finite element program, ANSYS, Version 5.2, is used to evaluate this condition.

Additionally, Calculation 457-2003.2 documents the maximum lift load under various loading scenarios. These loading scenarios are summarized below:

Load Condition	Description	Load (lbs)
I	Setting Pail In Water In Support Stand	9,096
II	Lowering Pail / Empty Cask To Pit Bottom	36,680
III	Raising Pail / Full Cask Off Bottom	53,730
IV	Raising Pail / Full Cask To Stand Height	57,877
V	Raising Fully Loaded Cask From Pit	59,820

Immersion Pail Support Structure - Safety Related Support Load Path (Calculation 457 2005.2)

Calculation Package 457-2005.2 evaluates the immersion pail support structure utilizing the load factor requirements defined in ANSI N14.6. Documented in the calculation package are evaluations of the pail support structure for composite frame buckling and corner post assembly buckling. Tie plates used to provide stability to the structure are sized and evaluated for compression loads. Bearing and shear stress evaluations were performed for the guide assembly and lock pin.

Lift Beam - Safety Related Support Load Path (Calculation 457-2005.3)

Calculation Package 457-2005.3 evaluates the lift beam utilizing the load factor requirements defined in ANSI N14.6. The evaluation documents the structural adequacy of the lift beam weldment and the eye plate.

Cold Vacuum Drying Lid - Safety Related Operations Pressure Loading (Calculation 457-2001.2)

Calculation Package 457-2001.2 evaluates the conditioning lid for internal pressure and lid lifting load conditions. The conditioning lid is used during the MCO vacuum drying operation in the conditioning facility immediately after the MCO is loaded. The internal pressure load is developed as a result of circulating hot water between the MCO outer surface and the inner surface of the cask. Once the cask is within the conditioning facility, the cask lid is removed and the conditioning lid installed. The lid is a "Z" shaped ring. The lower leg of the Z rests on the top of the cask. Three (3) lid bolts are used to join the conditioning lid to the cask. The upper Z leg bears against the MCO top surface. The lid provides pressure boundary (two seals) and pressure restraint during MCO draining/drying in addition to providing additional shielding during the vacuum drying operation.

The lid is assessed utilizing a pressure loading of 60 psi. The lid bolting and the upper Z leg of the lid are influenced by pressure loading.

Additionally, the lid lifting lugs and welds are designed and evaluated to carry the lid weight loading.

Immersion Pail Seal Lid - Non Safety Related (Calculation 457-2004.2)

Calculation Package 457-2004.2 evaluates the immersion pail lid for internal pressure and lid lifting load conditions. Maximum internal pressure of 5 psi is developed by the positive pressure anti-contamination water system. Only the lid bolting and adjacent flange are influenced by a pressure loading of this level.

Additionally, the lid lifting lugs and welds are designed and evaluated to carry the lid weight loading only.

Loadout Pit Work Platform - Non Safety Related (Calculation 457-2007.2)

Calculation Package 457-2007.2 evaluates the loadout pit platform for design loads based on OSHA requirements defined in Title 29 of the Code Of Federal Regulations. Frame brace, weld, and wall plate stresses are limited to the acceptance criteria defined in the requirements of the AISC Code.

Transport Trailer Work Platform - Non Safety Related (Calculation 457-2002.2)

Calculation Package 457-2002.2 evaluates the transport trailer work platform for design loads based on OSHA requirements defined in Title 29 of the Code Of Federal Regulations. Channels, support pipes, end caps, and end cap weld stresses are limited to the acceptance criteria defined in the requirements of the AISC Code.

The following Appendix Sections contain analyses calculation documentation.

Table A9.2-1
K Basin Loadout Pit and Related Operation Equipment
Safety Related Load Path Components
Summary of Stress Analysis

Calculation No.	Drawing No./ Component	Item No.	Item	Applied Load	Design Check	Calculated Loading	Allowable	Basis	M.S.
457-2003.2 457-2003.3	457-101/ Immersion Pail	1	Bottom Plate	3W	plate bending	17.728 ksi	30 ksi	N14.6	0.41
		19,1	Pail shell to bottom plate interface	3W, pressure	net tension shell bending & shear	3.6 ksi 16.636 ksi	30 ksi 30 ksi	N14.6	0.88 0.45
		10-11	lug to shell weld	3W	shear	90.680 kips	594 kips	N14.6	0.85
		10	pail shell flange	3W	lifting - longitudinal bending	24.970 ksi	30 ksi	N14.6	0.17
		10	pail shell flange, stiffening ring	3W	lifting circumferential bending + torsion circumferential shear	17.938 ksi 0.53 ksi	30 ksi 18 ksi	N14.6	0.40 large
		10	pail shell flange, stiffening ring	3W	stand resting bending + torsion (4 pt lift) memb. + bending, Von Mises (2 pt)	17.104 ksi 28.16 ksi	30 ksi 30 ksi	N14.6	0.43 0.065
		11	lug plate	3W	bearing - lifting lug location	35.771 ksi	75 ksi	N14.6	0.52
		11	lug plate	5W	net tension - lifting lug location	30.440 ksi	75 ksi	N14.6	0.62
		11	lug plate	5W	shear pull out - lifting lug location	30.434 ksi	48 ksi	N14.6	0.37
		11	lug plate	3W	bearing - guide assembly location	60.453 ksi	75 ksi	N14.6	0.19
457-2005.2	457-102/ Support Structure	98,99	assembly	5W	buckling	300 kips	1,064 kips	AISC	0.72
		4, 15	tie plates	5W	compression	0.48 ksi	0.694 ksi	AISC	0.31
		5	corner post	5W	buckling	72.5 kips	75.0 kips	AISC	0.03
457-2005.2	457-109/ Lock Pin	4	lock pin	5W	double shear	49 ksi	81 ksi	AISC	0.40
		10	guide assembly	5W	bearing	16 ksi	54 ksi	NC	0.70
457-2005.3	457-112/ Lift Beam	1	lift beam weldment	3W 3W 5W	beam bending beam shear trunnion shear	25.447 ksi 2.769 ksi 11.933 ksi	30 ksi 18 ksi 40.20 ksi	AISC	0.15 0.85 0.70
		10	eye plate	3W	tension bearing	14.4 ksi 10.65 ksi	30 ksi 45 ksi	AISC	0.52 0.76
457-2001.2	457-106/ Cold Vacuum Drying Lid	1	lid flange	pressure	torsion	5.031 ksi	16.7 ksi	NC	0.70
		2	bolt	pressure	tension	13.59 ksi	16.7 ksi	NC	0.19
		8	lifting lug	3W	bearing tension shear	4.093 ksi 4.093 ksi 8.187 ksi	30 ksi 30 ksi 18 ksi	AISC	0.86 0.86 0.55

Table A9.2-2
K Basin Loadout Pit and Related Operation Equipment
Non-Safety Related Components
Summary of Stress Analysis

Calculation No.	Drawing No./ Component	Item No.	Item	Applied Load	Design Check	Calculated Loading	Allowable	Basis	M.S.
457-2004.2	457-103/ Seal Lid	2	lid flange	pressure	bending	8.936 ksi	25.05 ksi	NC	0.70
		20	bolt	pressure	tension	4.201 ksi	16.7 ksi	NC	0.75
		3	lifting lug	3W	bearing tension shear	1.6 ksi 1.6 ksi 3.2 ksi	30 ksi 30 ksi 18 ksi	AISC	0.95 0.95 0.82
457-2002.2	457-105/ Trailer Work Platform	24	channel	125 lbs / ft	bending shear	8.676 ksi 0.820 ksi	21 ksi 14 ksi	AISC	0.59 0.94
		26	plank hook	591 lbs	bearing	1.182 ksi	35 ksi	AISC	0.97
457-2007.2	457-111	4, 5, 3	brace, extension, brace	2000 lbs	tube bending shear	22.077 ksi 2.0 ksi	27.6 ksi 18.4 ksi	AISC	0.20 0.89
		5 to 9	weld	2000 lbs	combined shear and torsion	1,824 lbs / in	2,545 lbs / in	AISC	0.28
		9 to 7	weld	2000 lbs	shear	0.133 ksi	14.4 ksi	AISC	0.99

Appendix A9.2.1 Immersion Pail Calculation 457-2003.2

NAC INTERNATIONAL	CALCULATION PACKAGE COVER SHEET	Work Request/Calc No: 457-2003.2
PROJECT NAME: K Basin Operations Equipment	CLIENT: Hanford (Transnuclear, Inc.)	

CALCULATION TITLE:

Immersion Pail

GEORGIA REGISTERED No. 15706 PROFESSIONAL ENGINEER NORMAN M. MEINERT

PROBLEM STATEMENT OR OBJECTIVE OF THE CALCULATION:

This calculation evaluates the immersion pail against the lifting design criteria requirements listed in ANSI N14.6 (Reference 7.3). The immersion pail is part of the TN-WHC Cask and Transportation System to be used at the K-Basin Area of the Hanford site.

The two point lift evaluation is performed in Calculation 457-2003.3.

Revision	Affected Pages	Revision Description	Preparer Name, Initials, Date	Checker Name, Initials, Date	Project Manager Approval/Date
0	1 thru 38	Original Issue	Jeffrey R. Dargis 11-10-96	Ravi Singh 11-14-96	Thomas A. Danner 11-15-96
1	1, 3 thru 39	Revised method of calculating margin of safety, revised weights of components. Correct administrative oversights.	Jeffrey R. Dargis JRD 12-2-96	Ravi Singh RS 12/2/96	Thomas A Danner [signature] 12/2/96

1 Total Pages 39

Appendix A9.2.1 Immersion Pail Calculation 457-2003.2 (Continued)

INDEPENDENT DESIGN VERIFICATION CHECK SHEET

Work Request/Calculation No: 457-2003.2 Revision 0

Scope Of Analysis File: This calculation structurally evaluates the immersion pail against the lifting design criteria requirements of ANSI N14.6.

Review Methodology:
- Check Of Calculations: RS
- Alternate Analyses: —
- Other (Explain): —

Confirm That The Work Request / Calculation Package Reviewed Includes:

1. Statement of Purpose — RS
2. Defined Method of Analysis — RS
3. Listing of Assumptions — RS
4. Detailed Analysis Record — RS
5. Statement of Conclusions / Recommendations (if applicable) — RS

Step	Activities	Verification Yes	No	N/A	Comments
1	For the scope of the defined analysis: A. Are the required data input complete? 1. Material properties 2. Geometry (drawing reference) 3. Loading source term *If a supporting analysis is required to define the load state, has it been defined?* B. Are boundary conditions acceptable?	✓ ✓ ✓ ✓ ✓			
2	Is the method of analysis adequate for the defined scope?	✓			
3	Is the worst case loading/configuration documented?	✓			
4	Are the acceptance criteria defined and complete?	✓			
5	Has all concurrent loading been considered?	✓			
6	Are analyses consistent with previous work for method and approach?			✓	NEW CALC. PACKAGE
7	Are the records for input and output complete?	✓			
8	Is traceability to verified software complete?			✓	NO SOFTWARE USED.
9	Is the statement of conclusions and recommendations complete and acceptable for the project and objectives of the defined purpose?	✓			

RAVI SINGH *Ravinder Singh* — Reviewer (Name/Signature) 11/14/96 — Date

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Appendix A9.2.1 Immersion Pail Calculation 457-2003.2 (Continued)

INDEPENDENT DESIGN VERIFICATION CHECK SHEET

Work Request/Calculation No: 457-2003.2 Revision 1

Scope Of Analysis File: This calculation structurally evaluates the immersion pail against the lifting design criteria requirements of ANSI N14.6.

Review Methodology: Check Of Calculations RS
Alternate Analyses —
Other (Explain) —

Confirm That The Work Request / Calculation Package Reviewed Includes:

1. Statement of Purpose ____
2. Defined Method of Analysis ____
3. Listing of Assumptions ____
4. Detailed Analysis Record ____
5. Statement of Conclusions / Recommendations (if applicable) ____

Step	Activities	Verification Yes	No	N/A	Comments
1	For the scope of the defined analysis: A. Are the required data input complete? 1. Material properties 2. Geometry (drawing reference) 3. Loading source term *If a supporting analysis is required to define the load state, has it been defined?* B. Are boundary conditions acceptable?	✓ ✓ ✓ ✓			
2	Is the method of analysis adequate for the defined scope?	✓			
3	Is the worst case loading/configuration documented?	✓			
4	Are the acceptance criteria defined and complete?	✓			
5	Has all concurrent loading been considered?	✓			
6	Are analyses consistent with previous work for method and approach?	✓			
7	Are the records for input and output complete?	✓			
8	Is traceability to verified software complete?			✓	NO SOFTWARE USED.
9	Is the statement of conclusions and recommendations complete and acceptable for the project and objectives of the defined purpose?	✓			

RAVI SINGH [signature] 12/2/96
Reviewer (Name/Signature) Date

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Appendix A9.2.1 Immersion Pail Calculation 457-2003.2 (Continued)

1.0 SYNOPSIS OF RESULTS

Summary of Stress Analysis

Drawing No.	Item No.	Component	Applied Load	Design Check	Calculated Loading	Allowable	M.S.
457-101	1	bottom plate	3W	plate bending	17,728 psi	30,000 psi	0.41
457-101	19, 1	pail shell to bottom plate interface	3W, pressure	net tension	3605 psi	30,000 psi	0.88
				shell bending & shear	16,636 psi	30,000 psi	0.45
457-101	10 to 11	lug to shell weld	3W	shear	90.68 kips	594 kips	0.85
457-101	10	flange shell	3W	lifting longitudinal bending	24,970 psi	30,000 psi	0.17
457-101	10	flange shell	3W	lifting circumferential bending + torsion	17,938 psi	30,000 psi	0.40
				circumferential shear	530 psi	18,000 psi	large
457-101	10	flange shell	3W	stand resting bending + torsion	17,104 psi	30,000 psi	0.43
457-101	11	lug plate	3W	bearing: lifting lug location	35,771 psi	75,000 psi	0.52
457-101	11	lug plate	5W	net tension: lifting lug location	30,440 psi	75,000 psi	0.62
457-101	11	lug plate	5W	shear pull out: lifting lug location	30,434 psi	48,000 psi	0.37
457-101	11	lug plate	3W	bearing: guide assembly location	60,453 psi	75,000 psi	0.19

The immersion pail design meets the criteria defined in Section 4.2.

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2.0 INTRODUCTION / PURPOSE

This calculation evaluates the immersion pail against the lifting design criteria requirements listed in Reference 7.3. The immersion pail is part of the TN-WHC Cask and Transportation System to be used at the K-Basin Area of the Hanford site. The immersion pail design was initially evaluated in Reference 7.1.

3.0 METHOD OF ANALYSIS

Hand calculations using classic textbook solutions are used to structurally evaluate the immersion pail.

The design will be assessed using the load factors discussed in Section 4.2.5. The acceptance criteria defined in Reference 7.3 limits the lifting induced tensile stresses to the lesser of:

(a) one-third material yield strength; or
(b) one-fifth the material ultimate strength.

Shear stresses will be limited to 0.6 times the tensile stress limits. Bearing stresses will be limited to 1.5 S_y in accordance with Reference 7.7.4.

The following evaluations are documented within this calculation.

- Component Weight Determination;
- Buoyancy Force And Buoyancy Rate Determination;
- Maximum Lift Load Determination;
- Maximum Lug Load Determination;
- Bottom Plate Evaluation;
- Primary Inner Shell Evaluation; and
- Lug Evaluation.

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Appendix A9.2.1 Immersion Pail Calculation 457-2003.2 (Continued)

4.0 ASSUMPTIONS / DESIGN INPUTS

4.1 Assumptions

There are no unverified assumptions within this calculation.

4.2 Design Criteria

4.2.1 Tensile Stresses

Calculated tensile stress (based on load factor of 3)	$< S_{yield}$	(Ref. 7.3)
Calculated tensile stress (based on load factor of 5)	$< S_{ultimate}$	(Ref. 7.3)

4.2.2 Shear Stresses

Calculated shear stress (based on load factor of 3)	$< 0.6 \times S_{yield}$
Calculated shear stress (based on load factor of 5)	$< 0.6 \times S_{ultimate}$

4.2.3 Bearing stresses

Calculated bearing stress $< 1.5 \times S_y$ (Ref. 7.7.4)

4.2.4 Material Properties

Poison's ratio:	ν	=	0.3	
Modulus of Elasticity:	E	=	28.3×10^6 psi	(Ref. 7.7.2)
Steel density:	ρ_{steel}	=	0.288 lbs / in^3.	
Water density:	ρ_{water}	=	0.036 lbs / in^3.	
Foam density:	ρ_{foam}	=	0.00347 lbs / in^3.	(Reference 7.6.1)

4.2.5 Stress Design Checks

All components evaluated within this calculation package are made of A240 Type 304 stainless steel or or A533 carbon steel. Normalizing the material yield and ultimate strengths by the Reference 7.3 load factors yields the following (See Section 4.2.1 for load factors):

A240 Type 304 Stainless Steel
(Reference 7.7.1)
Fy: 30 ksi
Fu: 75 ksi
$F_y/3 = 30{,}000 / 3 = 10{,}000$ psi
$F_u/5 = 75{,}000 / 5 = 15{,}000$ psi

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ASTM A533 Carbon Steel
(Reference 7.7.3)
Fy: 50 ksi
Fu: 80 ksi
$F_y/3$ = 50,000/3 = 16,700 psi
$F_u/5$ = 80,000/5 = 16,000 psi

Based on the above comparisons of yield and ultimate allowables for the two (2) materials, comparing a factor (LF) of 3 against yield is more restrictive for A240, while comparing a factor (LF) of 5 against ultimate is more restrictive for A533. Only the limiting conditions are evaluated within this calculation package.

4.3 Design Conditons

4.3.1 Temperature
Ambient, 100 °F.

4.3.2 Lifting
Two Point Lift (set) condition is design controlling.

4.3.3 Pressure Effects
Internal Pressure: 5 psi.

For a worst case condition, where pail loses internal pressure:

$$\text{Hydrostatic Pressure at Pit Bottom} = \frac{62.4\ \frac{\text{lbs}}{\text{ft}^3} \times 25.75\ \text{ft}}{144\ \frac{\text{in}^2}{\text{ft}^2}} = 11.2\ \text{psi}$$

Hoop Stress, Inner Shell (11.2 psi) = P x r / t
= 11.2 x 21.1875 / 0.375
= 633 psi

Longitudinal Stress = Hoop Stress / 2
= 633 / 2
= 317 psi

Both the pail hoop and longitudinal pressure stresses are insignificant. Pressure effects on the lid are addressed in a separate calculation.

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4.4 Weights

Cask weight (loaded, dry)	=	57,600 lbs	(Reference 7.1.1)
MCO weight (full, dry)	=	18,320 lbs	(Reference 7.1.1)
Cask lid weight	=	2,044 lbs	(Reference 7.1.1)
MCO cask annulus water weight	=	250 lbs	(Reference 7.1.2)
MCO water weight	=	1,200 lbs	(Reference 7.1.2)

4.5 Elevations of the Fuel Pit (Reference 7.1.3)

Pit floor elevation:	- 25'-9"
Fuel floor elevation:	- 20'-9"
Load pit floor elevation:	0'-0"
Top of pit wall elevation:	+ 2'-0"
Water elevation:	- 4'-9"

4.6 Pail Dimensional Data (Reference 7.6.1)

4.6.1 Inner Shell

ID_{shell} = 42.0 in

t_{shell} = 0.375 in

$length_{shell-inner}$ = 163.5 in

$length_{shell}$ (t = 0.375 in) = 163.5 - 23 = 140.5 in

A_{shell} (t = 0.375 in) $= \pi \times [((42.0 / 2) + 0.375)^2 - (42.0 / 2)^2]$
$= 49.922 \text{ in}^2$

$V_{pail} = \pi \times (ID_{shell} / 2)^2 \times length_{shell}$ (total)
$= \pi \times (42.0 / 2)^2 \times 163.5$
$= 226{,}520 \text{ in}^2$

OD_{flange} = 46.0 in

t_{flange} = 2.0 in, 1.375 in (shaved)

$length_{flange}$ ≅ 8.0 in

$A_{flange} = \pi \times [(46.0 / 2)^2 - (42.0 / 2)^2]$
$= 276.460 \text{ in}^2$

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Appendix A9.2.1 Immersion Pail Calculation 457-2003.2 (Continued)

$ID_{upper\ guide}$ = 41.25 in

$length_{upper\ guide}$ ≅ 2.0 in

$A_{upper\ guide}$ = $\pi \times [(46.0 / 2)^2 - (41.25 / 2)^2]$
= 325.50 in^2

$ID_{lower\ guide}$ = 40.0 in

$length_{lower\ guide}$ ≅ 2.0 in

$A_{lower\ guide}$ = $\pi \times [(44.75 / 2)^2 - (40.0 / 2)^2]$
= 316.17 in^2

4.6.2 Outer Shell Containing Foam
(consider as circular section)

$ID_{shell-outer}$ = 50.15 in

$t_{shell-outer}$ = 0.1196 in (11 gauge)

$length_{shell-outer}$ ≅ 102 in

$A_{shell-outer}$ ≅ $\pi \times [(50.15 / 2)^2 - ((50.15 / 2) - 0.1196))^2]$
= 18.798 in^2

4.6.3 Bottom Plate

$t_{bottom\ plate}$ = 2.0 in

size = 53.5" x 42.75" with 11.75" x 15" chamfered corners

$A_{bottom\ plate}$ = (53.5 x 42.75) - (4 x 0.5 x 11.75 x 15)
= 1,934 in^2

4.6.4 Lifting Lug

t_{lug} = 1.5 in

size = 24.5" x 9.0" with 6.42" x 5.39" and 10.38" x 7.00" chamfered corners

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A_{lug} $\cong$ (24.5 x 9.0) - (0.5 x 10.38 x (10.38 x tan 34°)) - (0.5 x 6.42 x (6.42 x tan 40°)

$\cong$ 166.870 in^2

4.6.5 Foam

A_{foam} $\cong$ $A_{bottom\ plate}$ - [π x ((42.0 + (2 x 0.375))/2)^2]

$\cong$ 1,934 - 1435

$\cong$ 499 in^2

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5.0 ANALYSIS DETAIL

5.1 Component Weight Determination

5.1.1 Pail

Inner Shell (t = 0.375 in)	=	ρ_{steel}	x	$length_{shell}$	x	A_{shell}		
	=	0.288	x	140.5	x	49.922		
	=	2020 lbs						
Inner Shell Flange	=	ρ_{steel}	x	$length_{flange}$	x	A_{flange}		
	=	0.288	x	8.0	x	276.460		
	=	637 lbs						
Inner Shell Upper Guide	=	ρ_{steel}	x	$length_{upper}$	x	A_{upper}		
	=	0.288	x	2.0	x	325.50		
	=	188 lbs						
Inner Shell Between Upper And Lower Guides	=	ρ_{steel}	x	length	x	A_{upper}		
	=	0.288	x	8.0	x			
		$[\pi \times (44.75 / 2)^2 - (42.0 / 2)^2]$						
	=	432 lbs						
Inner Shell Lower Guide	=	ρ_{steel}	x	$length_{lower}$	x	A_{lower}		
	=	0.288	x	2.0	x	316.17		
	=	182 lbs						
Lugs	=	ρ_{steel}	x	t_{lug}	x	A_{lug}	x	4 lugs
	=	0.288	x	1.5	x	166.870	x	4
	=	288 lbs						
Outer Shell	=	ρ_{steel}	x	$length_{shell\text{-}outer}$	x	$A_{shell\text{-}outer}$		
	=	0.288	x	102.0	x	18.798		
	=	552 lbs						
Foam	=	ρ_{foam}	x	$length_{shell\text{-}outer}$	x	A_{foam}		
	=	0.00347	x	102	x	499		
	=	177 lbs						
Bottom Plate	=	ρ_{steel}	x	$t_{bottom\ plate}$	x	$A_{botom\ plate}$		
	=	0.288	x	2	x	1934		
	=	1114 lbs						

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Appendix A9.2.1 Immersion Pail Calculation 457-2003.2 (Continued)

Total Pail Weight = 5590 lbs ≅ 6000 lbs
(Note: Approximated weight on drawing (Reference 7.6.1) is 5,700 lbs.)

5.1.2 Other Components

Pail Seal Lid	=	600 lbs	(Reference 7.6.3)
Cask	=	35,043 + 2017 + 100	(Reference 7.1.1)
	=	37,160 lbs	
Cask Lid	=	2000 lbs	(Reference 7.1.2)
MCO Shell	=	1540 lbs	(Reference 7.1.2)
MCO Contents	=	15,550 lbs	(Reference 7.1.2)
MCO Water (Loaded)	=	1200 lbs	(Reference 7.1.2)
MCO Water (Empty)	=	Calculated per Reference 7.1.4	
	=	$l_{MCO} \times \pi \times R^2_{MCO} \times \rho_{water}$	
	=	$(14 \times 12) \times \pi \times (23.25 / 2)^2 \times 0.036$	
	=	2568 lbs	
MCO Shield Plug	=	1230 lbs	(Reference 7.1.2)
MCO Wet (Loaded)	=	19,520 lbs	(Reference 7.1.2)
MCO / Cask Annulus Water	=	250 lbs	(Reference 7.1.2)
Lift Beam	=	750 lbs	(Reference 7.1.2)
Pail Slings	=	200 lbs	(Reference 7.1.2)
Pail Water	=	$V_{pail} \times \rho_{water} = 226{,}520 \times 0.036$	
	=	8,155 lbs	

5.2 Buoyancy Force and Buoyancy Rate Determination

Displaced Volume (pail immersed)

$$= [\pi \times (OD_{shell\text{-}outer} / 2)^2 \times l_{shell\text{-}outer}] + [\pi \times (OD_{shell\text{-}inner} / 2)^2 \times (l_{shell\text{-}inner} - l_{shell\text{-}outer})]$$
$$= [\pi \times (50.39 / 2)^2 \times 102] + [\pi \times (42.75 / 2)^2 \times (163.5 - 102)]$$
$$= 291{,}688 \text{ in}^3$$

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Buoyant Force = Displaced Volume x ρ_{water}
= 291,688 x 0.036
= 10,500 lbs

Buoyant Rate (above floatation interface)
= $\rho_{water} \times [\pi \times (OD_{shell\text{-}inner} / 2)^2 \times (l_{shell\text{-}inner} - l_{shell\text{-}outer})] / (l_{shell\text{-}inner} - l_{shell\text{-}outer})$
= $0.036 \times [\pi \times (42.75 / 2)^2 \times (163.5 - 102)] / (163.5 - 102)$
= 51.67 lbs / in

Buoyant Rate (below floatation interface)
= $\rho_{water} \times [\pi \times (OD_{shell\text{-}outer} / 2)^2 \times l_{shell\text{-}outer}] / l_{shell\text{-}outer}$
= $0.036 \times [\pi \times (50.39 / 2)^2 \times (102)] / (102)$
= 71.79 lbs / in

5.3 Maximum Lift Load Determination

The maximum lift load will be determined as the enveloping condition for the following lift conditions:

Condition I: Setting pail in water on support stand.
Condition II: Lowering pail / empty cask to pit bottom.
Condition III: Raising pail / full cask off bottom.
Condition IV: Raising pail / full cask to stand height. (Pail raised to floor elevation 1'-6", water level at -4'-9")
Condition V: Raising fully loaded cask from pit.

5.3.1 Lift Load for Condition I: Setting Pail In Water On Support Stand

Pail	5,700 lbs
Pail Slings	400 lbs
Lift Beam	550 lbs
Pail Water (conservatively, consider 4 feet of water in pail, 30% of 8155 lbs)	2,446 lbs
Lift Load I	9,096 lbs

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5.3.2 Lift Load for Condition II: Lowering Pail / Empty Cask To Pit Bottom

Pail	5,700 lbs
Pail Seal Lid	600 lbs
Pail Slings	400 lbs
Lift Beam	550 lbs
Cask	36,570 lbs
MCO / Cask Annulus Water	250 lbs
MCO Shell	1,900 lbs
MCO Water (Empty)	1,210 lbs
Buoyant Force	-10,500 lbs
Lift Load II	36,680 lbs

5.3.3 Lift Load for Condition III: Raising Pail / Full Cask Off Bottom

Pail	5,700 lbs
Pail Seal Lid	600 lbs
Pail Slings	400 lbs
Lift Beam	550 lbs
Cask	36,570 lbs
MCO / Cask Annulus Water	250 lbs
MCO Wet (Loaded)	20,160 lbs
Buoyant Force	-10,500 lbs
Lift Load III	53,730 lbs

5.3.4 Lift Load for Condition IV: Raising Pail / Full Cask To Stand Height
(Pail raised to floor elevation 1'-6", water level at -4'-9")

Pail	5,700 lbs
Pail Seal Lid	600 lbs
Pail Slings	400 lbs
Lift Beam	550 lbs
Cask	36,570 lbs
MCO / Cask Annulus Water	250 lbs
MCO Wet (Loaded)	20,160 lbs
Calculate Buoyant Force	
Pail submerged 163.5" - 75" =	88.5 in
Buoyant Force = 88.5 x 71.79 =	-6,353 lbs
Lift Load IV	57,877 lbs

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5.3.5 Lift Load for Condition V: Raising Fully Loaded Cask From Pit

Cask	36,570 lbs
Cask Lid	1,890 lbs
MCO / Cask Annulus Water	250 lbs
MCO Wet (Loaded)	20,160 lbs
Pail Slings	400 lbs
Lift Beam	550 lbs
Lift Load V	59,820 lbs

5.3.6 Maximum Lift Load

The limiting lift load condition is Condition V, Raising Fully Loaded Cask From Pit. The lift load associated with Condition V as determined in Section 5.3.5 is 59,820 lbs.

The lift load used in the design of the immersion pail will be:

P_{lift} = 60,000 lbs.

5.4 Lug Load Determination

The Hanford crane configuration employs a hook design, all attached to a shackle located at the center of the lift beam. The lug-to-lug distance in one direction per Reference 7.6.1 is:

$l_1 = 44.5 - (2 \times 4.5 \times \cos 38°)$
$= 37.41$ in

The lug-to-lug distance in the opposite direction per Reference 7.6.1 is:

$l_2 = 34.77 - (2 \times 4.5 \times \sin 38°)$
$= 28.6$ in

The sling is to be 16 feet long per Reference 7.6.5:

$l_3 = 16$ ft

The angle in the vertical plane with the hooks, θ, is:

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5.3.5 Lift Load for Condition V: Raising Fully Loaded Cask From Pit

Cask	36,570 lbs
Cask Lid	1,890 lbs
MCO / Cask Annulus Water	250 lbs
MCO Wet (Loaded)	20,160 lbs
Pail Slings	400 lbs
Lift Beam	550 lbs
Lift Load V	59,820 lbs

5.3.6 Maximum Lift Load

The limiting lift load condition is Condition V, Raising Fully Loaded Cask From Pit. The lift load associated with Condition V as determined in Section 5.3.5 is 59,820 lbs.

The lift load used in the design of the immersion pail will be:

P_{lift} = 60,000 lbs.

5.4 Lug Load Determination

The Hanford crane configuration employs a hook design, all attached to a shackle located at the center of the lift beam. The lug-to-lug distance in one direction per Reference 7.6.1 is:

$$l_1 = 44.5 - (2 \times 4.5 \times \cos 38°)$$
$$= 37.41 \text{ in}$$

The lug-to-lug distance in the opposite direction per Reference 7.6.1 is:

$$l_2 = 34.77 - (2 \times 4.5 \times \sin 38°)$$
$$= 28.6 \text{ in}$$

The sling is to be 16 feet long per Reference 7.6.5:

$$l_3 = 16 \text{ ft}$$

The angle in the vertical plane with the hooks, θ, is:

$$L_{lug} = LF \times P_{lift} / (2 \times \cos 7.04°)$$
$$= 3 \times 60{,}000 / (2 \times 0.9925)$$
$$\cong 90{,}680 \text{ lbs}$$

5.5 Bottom Plate Evaluation

Treating the bottom plate as a simply supported plate along the radial location of the inner shell with uniform loading along its surface, the maximum radial and tangential plate stress is:

$$\sigma_r = \sigma_t = \frac{3\,W}{8\,\pi m\,t^2}\,(3\,m + 1) \qquad \text{(Reference 7.4.1)}$$

where: W = $LF \times P_{lift}$

LF = Load factor based on yield strength comparison
= 3

P_{lift} = 60,000 lbs

m = Reciprocal of Poisson's ratio
= $1/\nu$ = $1 / 0.3$ = 3.33

t = plate thickness
= 2.0 in

Therefore:

$$\sigma_r = \sigma_t = \frac{3\,(3 \times 60{,}000)}{8\,\pi\,(3.33)\,(2)^2}\,(3\,(3.33) + 1)$$

$$\sigma_r = \sigma_t = 17{,}728 \text{ psi}$$

Plate material is A240 Type 304. The safety margin is:

$$\text{Safety Margin} = 1 - \frac{17{,}728}{30{,}000} = 0.41$$

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5.6 Inner Shell Evaluation (Primary Shell)

5.6.1 Net Tension Check

The net tension stress on the minimum cross section, t = 0.375 in, is:

$$\sigma_t = P_{lift} \times LF \,/\, A_{shell}\,(t{=}0.375\text{ in})$$
$$= 60{,}000 \times 3 / 49.922$$
$$= 3605 \text{ psi}$$

Shell material is A240 Type 304. The safety margin is:

$$\text{Safety Margin} = 1 - \frac{3{,}605}{30{,}000} = 0.88$$

5.6.2 Inner Shell To Bottom Plate Interface

The inner shell to bottom plate interface will be assessed by comparing the rotational stiffness of a plate at the outer edge to the rotational stiffness of a cylinder with an applied end moment.

The cylinder stiffness, M_0 / θ, is determined from Reference 7.4.2, where:

$$\theta = M_0 / \lambda D$$

where: $\lambda = \sqrt[4]{\dfrac{3(1-\nu^2)}{R_2^{\,2}\, t^2}}$

and: $D = \dfrac{E\, t^3}{12(1-\nu^2)}$

when: R = Outer radius of inner shell
= (42.0 + (2) (0.375)) / 2
= 21.375 in

ν = 0.3

E = 28.3×10^6 psi

t = inner shell thickness
= 0.375 in

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Therefore: $\lambda = \sqrt[4]{\dfrac{3(1 - (0.3)^2)}{(21.375)^2 (0.375)^2}}$

$= 0.454$ in

$D = \dfrac{(28.3 \times 10^6)(0.375)^3}{12(1 - (0.3)^2)}$

$= 136{,}665$

$M_0/\theta = \lambda D$
$= 0.454 (136{,}665)$
$= 62{,}046$ in-lb / rad

The plate stiffness, M_0 / θ, is determined from Reference 7.4.3, where:

$$\theta = \frac{12(m-1) M a}{E m t^3}$$

$$= \frac{12(m-1) M a}{E m t^3}$$

Therefore:

$$M_0/\theta = \frac{E m t^3}{12(m-1) a}$$

$$= \frac{(28.3 \times 10^6)(3.33)(2)^3}{12(3.33-1)\,21.375}$$

$= 1{,}261{,}471$ in-lb / rad

The bottom plate is 20 times stiffer than the inner shell. The plate behavior controls the joint interface response.

The rotation of the bottom plate under lift loading is determined by treating the plate as simply supported at the radial location of the inner shell:

$$\theta = \frac{3 W (m-1) a}{2 \pi E m t^3} \qquad \text{(Reference 7.4.1)}$$

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$$= \frac{3\,(3 \times 60{,}000)\,(3.33 - 1)\,21.375}{2\,\pi\,(28.3 \times 10^6)\,(3.33)\,(2)^3}$$

$= 0.0057$ radians

$= 0.33°$

Applying this rotation to the end of the cylinder and solving for the edge moment, M_0 :

$M_0 = \theta \times \lambda \times D$ (Reference 7.4.2)

$= 0.0057 \times 0.454 \times 136{,}665$

$= 354$ in-lbs

The maximum inner shell bending stress due to M_0 is:

$$s_2 = \frac{2\,M_0}{t}\,\lambda^2\,R$$

$$= \frac{2\,(354)}{0.375}\,(0.454)^2\,(21.375)$$

$= 8{,}318$ psi

The bending stress due to edge shear will yield smaller stresses than those due to M_0. Therefore, the maximum local bending stress due to edge bending and shear will be conservatively considered as $2 \times s_2$:

$2 \times s_2 = 2 \times 8318$
$= 16{,}636$ psi

Plate material is A240 Type 304. The safety margin is:

$$\text{Safety Margin} = 1 - \frac{16{,}636}{30{,}000} = 0.45$$

5.6.3 <u>Inner Shell To Top Flange, Determination of Reaction Loads</u>

Under a two (2) point lift, a radial load, a vertical load, and a bending moment

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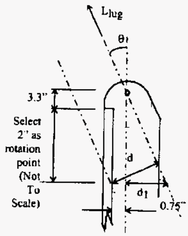
will be developed at the flange to lug midpoint location:



Per Section 5.4, the lift angle is 7.04°, and the lift load for a two (2) point lift is:

L_{lug} = 90.680 lbs

Therefore:

F_r = L_{lug} x sin θ
= 90,680 x sin (7.04°)
= 11,114 lbs

F_y = L_{lug} x cos θ
= 90,680 x cos (7.04°)
= 89,996 lbs

d_1 = 5.3 x tan θ
= 5.3 x tan (7.04°)
= 0.6545 in

d_2 = d_1 + 0.75
= 0.6545 + 0.75
= 1.4045 in

d = d_2 x cos θ
= 1.4045 x cos (7.04°)
= 1.383 in

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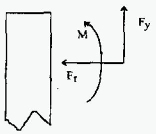
$M = L_{lug} \times d$
$= 90{,}680 \times 1.383$
$= 125{,}410$ in-lbs

The section view for the inner shell flange reaction loads are:



5.6.4 Lug To Shell Double Bevel Weld Evaluation

The shear capacity of the double bevel lug weld, $F_{capacity}$, is:

$F_{capacity} = 0.6 \times S_y \times area_{weld}$

$= 0.6 \times 30{,}000 \times 22\text{in} \times 1.5\text{ in}$

$= 594{,}000$ lbs

Per Section 5.4, the maximum lift load for a two (2) point lift is:

$L_{lug} = 90{,}680$ lbs

$$\text{Safety Margin} = 1 - \frac{90{,}680}{594{,}000} = 0.85$$

5.6.5 Maximum Longitudinal Shell Bending Stress

The maximum longitudinal bending stress will be determined by approximating an equivalent edge loading to be applied to the cylindrical outer shell.

The net compression reaction load at the shell flange end is:

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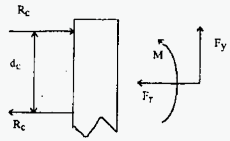

$$R_c = \frac{M}{d_c} + \frac{F_t}{2}$$

where: d_c = moment arm between flange rotation point and lower guide locations

= 24.5 - 2.5 - [7.84 - (3.29 + 2.5 / 2)] - 2

= 16.7 in

Therefore:

$$R_c = \frac{125,410}{16.7} + \frac{11,114}{2}$$

= 13,067 lbs

The compressive load, R_c , is spread over an effective arc length of 10 ° to determine an equivalent edge loading:

R_{shell} = 46.0 / 2
= 23 in

s = arc length
= R_{shell} x θ
= 23 x (10 x π / 180)
= 4.014 in

V_0 = edge load
= 13,067 / 4.014
= 3,255 lbs / in

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The maximum longitudinal bending stress, s_1', per Reference 7.4.6 is:

$$s_1' = \frac{1.932\ V_0}{\lambda\ t^2}$$

where: $t = 2.0$ in

$$\lambda = \sqrt[4]{\frac{3\,(1 - \nu^2)}{R_2^{\ 2}\ t^2}}$$

$$= \sqrt[4]{\frac{3\,(1 - (0.3)^2)}{(23.0)^2\ (2.0)^2}}$$

$$= 0.1895$$

$$s_1' = \frac{(1.932) \times (3255)}{(0.1895) \times (2.0)^2}$$

$$= 8{,}296 \text{ psi}$$

The maximum hoop membrane stress, s_2, per Reference 7.4.6 is:

$$s_2 = \frac{2\ V_0}{t}\ \lambda\ R$$

$$= \frac{2\ (3255)}{2}\ (0.1895)\ (23.0)$$

$$= 14{,}186 \text{ psi}$$

The maximum hoop bending stress, s_2', per Reference 7.4.6 is:

$$s_2' = \nu \times s_1'$$

$$= 0.3 \times 8296$$

$$= 2{,}488 \text{ psi}$$

Conservatively consider the maximum stress intensity (i.e., the largest principle stress difference) as the sum of s_1', s_2 and s_2' :

$$s_1' + s_2 + s_2' = 8{,}296 + 14{,}186 + 2{,}488$$

$$= 24{,}970 \text{ psi}$$

$$\text{Safety Margin} = 1 - \frac{24{,}970}{30{,}000} = 0.17$$

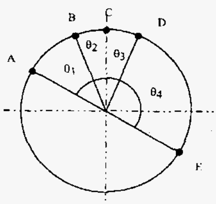
5.6.6 Maximum Circumferential Shell Bending Stress

The maximum circumferential bending stress will be determined through the use of a ring solution with diametrical radial loads applied (two point lift).

The compressive load, R_c, will be considered as a diametric load on the ring. The ring will be comprised of the flanged portion of the inner shell, eight (8) inches in length and two (2) inches thick.

The ring bending moment, M; shear load, V; and tension load, T, will be calculated for various locations of the ring. The flange is shaved on two (2) sides. Therefore, the critical stress locations are:

- At the maximum applied load location (i.e., the lug attachment point); and
- The minimum section location (i.e., shaved region begins 39° from the lug and extends to 65° from the lug).



θ_1 = 39°
θ_2 = 13°
θ_3 = 13°
θ_4 = 180 - 39 - 13 - 13 = 115°

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Location	Description	Angular Location °
A	Lug Location	0
B	Shave Section Start	39
C	Minimum Section	52
D	Shave Section End	65
E	Lug Location	180

5.6.6.1 <u>Maximum Circumferential Bending In Non-Shaved Areas</u>

The properties of the flange section in the non-shaved areas are:

$length_{flange}$ = (9.88 + 8.00) / 2 (Reference 7.6.1, Detail 11)
= 8.94 in

$width_{flange}$ = (46 - 42) / 2 (Reference 7.6.1, Section A-A)
= 2.00 in

A_{flange} = 8.94 x 2.00
= 17.88 in^2

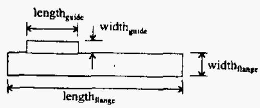
I_{flange} = 8.94 x $(2.00)^3$ / 12
= 5.96 in^4

$length_{guide}$ = [(4.63 - 2.32) + (3.98 - 3.01)] / 2 (Reference 7.6.1, Section B-B)
= 1.64 in

$width_{guide}$ = (42 - 41.25) / 2 (Reference 7.6.1, Section A-A)
= 0.375 in

A_{guide} = 1.64 x 0.375
= 0.615 in^2

I_{guide} = 1.64 x $(0.375)^3$ / 12
= 0.007 in^4



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Appendix A9.2.1 Immersion Pail Calculation 457-2003.2 (Continued)

$A_{tensile}$ = 17.88 + 0.615
= 18.495 in^2

A_{shear} = 2/3 $A_{tensile}$
= 12.33 in^2

The neutral axis is:

$$n = \frac{\text{sum of all moments}}{\text{total area}}$$

$$= \frac{(2 \times 8.94 \times 1) + (0.375 \times 1.64 \times (2 + (0.375 / 2))}{(2 \times 8.94) + (0.375 \times 1.64)}$$

= 1.04 in

y_{flange} = 1.04 - 1.00 = 0.04 in

y_{guide} = (2.0 + (0.375 / 2)) - 1.04 = 1.1475 in

$$I_n = I_{flange} + (A_{flange} \times y_{flange}^2) + I_{guide} + (A_{guide} \times y_{guide}^2)$$

$$= 5.96 + (17.88 \times (0.04)^2) + 0.007 + (0.615 \times (1.1475)^2)$$

$$= 6.806 \text{ in}^4$$

c_{inner} = (2 − 0.375) - 1.04
= 1.335 in

c_{outer} = 1.04 in

$$\left(\frac{c}{I}\right)_{max} = 1.335 / 6.806$$

= 0.196

Per Reference 7.4.5:

$M = W R (0.3183 - 0.5 \sin \theta)$

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$T = 0.5\ W\ (\sin\theta)$

$V = 0.5\ W\ (\cos\theta)$

where: $W = 13{,}067$ lbs

$R = 22$ in

σ_t = tensile stress
$= (M \times (c / I)_{max}) + (T / A_{tensile})$

σ_v = shear stress
$= V / A_{shear}$

Table 5.6.6-1

Angle (degrees)	Angle (radians)	Moment (in-lbs)	Tension (lbs)	Shear (lbs)	Tensile Stress (psi)	Shear Stress (psi)
0	0.000	91,503	0	6,534	17,935	530
13	0.227	59,168	-1,470	6,366	11,517	516
26	0.454	28,491	-2,864	5,872	5,429	476
38	0.663	3,007	-4,023	5,148	372	418
66	1.152	-39,810	-5,969	2,657	-8,125	216
78	1.361	-49,094	-6,391	1,358	-9,968	110
90	1.571	-52,234	-6,533	0	-10,591	0
112.5	1.964	-41,289	-6,036	-2,501	-8,419	-203
135	2.356	-10,126	-4,620	-4,620	-2,235	-375
157.5	2.749	36,510	-2,500	-6,036	7,021	-490
180	3.142	91,518	1	-6,533	17,938	-530

5.6.6.2 <u>Maximum Circumferential Bending In Shaved Areas</u>

The properties of the flange section in the shaved areas are:

$length_{flange} = (9.88 + 8.00) / 2$ (Reference 7.6.1, Detail 11)
$= 8.94$ in

$width_{flange} = (44.75 - 42) / 2$ (Reference 7.6.1, Section A-A)
$= 1.375$ in

$A_{flange} = 8.94 \times 1.375$
$= 12.29\ in^2$

$I_{flange} = 8.94 \times (1.375)^3 / 12$

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Appendix A9.2.1 Immersion Pail Calculation 457-2003.2 (Continued)

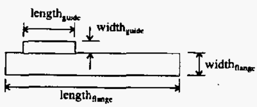
$$= 1.937\ \text{in}^4$$

$$\text{length}_{guide} = [(4.63 - 2.32) + (3.98 - 3.01)] / 2 \quad \text{(Reference 7.6.1, Section B-B)}$$
$$= 1.64\ \text{in}$$

$$\text{width}_{guide} = (42 - 41.25) / 2 \quad \text{(Reference 7.6.1, Section A-A)}$$
$$= 0.375\ \text{in}$$

$$A_{guide} = 1.64 \times 0.375$$
$$= 0.615\ \text{in}^2$$

$$I_{guide} = 1.64 \times (0.375)^3 / 12$$
$$= 0.007\ \text{in}^4$$



$$A_{tensile} = 12.29 + 0.615$$
$$= 12.905\ \text{in}^2$$

$$A_{shear} = 2/3\ A_{tensile}$$
$$= 8.603\ \text{in}^2$$

The neutral axis is:

$$n = \frac{\text{sum of all moments}}{\text{total area}}$$

$$= \frac{(1.375 \times 8.94 \times 0.6875) + (0.375 \times 1.64 \times (1.375 + (0.375 / 2))}{(1.375 \times 8.94) + (0.375 \times 1.64)}$$

$$= 0.729\ \text{in}$$

$$y_{flange} = 0.729 - 0.6875 = 0.0415\ \text{in}$$

$$y_{guide} = (1.375 + (0.375 / 2)) - 0.729 = 0.8335\ \text{in}$$

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Appendix A9.2.1 Immersion Pail Calculation 457-2003.2 (Continued)

$$I_n = I_{flange} + (A_{flange} \times y_{flange}^2) + I_{guide} + (A_{guide} \times y_{guide}^2)$$
$$= 1.937 + (12.29 \times (0.0415)^2) + 0.007 + (0.615 \times (0.8335)^2)$$
$$= 2.392 \text{ in}^4$$

$$c_{inner} = (1.375 - 0.375) - 0.8335$$
$$= 0.9165 \text{ in}$$

$$c_{outer} = 0.8335 \text{ in}$$

$$\left(\frac{c}{I}\right)_{max} = 0.9165 / 2.392$$
$$= 0.383$$

Per Reference 7.4.5:

$$M = W R (0.3183 - 0.5 \sin\theta)$$

$$T = 0.5 \; W \; (\sin\theta)$$

$$V = 0.5 \; W \; (\cos\theta)$$

where: $W = 13{,}067$ lbs

$R = 22$ in

σ_t = tensile stress
$= (M \times (c/I)_{max}) + (T / A_{tensile})$

σ_v = shear stress
$= V / A_{shear}$

Table 5.6.6-2

Angle (degrees)	Angle (radians)	Moment (in-lbs)	Tension (lbs)	Shear (lbs)	Tensile Stress (psi)	Shear Stress (psi)
39	0.681	1,044	-4,112	5,077	81	412
52	0.908	-21,766	-5,149	4,022	-4,545	326
65	1.135	-38,769	-5,921	2,761	-7,919	224

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5.6.6.3 Maximum Circumferential Bending Stress, Maximum Shear Stress

The maximum circumferential bending stress from Tables 5.6.6-1 and 5.6.6-2 is at 180°, a lug location.

σ_t = 17,938 psi

$$\text{Safety Margin} = 1 - \frac{17{,}938}{30{,}000} = 0.40$$

The maximum shear stress from Tables 5.6.6-1 and 5.6.6-2 is:

σ_v = 530 psi

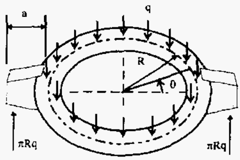
The maximum shear stress is insignificant.

5.6.7 Inner Shell Upper Flange Evaluation Under Stand Resting Conditions

The inner shell upper flange evaluation shall be performed for both the NORMAL (4 point) and OTHER THAN NORMAL (2 point) conditions.

5.6.7.1 Normal Resting Condition (4 point)

The analysis of the upper flange under stand resting conditions using a normal four (4) point lift will be conducted utilizing the principle of superposition and ring equations as quoted in Reference 7.15. The case to be analyzed involves uniform loads disposed symmetrically with respect to the trunnion axis.



Considering Lift Condition IV, without slings and lift beam for design of pail, and a four (4) point lift factor and a load factor of three (3):
P = (57,877 - 400 - 550) x 3 / 4 = 42,695 lbs*.

* Use of 43,288 lbs from Revision 0 is conservative.

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Calculation Of Ring Moment and Twist
Per Blake's Practical Stress Analysis In Engineering Design (Reference 7.15)
Table 30.4, Page 394

$M_q = 2\,q\,R\,(a + R)\,C_5 - q\,R^2$ $T_q = q\,R\,(a + R)\,C_7 - q\,R^2\,C_8$ $C_5 = 0.7854\,SIN(x)$ $C_7 = 1.5708\,COS(x)$ $C_8 = 1.5708 - (x)$ P = Load $q = P / (PI)\,R$	$Z = b\,h^2 / 6$ b = 1.375 h = 23.000 Z = 121.23 $s_b = M_q / Z$	$J = h\,b^3 / 3$ b = 1.375 h = 23.000 J = 19.93 c = 1.375 $s_t = T_q \times c / J$	Notes: (1) Shaved area of pail is shaded in table.

Degrees	Radians	P	R	a	q	C_5	C_7	C_8	M_q	T_q	Z	s_b	J	s_t	s_b+s_t
0	0.00	43,288	21.6875	8	635	0.0000	1.5708	1.57	-298,832	173,152	121.23	-2,465	19.93	11,946	14,411
13	0.23	43,288	21.6875	8	635	0.1767	1.5305	1.34	-154,288	224,487	121.23	-1,273	19.93	15,487	16,760
26	0.45	43,288	21.6875	8	635	0.3443	1.4118	1.12	-17,153	243,727	121.23	-141	19.93	16,815	16,956
38	0.66	43,288	21.6875	8	635	0.4835	1.2378	0.91	96,766	235,130	121.23	798	19.93	16,222	17,020
39	0.68	43,288	21.6875	8	635	0.4943	1.2207	0.89	105,543	233,364	121.23	871	19.93	16,100	16,970
52	0.91	43,288	21.6875	8	635	0.6189	0.9671	0.66	207,510	197,404	121.23	1,712	19.93	13,619	15,331
65	1.13	43,288	21.6875	8	635	0.7118	0.6638	0.44	283,523	141,165	121.23	2,339	19.93	9,739	12,078
66	1.15	43,288	21.6875	8	635	0.7175	0.6389	0.42	288,174	136,176	121.23	2,377	19.93	9,395	11,772
78	1.36	43,288	21.6875	8	635	0.7682	0.3266	0.21	329,684	71,007	121.23	2,720	19.93	4,899	7,618
90	1.57	43.288	21.6875	8	635	0.7854	0.0000	0.00	343,726	-1	121.23	2,835	19.93	0	2,835
112.5	1.96	43,288	21.6875	8	635	0.7256	-0.6011	-0.39	294,814	-128,546	121.23	2,432	19.93	-8,868	11,300
135	2.36	43,288	21.6875	8	635	0.5554	-1.1107	-0.79	155,525	-219,656	121.23	1,283	19.93	-15,154	16,437
157.5	2.75	43,288	21.6875	8	635	0.3006	-1.4512	-1.18	-52,936	-241,594	121.23	-437	19.93	-16,668	17,104
180	3.14	43,288	21.6875	8	635	0.0000	-1.5708	-1.57	-298,832	-173,155	121.23	-2,465	19.93	-11,946	14,411

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The maximum stress intensity is:

$s_b + s_t = 17{,}104$ psi

$$\text{Safety Margin} = 1 - \frac{17{,}104}{30{,}000} = 0.43$$

5.6.7.2 Other Than Normal Resting Condition (2 point)

The analysis of the upper flange under stand resting conditions conditions using a two (2) point lift is contained in a separate calculation (Reference 7.16).

5.8 Lug Evaluation, Lifting Lug Region

5.8.1 Bearing Check

The pin bearing area is:

$$\begin{aligned} \text{Bearing area} &= t \times D_{hole} \\ &= 1.5 \times 1.69 \\ &= 2.535 \text{ in}^2 \end{aligned}$$

The bearing stress is:

$$\begin{aligned} \text{Stress} &= L_{lug} / \text{area} \\ &= 90{,}680 / 2.535 \\ &= 35{,}771 \text{ psi} \end{aligned}$$

The safety margin is:

$$\begin{aligned} \text{Safety Margin} &= 1 - (\text{stress} / (1.5\ S_y)) \\ &= 1 - (35{,}771 / (1.5 \times 50{,}000)) \\ &= 0.52 \end{aligned}$$

5.8.2 Net Tension

$$\begin{aligned} \text{Area} &= t\,(D_{lug} - D_{hole}) \\ &= 1.5\,(5.0 - 1.69) \\ &= 4.965 \text{ in}^2 \end{aligned}$$

Since $S_u / 5$ is controlling:

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L_{lug} = 90680 x (5 / 3)
= 151,133 lbs

The stress is:

Stress = L_{lug} / (Area)
= 151,133 / (4.965)
= 30,440 psi

The safety margin is:

Safety Margin = 1 - (stress / S_u)
= 1 - (30,440 / 80,000)
= 0.62

5.8.3 Shear Pull Out At 45 Degrees

Shear Area = t (R_{lug} - R_{hole})
= 1.5 (2.5 -0.845)
= 2.483 in^2

The shear stress is:

Stress = L_{lug} / 2 x (Shear Area)
= 151,133 / 2 x (2.483)
= 30,434 psi

The safety margin is:

Safety Margin = 1 - (stress / (0.6 S_u))
= 1 - (30,434 / (0.6 x 80,000))
= 0.37

5.9 Lug Evaluation, Stand Resting Lug Region

5.9.1 Bearing Check

The bearing area is:

The pin is 1.5" x 1.25" with 1 / 8" chamfers. The bearing line is conservatively determined to be:

W = 1.25 - 0.125 - 0.125
= 1.0 in

Bearing area = t x W
= 1.5 x 1.0
= 1.5 in^2

The bearing stress is:

Stress = L_{lug} / area
= 90,680 / 1.5
= 60,453 psi

The safety margin is:

Safety Margin = 1 - (stress / (1.5 S_y))
= 1 - (60,453 / (1.5 x 50,000))
= 0.19

5.9.2 Net Tension & Shear

The tensile and shear stress areas are larger than that evaluated in Section 5.8. Therefore, tension and shear stresses are aceptable by comparison to stresses in Section 5.8.

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6.0 SUMMARY OF RESULTS/CONCLUSIONS

Summary of Stress Analysis

Drawing No.	Item No.	Component	Applied Load	Design Check	Calculated Loading	Allowable	M.S.
457-101	1	bottom plate	3W	plate bending	17,728 psi	30,000 psi	0.41
457-101	19, 1	pail shell to bottom plate interface	3W, pressure	net tension	3605 psi	30,000 psi	0.88
				shell bending & shear	16,636 psi	30,000 psi	0.45
457-101	10 to 11	lug to shell weld	3W	shear	90.68 kips	594 kips	0.85
457-101	10	flange shell	3W	<u>lifting</u> longitudinal bending	24,970 psi	30,000 psi	0.17
457-101	10	flange shell	3W	<u>lifting</u> circumferential bending + torsion	17,938 psi	30,000 psi	0.40
				circumferential shear	530 psi	18,000 psi	large
457-101	10	flange shell	3W	<u>stand resting</u> bending + torsion	17,104 psi	30,000 psi	0.43
457-101	11	lug plate	3W	bearing: lifting lug location	35,771 psi	75,000 psi	0.52
457-101	11	lug plate	5W	net tension: lifting lug location	30,440 psi	75,000 psi	0.62
457-101	11	lug plate	5W	shear pull out: lifting lug location	30,434 psi	48,000 psi	0.37
457-101	11	lug plate	3W	bearing: guide assembly location	60,453 psi	75,000 psi	0.19

The immersion pail design meets the criteria defined in Section 4.2.

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7.0 REFERENCES

7.1 Preliminary Design Analysis Report For The TN-WHC Cask and Transporation System
Project 3035
Transnuclear, Inc.
- 7.1.1 Page A2-10.
- 7.1.2 Page A2-11.
- 7.1.3 Drawing 457-008.
- 7.1.4 Page A3-2

7.2 Fax from Glenn Guerra to Tom Danner dated 11-26-96, "Component Weights".

7.3 ANSI N14.6
American National Standard for Radioactive Materials
"special lifting devices for shipping containers weighing 10,000 lbs (4,500 kg) or more"
- 7.3.1 Section 4.2.1.1.

7.4 Roark's Formulas for Stress and Strain, 3rd edition.
- 7.4.1 Table X, Case 1, page 194.
- 7.4.2 Table XIII, Case 11, page 271.
- 7.4.3 Table X, Case 12, page 197.
- 7.4.4 Article 62, page 230.
- 7.4.5 Table VIII, Case 1, page 156.
- 7.4.6 Table XIII, Case 10, page 271.

7.5 Hanford ECN 191402.

7.6 K Basin Immersion Pail Assembly TN WHC Transport Cask Drawings.
- 7.6.1 Project 457, Drawing 101, sheet 1 / 1.
- 7.6.2 Project 457, Drawing 102, sheets 1, 2 / 2.
- 7.6.3 Project 457, Drawing 103, sheets 1, 2 / 2.
- 7.6.4 Project 457, Drawing 112, sheet 1, 2 / 2.
- 7.6.5 Project 457, Drawing 107, sheet 1 / 1.

7.7 ASME Boiler & Pressure Vessel Code, 1995 edition.
- 7.7.1 Section II-D, page 440, Table U & page 530, Table Y-1.
- 7.7.2 Section TM-1, page 614.
- 7.7.3 Section II-D, page 435, Table U & page 500, Table Y-1.
- 7.7.4 Section III, NB-3227.1(a).

7.8 Mark's Standard Handbook for Mechanical Engineers.
- 7.8.1 Page 6-7.

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7.9 Shigley's Mechanical Engineering Design, 1963.
7.9.1 Page 603

7.10 Specification WHC-S-0396, Revision 1, dated September, 1995.
Performance Specification for the SNF Path Forward Cask and Transportation System.
7.10.1 Page 36.

7.11 Meeting Minutes, NAC/TN, September 1996.

7.12 Design Specification 457-S-01, Revision 0.

7.13 Blodgett's Design Of Welded Structures, 1966.

7.14 AISC Manual Of Steel Construction, 9th edition.

7.15 Practical Stress Analysis In Engineering Design, Table 30.4, Page 394.

7.16 Calculation 457-2003.3, Revision 0.

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Appendix A9.2.2 Immersion Pail Calculation 457-2003.3

NAC INTERNATIONAL	CALCULATION PACKAGE COVER SHEET	Work Request/Calc No: 457-2003.3
PROJECT NAME: K Basin Operations Equipment	CLIENT: Hanford (Transnuclear, Inc.)	

CALCULATION TITLE:

Immersion Pail Evaluation For Two (2) Point Lift Load

GEORGIA REGISTERED No. 15706 PROFESSIONAL ENGINEER NORMAN M. MEINERT

PROBLEM STATEMENT OR OBJECTIVE OF THE CALCULATION:

This calculation analyzes the immersion pail upper pail region for a two (2) point lift load when the pail is resting on the stand. The resulting stresses are evaluated against the lifting design criteria requirements listed in ANSI N14.6 (Reference 7.3). The immersion pail is part of the TN-WHC Cask and Transportation System to be used at the K-Basin Area of the Hanford site.

All other loadings of the immersion pail are evaluated in Calculation 457-2003.2.

Revision	Affected Pages	Revision Description	Preparer Name, Initials, Date	Checker Name, Initials, Date	Project Manager Approval/Date
0	1 thru 12 A1 thru A11 B1 thru B37 C1 thru C2 D1 thru D12	Original Issue	Michael C. Yaksh 11-11-96	Jeffrey R. Dargis 11-11-96	Thomas A. Danner 11-15-96
1	1, 3 thru 13	Revised to incorporate design load change.	Michael C. Yaksh my 12/2/96	Jeffrey R. Dargis JRD 12-2-96	Thomas A Danner [signature] 12-2-96

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Total Pages 75

Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

INDEPENDENT DESIGN VERIFICATION CHECK SHEET

Work Request/Calculation No: 457-2003.3 Revision 0

Scope Of Analysis File: This calculation analyzes the immersion pail upper region for a two point lift load when the pail is resting on the stand. The resulting stresses are evaluated against the requirements of ANSI N14.6.

Review Methodology:
Check Of Calculations JRD
Alternate Analyses N/A
Other (Explain) N/A

Confirm That The Work Request / Calculation Package Reviewed Includes:

1. Statement of Purpose JRD
2. Defined Method of Analysis JRD
3. Listing of Assumptions JRD
4. Detailed Analysis Record JRD
5. Statement of Conclusions / Recommendations (if applicable) JRD

Step	Activities	Verification Yes	No	N/A	Comments
1	For the scope of the defined analysis: A. Are the required data input complete? 1. Material properties 2. Geometry (drawing reference) 3. Loading source term *If a supporting analysis is required to define the load state, has it been defined?* B. Are boundary conditions acceptable?	✓ ✓ ✓ ✓ ✓			
2	Is the method of analysis adequate for the defined scope?	✓			
3	Is the worst case loading/configuration documented?	✓			
4	Are the acceptance criteria defined and complete?	✓			
5	Has all concurrent loading been considered?	✓			
6	Are analyses consistent with previous work for method and approach?	✓			
7	Are the records for input and output complete?	✓			
8	Is traceability to verified software complete?	✓			
9	Is the statement of conclusions and recommendations complete and acceptable for the project and objectives of the defined purpose?	✓			

JEFFREY R. DARGIS / Jeffrey R Dargis 11-11-96
Reviewer (Name/Signature) Date

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Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

INDEPENDENT DESIGN VERIFICATION CHECK SHEET

Work Request/Calculation No: 457-2003.3 Revision 1

Scope Of Analysis File: This calculation analyzes the immersion pail upper region for a two point lift load when the pail is resting on the stand. The resulting stresses are evaluated against the requirements of ANSI N14.6.

Review Methodology: Check Of Calculations JRD
Alternate Analyses N/A
Other (Explain) N/A

Confirm That The Work Request / Calculation Package Reviewed Includes:

1. Statement of Purpose JRD
2. Defined Method of Analysis JRD
3. Listing of Assumptions JRD
4. Detailed Analysis Record JRD
5. Statement of Conclusions / Recommendations (if applicable) JRD

Step	Activities	Verification Yes	No	N/A	Comments
1	For the scope of the defined analysis: A. Are the required data input complete? 1. Material properties 2. Geometry (drawing reference) 3. Loading source term *If a supporting analysis is required to define the load state, has it been defined?* B. Are boundary conditions acceptable?	 ✓ ✓ ✓ ✓			
2	Is the method of analysis adequate for the defined scope?	✓			
3	Is the worst case loading/configuration documented?	✓			
4	Are the acceptance criteria defined and complete?	✓			
5	Has all concurrent loading been considered?	✓			
6	Are analyses consistent with previous work for method and approach?	✓			
7	Are the records for input and output complete?	✓			
8	Is traceability to verified software complete?	✓			
9	Is the statement of conclusions and recommendations complete and acceptable for the project and objectives of the defined purpose?	✓			

JEFFREY R. DARGIS / Jeffrey R Dargis 12-2-96
Reviewer (Name/Signature) Date

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Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

1.0 SYNOPSIS OF RESULTS

Summary of Stress Analysis

Drawing No.	Item No.	Component	Applied Load	Design Check	Calculated Loading	Allowable	M.S.
457-101	10	flange shell	3W	stand resting Von Mises, membrane plus bending	28,160 psi	30,000 psi	0.065

The immersion pail design meets the criteria defined in Section 5.5 for a two (2) point lift load.

2.0 INTRODUCTION / PURPOSE

This calculation analyzes the immersion pail upper pail region for a two (2) point lift load when the pail is resting on the stand. The resulting stresses are evaluated against the lifting design criteria requirements listed in Reference 7.3. The immersion pail is part of the TN-WHC Cask and Transportation System to be used at the K-Basin Area of the Hanford site. The immersion pail design was initially evaluated in Reference 7.1. The design was revised as a result of discussions documented in Reference 7.5.

3.0 METHOD OF ANALYSIS

ANSYS, Revision 5.2, a structural analysis finite element program, is used to generate a 180° structural model of the upper immersion pail region. Input files and macros used to construct the ANSYS models and perform a linear structural analysis are contained in Appendix A. All work under this calculation designation was performed on the DEC ALPHA XL 266 computer (NAC Serial No. 02207).

4.0 ASSUMPTIONS / DESIGN INPUTS

4.1 Assumptions

There are no unverified assumptions within this calculation.

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4.2 Design Inputs

4.2.1 Design Load (Reference 7.8, Section 5.3.4)

$Load_{Design}$ = 57,717* lbs for Condition IV (Full Cask At Stand Height).

* Revised load from Reference 7.9, Section 5.3.4 minus the weight of the slings and lift beam is 57,877 - 400 - 550 = 56,927 lbs. Use of Revision 0 load is conservative.

4.2.2 Two Point Lift Load

$Load_{Pail}$ = Total pail load

= $Load_{Design}$ x Load Factor

= 57,717 x 3

= 173,151 lbs

$Load_{2PT}$ = $Load_{Pail}$ / 2 Point Lift

= 173,151 / 2

= 86,575 lbs

= 86,575 lbs

4.2.3 Applied Load

The load used in the analysis, $Load_{Applied}$, is:

$Load_{Applied}$ = 86,871 lbs

The load applied in the ANSYS analysis, 86,871 lbs, is greater than the load calculated for a two point lift, 86,575 lbs (conservative).

4.2.4 Upper Pail Ring Configuration

The model was developed based on data contained on the drawing numbered "Project 457, Drawing 101, sheet 1 / 1" (Reference 7.6.1).

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4.2.5 Material Yield Strength

A240 Type 304 Stainless Steel
(Reference 7.7.1)
Fy: 30 ksi
Fu: 75 ksi

5.0 ANALYSIS DETAIL

5.1 Modeling Considerations

This model has been developed for the sole purpose of performing a cross sectional stress analysis. The model was not intended for evaluation of stress concentrations arising from sharp discontunities.

5.2 Material Properties

Modulus of Elasticity, E = 27×10^8 psi

Poisson's ratio, ν = 0.3

5.3 Model Description

The orgin of the model is located at the center line of the pail at the bottom surface of the model (see Figure 5-1). The centerline of the pail corresponds to the global Z axis. Using half symmetry, a 180 degree section of the cask is modeled.

Dimensions in the model correspond to nominal dimensions provided in Reference 7.6.1.

The pail ring model uses element SOLID45. The model was extended twenty-six (26") inches (26") from the top of the pail. This corresponds to 3.3 $\sqrt{r\,t}$, which is sufficient to represent the distribution of the load from the lugs into the pail.

The lug attachment was modeled with a spider of beam elements using element BEAM4, a three (3) dimensional beam (See Figure 5-1). The center point of the spider corresponds to the location where the pail is pinned to the support structure. This point also represents the load reaction point. The beam elements are rigid, with input values of 1000 for the cross sectional area and moments of inertia. The applied load of 86,871 lbs (1/2 the total load since only 1/2 of the pail was modeled) was distributed along the lower edge of the model by point mass elements (i.e., Element Type 21, using 3D, without rotational inertia).

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The method used to generate the model was to initiate a cross section in the XZ plane with area elements and then rotate them about the Z axis for 180 degrees. The pail outer diameter has a shaved section between 39° and 65°. The shaved section was modeled by detaching the solid model and moving the nodes to form a flat surface (See Figure 5-1).

The input file to generate the model is contained in Appendix A. The output file corresponding to the input file is contained in Appendix B.

5.4 Analysis Description

Symmetrical displacement boundary conditions were applied at the plane of symmetry. (UY=0). The center point of one spider of beam elements was modeled with all displacement degrees of freedom restrained. The opposite centerpoint restrained the UY and UZ degrees of freedom only, to avoid introduction of artifical stiffness into the pail.

Only a inertia load of 1G was applied, since the real constants for the mass element was in pounds (not slugs).

The input for the linear static analysis is contained in the file K_PAIL.MAC, which is listed in Appendix A.

To generate the model, perform the analysis, and to obtain the plots and the section data, enter ANSYS, then enter

k_pail

The output file is denoted kbas1.out and the plots are contained in the file kbasin.plt.

5.5 Stress Criteria

Per ANSI 14.6, the stress is not to exceed the yield stress with a safety factor of three (3). For this application, stress linearization is used to determine the stress components acting on a section. The stress components are then combined to determine the Von Mises Stress, which corresponds to a distortion energy stress criteria. ANSYS, upon selecting the two nodes on the surface, detemines the Von Mises stress due to membrane plus bending components.

Local stress concentrations will occur next to the beam elements. These stress concentrations are purely a result of techniques used in modeling. Local stress concentrations will also arise at the radii of the juncture of the rib and the pail.

5.6 Stress Results

The section stresses resulting from the analysis are contained in the output file of Appendix B. A series of sectional stresses were extracted. The output file contains the stress results with the polar coordinates of the nodes forming the section. The polar system designation is:

X = radial;
Y = circumferential angle (measured +Z rotation); and
Z = axial location (measured from the bottom of the model).

The maximium membrane plus bending Von Mises stress (SEQV) was determined to be 28,160 psi, which corresponds to a positive margin of +.065 when compared to a yield strength of 30,000 psi for A240 stainless steel.

A plot of the Von Mises stress is shown in Figure 5-2. Each circumferential divison corresponds to a 5 degree increment.

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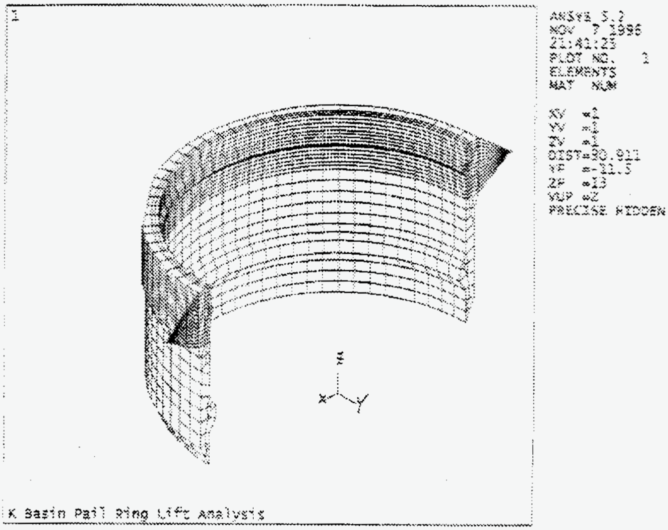
Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

Figure 5-1

Model Geometry Plot
Pail - Half Model



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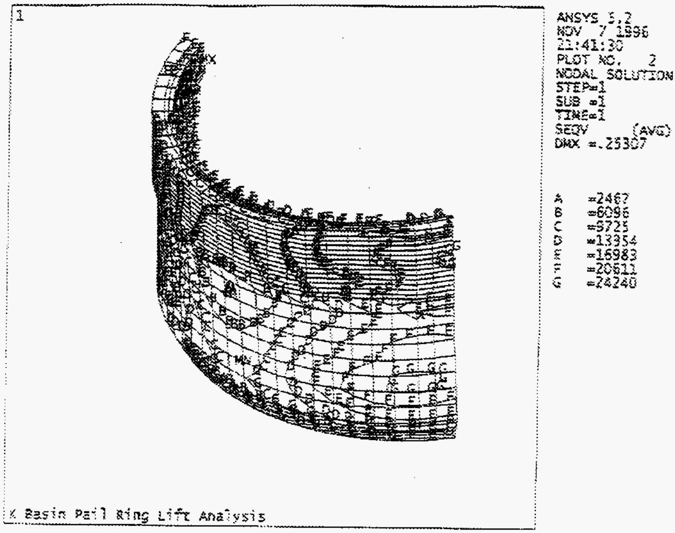
Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

Figure 5-2

Von Mises Stress Plot
Pail- Half Model
Load Factor = 3



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6.0 SUMMARY OF RESULTS/CONCLUSIONS

Summary of Stress Analysis

Drawing No.	Item No.	Component	Applied Load	Design Check	Calculated Loading	Allowable	M.S.
457-101	10	flange shell	3W	<u>stand resting</u> Von Mises, membrane plus bending	28,160 psi	30,000 psi	0.065

The immersion pail design meets the criteria defined in Section 5.5 for a two (2) point lift load.

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7.0 REFERENCES

7.1 Preliminary Design Analysis Report For The TN-WHC Cask and Transporation System
Project 3035
Transnuclear, Inc.
- 7.1.1 Page A2-10.
- 7.1.2 Page A2-11.
- 7.1.3 Drawing 457-008.
- 7.1.4 Page A3-2

7.2 Not Used.

7.3 ANSI N14.6
American National Standard for Radioactive Materials
"special lifting devices for shipping containers weighing 10,000 lbs (4,500 kg) or more"
- 7.3.1 Section 4.2.1.1.

7.4 ANSYS, Revision 5.2 User Manual

7.5 Hanford ECN 191402.

7.6 K Basin Immersion Pail Assembly TN WHC Transport Cask Drawings.
- 7.6.1 Project 457, Drawing 101, sheet 1 / 1.

7.7 ASME Boiler & Pressure Vessel Code, 1995 edition.
- 7.7.1 Section II-D, page 440, Table U & page 530, Table Y-1.

7.8 Calculation 457-2003.2, Revision 0.

7.9 Calculation 457-2003.2, Revision 1.

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Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

APPENDIX A
List Of Input Files For The Finite Element Model

There a a total of 11 pages in Appendix A.

Input Files

File Name	Description
k_pail.mac	Main Input File
mas21.mac	Applies The Mass Elements
r_beam.mac	Generates The Spider Of Beams To Represent The Attachment Lug

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```
!   k_pail.mac
!   Builds pail upper model of ring and attachment
!   solves/plots S_EQV stress
!
! macros used:
!    mas21.mac   builds the mass elements
!    r_beam.mac  builds the attachement with stiff beams
!
!
/out,kbas1,out
/nerr,0,1e5

*if,arg1,eq,0,then

fini
/cle,all

/prep7
et,1,45
et,2,21    !  use real = 2
et,3,4     !  use real = 3
et,4,63    !  use real = 4
et,5,21,,,2   ! use real  =5
mp,ex,1,27e6
shpp,off
local,11,0,-23,0
k,1,0,,26
k,2,,,18
k,3,.625,,16.125
k,4,.625,,3
k,5,2
k,6,2,,4.66
k,7,3,,6.39
k,8,3,,8.22
k,9,2,,9.96
k,10,2,,21.37
k,11,2.375,,22.02
k,12,2.375,,22.99
k,13,2,,23.68
k,14,2,,26
k,15,.625,,26
k,16,.625+.5,,26
k,17,.625+.5,,18
k,18,2,,18

*do,i1,1,9
   l,i1,i1+1
*enddo
```

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```
1,14,16
1,16,17
1,17,3
1,1,16
1,18,10
1,10,11
1,11,12
1,13,14
1,9,18
1,17,18
1,12,13
1,2,17

lsel,,,,1,11,10
lesi,all,.6
cm,c_13,line

lsel,,,,13,21,8
lsel,a,,,2,12,10
lesi,all,,,1
cm,c_11,line

lsel,,,,14,17
lsel,a,,,19,20
lsel,a,,,10
cm,c_12,line
lesi,all,.6
alls

cmsel,u,c_11
cmsel,u,c_12
lesi,all,2

alls
ldel,9

!  upper left
ksel,all
a,1,16,17,2

!  upper right
ksel,,,,10,14
ksel,a,,,16,18
lslk,,1
al,all

!  triangle transition
```

```
ksel,all
lsel,all
a,2,3,17,17

!  lower
ksel,,,,3,9
ksel,a,,,17,18
lslk,,1
al,all

alls
type,4
mat,1
real,1

ames,all
/vup,1,z
/view,1,1,1,1
eplo

csys
k,20
k,21,0,0,20
esize,,18
type,1
real,1
mat,1
vrot,all,,,,,,20,21,180,2

*endif

csys
nsel,,loc,y,-.01,1
d,all,uy

nsel,all

!   add the mass elements for the weight
et,5,21,,,2
*get,zmin,node,,mnloc,z
nsel,,loc,z,zmin-1,zmin+.01
mas21,86871*2/2,5,5
/out,kbas1,out,,append
/gopr

alls
```

Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

```
!  add the beam elements for the attachments
*get,ndmx,node,,num,max
gndmx=ndmx+1
csys,11
n,gndmx,-5.24,,21.46
d,gndmx,ux
d,gndmx,uy
d,gndmx,uz

r,3,1000,1000,1000,1000,1000
csys
esel,all
nsle
*get,r_o,node,,mnloc,x
nsel,,loc,y,-.01,1
nsel,r,loc,x,r_o-.1,r_o+.01
r_beam,gndmx,1,3,3
/out,kbas1,out,,append
/gopr

csys
*get,s_x,node,gndmx,loc,x
*get,s_z,node,gndmx,loc,z
n,gndmx+1,-s_x,,s_z
d,gndmx+1,uy
d,gndmx+1,uz

nsel,,loc,y,-.01,1
nsel,r,loc,x,-r_o-.1,-r_o+.01
r_beam,gndmx+1,1,3,3

alls
modm,detach
!   move the nodes for the flat
csys,1
esel,,ename,,45
nsle
nsel,r,loc,y,-41,-39
nmod,all,,-39
nsle
*get,r_o,node,,mxloc,x
nsel,r,loc,x,r_o-.1,r_o+1
nsel,r,loc,y,-66,-38
local,12,0,0,0,0,-52
nmod,all,44.75/2

esel,,type,,4
edel,all
```

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```
etdel,4

alls
fini
/solu
acel,,,1
solve
fini
/post1

alls
fsum
/sho,kbasin,plt,1
/title,K Basin Pail Ring Lift Analysis
/device,vector,on
/type,,3
/num,-1
/view,1,1,1,1
eplo
/num,2

esel,,ename,,45
nsle

/aut
/view,1,1,-1,1
/vup,1,z
csys,1
nsel,r,loc,y,-161,-29
esln,,1
plns,s,eqv


dsys,1
nlis,2221,2630,2630-2221
dsys
lpath,2221,2630
prsect

dsys,1
nlis,2272,2596,2596-2272
dsys
lpath,2272,2596
prsect


dsys,1
nlis,1847,2392,2392-1847
```

```
dsys
lpath,1847,2392
prsect

dsys,1
nlis,129,742,742-129
dsys
lpath,129,742
prsect


dsys,1
nlis,231,912,912-231
dsys
lpath,231,912
prsect

dsys,1
nlis,333,861,861-333
dsys
lpath,333,861
prsect

dsys,1
nlis,1367,1486,1486-1367
dsys
lpath,1367,1486
prsect

dsys,1
nlis,1373,1492,1492-1373
dsys
lpath,1373,1492
prsect


dsys,1
nlis,3082,3201,3201-3082
dsys
lpath,3082,3201
prsect
```

```
dsys,1
nlis,2184,2474,2474-2184
dsys
lpath,2184,2474
prsect

/sho,xxx
/sho,term
/type,,3


/out
```

Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

```
/out,m21,out,,append
*msg,info,arg1,arg2
 mas21 arg1,arg2:  %g %g
!   mas21.mac
!   Generates the mass elements off a surface of nodes
!   and forms the real constant set so that the
!   total mass equals that of the input mass  (weight)
!
!   arg1 = total weight to be simulated (lb)
!   arg2 = element type for the mass element
!   arg3 = real constant set for the mass element


!   et,arg2,21,,0,2
type,arg2
real,arg3
cm,c_masn,node   !  current set of nodes for the mass generation
*get,ndmn,node,,num,min
*get,nmasse,node,,count
r,arg3,arg1/nmasse
!  define the node number array
alls
*get,ndmx,node,,num,max

cmsel,,c_masn
*set,_mskv
*dim,_mskv,,ndmx
*vget,_mskv(1),node,1,nsel
*voper,_mskv(1),_mskv(1),gt,0
*set,nd_ns
*dim,nd_ns,,ndmx
*set,nd_nsg
*dim,nd_nsg,,ndmx
*vmask,_mskv(1)
*vfill,nd_ns(1),ramp,1,1
!   write the nodes to generate the elements
*vmask,_mskv(1)
/nopr
/out,mas,tmp
*vwrite,nd_ns(1)
('e,',f15.0)
/out,mas,out,,append
/inp,mas,tmp
/gopr
/out,_mas,sum
*msg,info,arg1
 Total mass distributed:________________ %g
*msg,info,nmasse
```

Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

```
 Number of mass elements generated:_____ %i
/out
*list,_mas,sum
!  parsav,all,temp,par
```

Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

```
!    r_beam.mac
!    arg1 = node to which all beams will be connected
!    arg2 = material
!    arg3 = real
!    arg4 = type
mat,arg2
real,arg3
type,arg4
nsel,u,,,arg1
cm,c_n,node
cm,c_nn,node
*get,ncnt,node,,count
*do,i1,1,ncnt
*get,ndmx,node,,num,max
nsel,a,,,arg1
e,arg1,ndmx
cmsel,,c_nn
nsel,u,,,arg1
nsel,u,,,ndmx
cm,c_nn,node
*enddo
cmsel,,c_n
nsel,a,,,arg1
/pnum,mat,1
/num,1
/aut
eplo
```

APPENDIX B

Output File for the Finite Element Model

There a a total of 37 pages in Appendix B.

Output Files

File Name	Description
kbas1.out	Output File For Model / Solution / Stresses

NAC INTERNATIONAL	Performed by: mg	Date: 11-11-96	Calculation No. 457-2003.3 Revision 0
	Checked by: JRO	Date: 11-11-96	Page B1 of 37

Computer Output Cover Sheet

Title of Analysis: Immersion Pail Evaluation For Two (2) Point Lift Load

Work Request And Report Number: 457-2003.3, Revision 0

Program: ANSYS **Version:** 5.2 **Originator:** Michael C. Yaksh

Date of Verification: 06 / 28 / 96

Computer Identification/NAC Control Number: DEC ALPHA XL 266
NAC Serial No. 02207

Title of Case: Deadweight (Inertia Load = 1g).

Total Number of Pages: 35 (Not including this cover sheet).

Performed By: MY **Date:** 11-11-96

Checked By: JRO **Date:** 11-11-96

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```
NUMBER OF DISPLAYED ERRORS ALLOWED PER COMMAND=          0
 NUMBER OF ERRORS ALLOWED PER COMMAND BEFORE ANSYS ABORT= 100000

 *IF arg1              ( = 0.000000E+00 ) EQ
   0                   ( = 0.000000E+00 ) THEN

 EXIT THE ANSYS POST1 DATABASE PROCESSOR


 ***** ROUTINE COMPLETED ***** CP =     562.727



 *** NOTE ***              CP=   562.727  TIME= 21:59:57
 A total of 347 warnings and errors written to ftube.err.

 CLEAR ANSYS DATABASE AND RESTART

      ***** ANSYS ANALYSIS DEFINITION (PREP7) *****

 ENTER /SHOW,DEVICE-NAME  TO ENABLE GRAPHIC DISPLAY
 ENTER  FINISH        TO LEAVE PREP7
 PRINTOUT KEY SET TO /GOPR (USE /NOPR TO SUPPRESS)

 ELEMENT TYPE   1 IS SOLID45     3-D STRUCTURAL SOLID
  KEYOPT(1-12)=  0 0 0  0 0 0  0 0 0  0 0 0

 CURRENT NODAL DOF SET IS  UX   UY   UZ
  THREE-DIMENSIONAL MODEL

 ELEMENT TYPE   2 IS MASS21      STRUCTURAL MASS
  KEYOPT(1-12)=  0 0 0  0 0 0  0 0 0  0 0 0

 CURRENT NODAL DOF SET IS  UX   UY   UZ   ROTX  ROTY  ROTZ
  THREE-DIMENSIONAL MODEL

 ELEMENT TYPE   3 IS BEAM4       3-D ELASTIC BEAM
  KEYOPT(1-12)=  0 0 0  0 0 0  0 0 0  0 0 0

 CURRENT NODAL DOF SET IS  UX   UY   UZ   ROTX  ROTY  ROTZ
  THREE-DIMENSIONAL MODEL

 ELEMENT TYPE   4 IS SHELL63     ELASTIC SHELL
  KEYOPT(1-12)=  0 0 0  0 0 0  0 0 0  0 0 0

 CURRENT NODAL DOF SET IS  UX   UY   UZ   ROTX  ROTY  ROTZ
  THREE-DIMENSIONAL MODEL

 ELEMENT TYPE   5 IS MASS21      STRUCTURAL MASS
  KEYOPT(1-12)=  0 0 2  0 0 0  0 0 0  0 0 0

 CURRENT NODAL DOF SET IS  UX   UY   UZ   ROTX  ROTY  ROTZ
```

```
THREE-DIMENSIONAL MODEL

MATERIAL  1   EX  = 0.2700000E+08

TURN OFF ELEMENT SHAPE CHECKING

COORDINATE SYSTEM    11 DEFINITION.  TYPE= 0  (CARTESIAN)
 XC,YC,ZC= -23.000    0.00000E+00 0.00000E+00
 ANGLES=   0.00   0.00   0.00  PARAMETERS=  1.000   1.000
 ORIENTATION=  1.00 0.00 0.00  0.00 1.00 0.00  0.00 0.00 1.00

ACTIVE COORDINATE SYSTEM SET TO    11  (CARTESIAN)

KEYPOINT    1  X,Y,Z= 0.000000E+00 0.000000E-00  26.0000    IN CSYS= 11

            -23.0000    0.000000E+00  26.0000    IN CSYS= 0

KEYPOINT    2  X,Y,Z= 0.000000E+00 0.000000E+00  18.0000    IN CSYS= 11

            -23.0000    0.000000E+00  18.0000    IN CSYS= 0

KEYPOINT    3  X,Y,Z= 0.625000    0.000000E+00  16.1250    IN CSYS= 11

            -22.3750    0.000000E+00  16.1250    IN CSYS= 0

KEYPOINT    4  X,Y,Z= 0.625000    0.000000E+00  3.00000    IN CSYS= 11

            -22.3750    0.000000E+00  3.00000    IN CSYS= 0

KEYPOINT    5  X,Y,Z=  2.00000    0.000000E+00 0.000000E+00 IN CSYS= 11

            -21.0000    0.000000E+00 0.000000E+00 IN CSYS= 0

KEYPOINT    6  X,Y,Z=  2.00000    0.000000E+00  4.66000    IN CSYS= 11

            -21.0000    0.000000E+00  4.66000    IN CSYS= 0

KEYPOINT    7  X,Y,Z=  3.00000    0.000000E+00  6.39000    IN CSYS= 11

            -20.0000    0.000000E+00  6.39000    IN CSYS= 0

KEYPOINT    8  X,Y,Z=  3.00000    0.000000E+00  8.22000    IN CSYS= 11

            -20.0000    0.000000E+00  8.22000    IN CSYS= 0

KEYPOINT    9  X,Y,Z=  2.00000    0.000000E+00  9.96000    IN CSYS= 11

            -21.0000    0.000000E+00  9.96000    IN CSYS= 0

KEYPOINT   10  X,Y,Z=  2.00000    0.000000E+00  21.3700    IN CSYS= 11

            -21.0000    0.000000E+00  21.3700    IN CSYS= 0
```

```
KEYPOINT   11  X,Y,Z=  2.37500    0.000000E+00  22.0200    IN CSYS= 11
              -20.6250    0.000000E+00  22.0200    IN CSYS= 0
KEYPOINT   12  X,Y,Z=  2.37500    0.000000E+00  22.9900    IN CSYS= 11
              -20.6250    0.000000E+00  22.9900    IN CSYS= 0
KEYPOINT   13  X,Y,Z=  2.00000    0.000000E+00  23.6800    IN CSYS= 11
              -21.0000    0.000000E+00  23.6800    IN CSYS= 0
KEYPOINT   14  X,Y,Z=  2.00000    0.000000E+00  26.0000    IN CSYS= 11
              -21.0000    0.000000E+00  26.0000    IN CSYS= 0
KEYPOINT   15  X,Y,Z=  0.625000   0.000000E+00  26.0000    IN CSYS= 11
              -22.3750    0.000000E+00  26.0000    IN CSYS= 0
KEYPOINT   16  X,Y,Z=  1.12500    0.000000E+00  26.0000    IN CSYS= 11
              -21.8750    0.000000E+00  26.0000    IN CSYS= 0
KEYPOINT   17  X,Y,Z=  1.12500    0.000000E+00  18.0000    IN CSYS= 11
              -21.8750    0.000000E+00  18.0000    IN CSYS= 0
KEYPOINT   18  X,Y,Z=  2.00000    0.000000E+00  18.0000    IN CSYS= 11
              -21.0000    0.000000E+00  18.0000    IN CSYS= 0

*DO LOOP ON PARAMETER= I1     FROM  1.0000    TO  9.0000    BY  1.0000

LINE CONNECTS KEYPOINTS     1    2
 LINE NO.=    1  KP1=    1  TAN1=   0.0000  0.0000  1.0000
          KP2=    2  TAN2=   0.0000  0.0000 -1.0000

*ENDDO  INDEX= I1

LINE CONNECTS KEYPOINTS    14   16
 LINE NO.=   10  KP1=   14  TAN1=   1.0000  0.0000  0.0000
          KP2=   16  TAN2=  -1.0000  0.0000  0.0000

LINE CONNECTS KEYPOINTS    16   17
 LINE NO.=   11  KP1=   16  TAN1=   0.0000  0.0000  1.0000
          KP2=   17  TAN2=   0.0000  0.0000 -1.0000

LINE CONNECTS KEYPOINTS    17    3
 LINE NO.=   12  KP1=   17  TAN1=   0.2577  0.0000  0.9662
          KP2=    3  TAN2=  -0.2577  0.0000 -0.9662
```

```
LINE CONNECTS KEYPOINTS    1   16
 LINE NO.=  13 KP1=    1 TAN1=  -1.0000  0.0000  0.0000
          KP2=   16 TAN2=   1.0000  0.0000  0.0000

LINE CONNECTS KEYPOINTS   18   10
 LINE NO.=  14 KP1=   18 TAN1=   0.0000  0.0000 -1.0000
          KP2=   10 TAN2=   0.0000  0.0000  1.0000

LINE CONNECTS KEYPOINTS   10   11
 LINE NO.=  15 KP1=   10 TAN1=  -0.4997  0.0000 -0.8662
          KP2=   11 TAN2=   0.4997  0.0000  0.8662

LINE CONNECTS KEYPOINTS   11   12
 LINE NO.=  16 KP1=   11 TAN1=   0.0000  0.0000 -1.0000
          KP2=   12 TAN2=   0.0000  0.0000  1.0000

LINE CONNECTS KEYPOINTS   13   14
 LINE NO.=  17 KP1=   13 TAN1=   0.0000  0.0000 -1.0000
          KP2=   14 TAN2=   0.0000  0.0000  1.0000

LINE CONNECTS KEYPOINTS    9   18
 LINE NO.=  18 KP1=    9 TAN1=   0.0000  0.0000 -1.0000
          KP2=   18 TAN2=   0.0000  0.0000  1.0000

LINE CONNECTS KEYPOINTS   17   18
 LINE NO.=  19 KP1=   17 TAN1=  -1.0000  0.0000  0.0000
          KP2=   18 TAN2=   1.0000  0.0000  0.0000

LINE CONNECTS KEYPOINTS   12   13
 LINE NO.=  20 KP1=   12 TAN1=   0.4775  0.0000 -0.8786
          KP2=   13 TAN2=  -0.4775  0.0000  0.8786

LINE CONNECTS KEYPOINTS    2   17
 LINE NO.=  21 KP1=    2 TAN1=  -1.0000  0.0000  0.0000
          KP2=   17 TAN2=   1.0000  0.0000  0.0000

SELECT    FOR ITEM=LINE COMPONENT=
 IN RANGE      1 TO     11 STEP     10

  2 LINES (OF   21 DEFINED) SELECTED BY LSEL  COMMAND.

SET DIVISIONS ON ALL SELECTED UNMESHED LINES
   FOR ELEMENT SIZE = 0.60000     SPACING RATIO =    1.0000

DEFINITION OF COMPONENT = C_L3     ENTITY=LINE

SELECT    FOR ITEM=LINE COMPONENT=
 IN RANGE     13 TO     21 STEP      8

  2 LINES (OF   21 DEFINED) SELECTED BY LSEL  COMMAND.
```

```
ALSO SELECT  FOR ITEM=LINE COMPONENT=
 IN RANGE     2 TO     12 STEP    10

  4 LINES (OF   21 DEFINED) SELECTED BY LSEL COMMAND.

SET DIVISIONS ON ALL SELECTED UNMESHED LINES
   TO NDIV =   1, SPACING RATIO =  1.000

DEFINITION OF COMPONENT = C_L1     ENTITY=LINE

SELECT      FOR ITEM=LINE COMPONENT=
 IN RANGE     14 TO    17 STEP     1

  4 LINES (OF   21 DEFINED) SELECTED BY LSEL  COMMAND.

ALSO SELECT  FOR ITEM=LINE COMPONENT=
 IN RANGE     19 TO    20 STEP     1

  6 LINES (OF   21 DEFINED) SELECTED BY LSEL COMMAND.

ALSO SELECT  FOR ITEM=LINE COMPONENT=
 IN RANGE     10 TO    10 STEP     1

  7 LINES (OF   21 DEFINED) SELECTED BY LSEL COMMAND.

DEFINITION OF COMPONENT = C_L2     ENTITY=LINE

SET DIVISIONS ON ALL SELECTED UNMESHED LINES
   FOR ELEMENT SIZE =  0.60000      SPACING RATIO =    1.0000

SELECT ALL ENTITIES OF TYPE= ALL  AND BELOW

ALL SELECT   FOR ITEM=VOLU COMPONENT=
 IN RANGE     0 TO     0 STEP     1

  0 VOLUMES (OF     0 DEFINED) SELECTED BY  VSEL  COMMAND.

ALL SELECT   FOR ITEM=AREA COMPONENT=
 IN RANGE     0 TO     0 STEP     1

  0 AREAS (OF    0 DEFINED) SELECTED BY ASEL COMMAND.

ALL SELECT   FOR ITEM=LINE COMPONENT=
 IN RANGE     1 TO    21 STEP     1

 21 LINES (OF   21 DEFINED) SELECTED BY LSEL COMMAND.

ALL SELECT   FOR ITEM=KP   COMPONENT=
 IN RANGE     1 TO    18 STEP     1

 18 KEYPOINTS (OF    18 DEFINED) SELECTED BY  KSEL  COMMAND.
```

Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

```
ALL SELECT   FOR ITEM=ELEM COMPONENT=
 IN RANGE     0 TO     0 STEP     1

   0 ELEMENTS (OF    0 DEFINED) SELECTED BY  ESEL  COMMAND.

ALL SELECT   FOR ITEM=NODE COMPONENT=
 IN RANGE     0 TO     0 STEP     1

   0 NODES (OF    0 DEFINED) SELECTED BY  NSEL  COMMAND.

UNSELECT   COMPONENT C_L1

UNSELECT   COMPONENT C_L2

SET DIVISIONS ON ALL SELECTED UNMESHED LINES
   FOR ELEMENT SIZE =  2.0000     SPACING RATIO =    1.0000

SELECT ALL ENTITIES OF TYPE= ALL  AND BELOW

ALL SELECT   FOR ITEM=VOLU COMPONENT=
 IN RANGE     0 TO     0 STEP     1

   0 VOLUMES (OF    0 DEFINED) SELECTED BY  VSEL  COMMAND.

ALL SELECT   FOR ITEM=AREA COMPONENT=
 IN RANGE     0 TO     0 STEP     1

   0 AREAS (OF    0 DEFINED) SELECTED BY ASEL COMMAND.

ALL SELECT   FOR ITEM=LINE COMPONENT=
 IN RANGE     1 TO    21 STEP     1

  21 LINES (OF   21 DEFINED) SELECTED BY LSEL COMMAND.

ALL SELECT   FOR ITEM=KP   COMPONENT=
 IN RANGE     1 TO    18 STEP     1

  18 KEYPOINTS (OF   18 DEFINED) SELECTED BY  KSEL  COMMAND.

ALL SELECT   FOR ITEM=ELEM COMPONENT=
 IN RANGE     0 TO     0 STEP     1

   0 ELEMENTS (OF    0 DEFINED) SELECTED BY  ESEL  COMMAND.

ALL SELECT   FOR ITEM=NODE COMPONENT=
 IN RANGE     0 TO     0 STEP     1

   0 NODES (OF    0 DEFINED) SELECTED BY  NSEL  COMMAND.

DELETE SELECTED LINES FROM     9 TO     9 BY   1

  DELETED    1 LINES
```

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Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

```
ALL SELECT  FOR ITEM=KP  COMPONENT=
 IN RANGE      1 TO     18 STEP     1

  18 KEYPOINTS (OF    18 DEFINED) SELECTED BY  KSEL  COMMAND.

DEFINE AREA BY LIST OF KEYPOINTS
 KEYPOINT LIST =    1   16   17   2

  AREA NUMBER =     1

SELECT      FOR ITEM=KP  COMPONENT=
 IN RANGE     10 TO     14 STEP     1

   5 KEYPOINTS (OF    18 DEFINED) SELECTED BY  KSEL  COMMAND.

ALSO SELECT  FOR ITEM=KP  COMPONENT=
 IN RANGE     16 TO     18 STEP     1

   8 KEYPOINTS (OF    18 DEFINED) SELECTED BY KSEL COMMAND.

SELECT     ALL LINES COMPLETELY CONTAINED WITHIN KEYPOINT SET.

   8 LINES (OF   20 DEFINED) SELECTED FROM
   8 SELECTED KEYPOINTS BY LSLK COMMAND.

DEFINE AREA BY LIST OF LINES
   LINE LIST = ALL SELECTED LINES
   (TRAVERSED IN SAME DIRECTION AS LINE    10)

  AREA NUMBER =     2

ALL SELECT  FOR ITEM=KP  COMPONENT=
 IN RANGE      1 TO     18 STEP     1

  18 KEYPOINTS (OF    18 DEFINED) SELECTED BY  KSEL  COMMAND.

ALL SELECT  FOR ITEM=LINE COMPONENT=
 IN RANGE      1 TO     21 STEP     1

  20 LINES (OF   20 DEFINED) SELECTED BY LSEL COMMAND.

DEFINE AREA BY LIST OF KEYPOINTS
 KEYPOINT LIST =    2   3   17   17

  AREA NUMBER =     3

SELECT      FOR ITEM=KP  COMPONENT=
 IN RANGE      3 TO      9 STEP     1

   7 KEYPOINTS (OF    18 DEFINED) SELECTED BY  KSEL  COMMAND.
```

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Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

```
ALSO SELECT  FOR ITEM=KP  COMPONENT=
 IN RANGE     17 TO     18 STEP    1

   9 KEYPOINTS (OF    18 DEFINED) SELECTED BY KSEL COMMAND.

SELECT     ALL LINES COMPLETELY CONTAINED WITHIN KEYPOINT SET.

  9 LINES (OF   20 DEFINED) SELECTED FROM
   9 SELECTED KEYPOINTS BY LSLK COMMAND.

DEFINE AREA BY LIST OF LINES
   LINE LIST = ALL SELECTED LINES
   (TRAVERSED IN SAME DIRECTION AS LINE    3)

  AREA NUMBER =    4

SELECT ALL ENTITIES OF TYPE= ALL  AND BELOW

ALL SELECT   FOR ITEM=VOLU COMPONENT=
 IN RANGE     0 TO      0 STEP     1

   0 VOLUMES (OF     0 DEFINED) SELECTED BY  VSEL  COMMAND.

ALL SELECT   FOR ITEM=AREA COMPONENT=
 IN RANGE     1 TO      4 STEP     1

  4 AREAS (OF    4 DEFINED) SELECTED BY ASEL COMMAND.

ALL SELECT   FOR ITEM=LINE COMPONENT=
 IN RANGE     1 TO     21 STEP     1

 20 LINES (OF   20 DEFINED) SELECTED BY LSEL COMMAND.

ALL SELECT   FOR ITEM=KP   COMPONENT=
 IN RANGE     1 TO     18 STEP     1

  18 KEYPOINTS (OF    18 DEFINED) SELECTED BY  KSEL  COMMAND.

ALL SELECT   FOR ITEM=ELEM COMPONENT=
 IN RANGE     0 TO      0 STEP     1

   0 ELEMENTS (OF     0 DEFINED) SELECTED BY  ESEL  COMMAND.

ALL SELECT   FOR ITEM=NODE COMPONENT=
 IN RANGE     0 TO      0 STEP     1

   0 NODES (OF     0 DEFINED) SELECTED BY  NSEL  COMMAND.

ELEMENT TYPE SET TO     4

MATERIAL NUMBER SET TO     1
```

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Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

REAL CONSTANT NUMBER= 1

GENERATE NODES AND ELEMENTS IN ALL SELECTED AREAS

** Meshing of area 1 in progress **
** Meshing of area 1 completed ** 14 elements.

** Meshing of area 2 in progress **

** Initial meshing of area 2 complete **
** AREA 2 MESHED WITH 32 QUADRILATERALS, 0 TRIANGLES **
** Meshing of area 2 completed ** 32 elements.

** Meshing of area 3 in progress **

** Initial meshing of area 3 complete **
** AREA 3 MESHED WITH 0 QUADRILATERALS, 1 TRIANGLES **
** Meshing of area 3 completed ** 1 elements.

** Meshing of area 4 in progress **

** Initial meshing of area 4 complete **
** AREA 4 MESHED WITH 18 QUADRILATERALS, 4 TRIANGLES **
** Meshing of area 4 completed ** 22 elements.

NUMBER OF AREAS MESHED = 4
MAXIMUM NODE NUMBER = 95
MAXIMUM ELEMENT NUMBER = 69

VIEW UP DIRECTION FOR WINDOW 1 IS GCS Z AXIS

view point for window 1 1.0000 1.0000 1.0000

PRODUCE ELEMENT PLOT IN DSYS = 0

ACTIVE COORDINATE SYSTEM SET TO 0 (CARTESIAN)

KEYPOINT 20 X,Y,Z= 0.000000E+00 0.000000E+00 0.000000E+00 IN CSYS= 0

KEYPOINT 21 X,Y,Z= 0.000000E+00 0.000000E+00 20.0000 IN CSYS= 0

DEFAULT ELEMENT DIVISIONS PER LINE = 18

ELEMENT TYPE SET TO 1

REAL CONSTANT NUMBER= 1

MATERIAL NUMBER SET TO 1

ROTATE AREAS
1, 2, 3, 4,
ABOUT THE AXIS DEFINED BY KEYPOINTS 20 21

```
 DEGREES OF ARC=  180.00  NUMBER OF SEGMENTS=  2

MAXIMUM NODE NUMBER      =  3515
MAXIMUM ELEMENT NUMBER   =  2553

*ENDIF

ACTIVE COORDINATE SYSTEM SET TO    0 (CARTESIAN)

SELECT    FOR ITEM=LOC COMPONENT=Y   BETWEEN-0.10000E-01 AND  1.0000
 KABS= 0.  TOLERANCE= 0.000000E+00

 190 NODES (OF  3515  DEFINED) SELECTED BY  NSEL  COMMAND.

SPECIFIED CONSTRAINT UY  FOR SELECTED NODES     1 TO   3515 BY    1
REAL= 0.000000000E+00  IMAG= 0.000000000E+00

ALL SELECT  FOR ITEM=NODE COMPONENT=
 IN RANGE     1 TO    3515 STEP     1

 3515 NODES (OF  3515  DEFINED) SELECTED BY  NSEL  COMMAND.

ELEMENT TYPE   5 IS MASS21     STRUCTURAL MASS
 KEYOPT(1-12)=   0 0 2   0 0 0   0 0 0   0 0 0

CURRENT NODAL DOF SET IS  UX   UY   UZ   ROTX  ROTY  ROTZ
 THREE-DIMENSIONAL MODEL

*GET zmin    FROM  NODE  ITEM=MNLO Z    VALUE= 0.000000000E+00

SELECT    FOR ITEM=LOC COMPONENT=Z   BETWEEN -1.0000    AND 0.10000E-01
 KABS= 0.  TOLERANCE= 0.000000E+00

  37 NODES (OF  3515  DEFINED) SELECTED BY  NSEL  COMMAND.

USE COMMAND MACRO MAS21
ARGS=  86871.    5.0000     5.0000

/OUTPUT FILE= m21.out

PRINTOUT RESUMED BY /GOP

SELECT ALL ENTITIES OF TYPE= ALL  AND BELOW

ALL SELECT  FOR ITEM=VOLU COMPONENT=
 IN RANGE     1 TO     8 STEP     1

   8  VOLUMES (OF    8 DEFINED) SELECTED BY  VSEL  COMMAND.

ALL SELECT  FOR ITEM=AREA COMPONENT=
 IN RANGE     1 TO    52 STEP     1
```

```
 52 AREAS (OF  52 DEFINED) SELECTED BY ASEL COMMAND.

ALL SELECT  FOR ITEM=LINE COMPONENT=
 IN RANGE    1 TO    94 STEP    1

 94 LINES (OF  94 DEFINED) SELECTED BY LSEL COMMAND.

ALL SELECT  FOR ITEM=KP  COMPONENT=
 IN RANGE    1 TO    54 STEP    1

 54 KEYPOINTS (OF  54 DEFINED) SELECTED BY KSEL COMMAND.

ALL SELECT  FOR ITEM=ELEM COMPONENT=
 IN RANGE    1 TO   2590 STEP    1

 2590 ELEMENTS (OF  2590 DEFINED) SELECTED BY ESEL COMMAND.

ALL SELECT  FOR ITEM=NODE COMPONENT=
 IN RANGE    1 TO   3515 STEP    1

 3515 NODES (OF  3515 DEFINED) SELECTED BY NSEL COMMAND.

*GET ndmx    FROM NODE ITEM=NUM MAX  VALUE= 3515.00000

PARAMETER GNDMX  =   3516.000

ACTIVE COORDINATE SYSTEM SET TO   11 (CARTESIAN)

NODE  3516 KCS= 11 X,Y,Z= -5.2400   0.00000E+00 21.460

SPECIFIED CONSTRAINT UX  FOR SELECTED NODES   3516 TO  3516 BY    1
REAL= 0.000000000E+00  IMAG= 0.000000000E+00

SPECIFIED CONSTRAINT UY  FOR SELECTED NODES   3516 TO  3516 BY    1
REAL= 0.000000000E+00  IMAG= 0.000000000E+00

SPECIFIED CONSTRAINT UZ  FOR SELECTED NODES   3516 TO  3516 BY    1
REAL= 0.000000000E+00  IMAG= 0.000000000E+00

REAL CONSTANT SET    3 ITEMS   1 TO   6
  1000.0    1000.0    1000.0    1000.0    1000.0    0.00000E+00

ACTIVE COORDINATE SYSTEM SET TO    0 (CARTESIAN)

ALL SELECT  FOR ITEM=ELEM COMPONENT=
 IN RANGE    1 TO   2590 STEP    1

 2590 ELEMENTS (OF  2590 DEFINED) SELECTED BY ESEL COMMAND.

SELECT    ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

 3515 NODES (OF  3516 DEFINED) SELECTED FROM
```

Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

```
 2590 SELECTED ELEMENTS BY NSLE COMMAND.

*GET r_o    FROM NODE ITEM=MNLO X    VALUE= -23.0000000

SELECT    FOR ITEM=LOC COMPONENT=Y   BETWEEN-0.10000E-01 AND  1.0000
 KABS= 0.  TOLERANCE= 0.000000E+00

  191 NODES (OF  3516 DEFINED) SELECTED BY NSEL COMMAND.

RESELECT   FOR ITEM=LOC COMPONENT=X   BETWEEN -23.100   AND -22.990
 KABS= 0.  TOLERANCE= 0.000000E+00

  15 NODES (OF  3516 DEFINED) SELECTED BY NSEL COMMAND.

USE COMMAND MACRO R_BEAM
ARGS=  3516.0    1.0000    3.0000    3.0000

MATERIAL NUMBER SET TO   1

REAL CONSTANT NUMBER=   3

ELEMENT TYPE SET TO   3

UNSELECT   FOR ITEM=NODE COMPONENT=
 IN RANGE   3516 TO    3516 STEP     1

  15 NODES (OF  3516 DEFINED) SELECTED BY NSEL COMMAND.

DEFINITION OF COMPONENT = C_N     ENTITY=NODE

DEFINITION OF COMPONENT = C_NN    ENTITY=NODE

*GET ncnt    FROM NODE ITEM=COUN    VALUE= 15.0000000

*DO LOOP ON PARAMETER= II    FROM 1.0000   TO 15.000   BY 1.0000

*GET ndmx    FROM NODE ITEM=NUM MAX  VALUE= 30.0000000

ALSO SELECT  FOR ITEM=NODE COMPONENT=
 IN RANGE   3516 TO    3516 STEP     1

  16 NODES (OF  3516 DEFINED) SELECTED BY NSEL COMMAND.

ELEMENT  2591   3516   30   0

SELECT    COMPONENT C_NN

UNSELECT   FOR ITEM=NODE COMPONENT=
 IN RANGE   3516 TO    3516 STEP     1

  15 NODES (OF  3516 DEFINED) SELECTED BY NSEL COMMAND.
```

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```
UNSELECT   FOR ITEM=NODE COMPONENT=
 IN RANGE    30 TO     30 STEP     1

  14 NODES (OF  3516  DEFINED) SELECTED BY  NSEL  COMMAND.

DEFINITION OF COMPONENT = C_NN     ENTITY=NODE

*ENDDO INDEX= 11

SELECT     COMPONENT C_N

ALSO SELECT  FOR ITEM=NODE COMPONENT=
 IN RANGE    3516 TO    3516 STEP     1

  16 NODES (OF  3516  DEFINED) SELECTED BY  NSEL  COMMAND.

MAT  NUMBERING KEY =  1

NUMBER KEY SET TO  1  -1=NONE  0=BOTH  1=COLOR  2=NUMBER

AUTOMATIC SCALING FOR WINDOW 1
 DISTANCE AND FOCUS POINT AUTOMATICALLY CALCULATED

PRODUCE ELEMENT PLOT IN DSYS =  0

/OUTPUT FILE= kbas1.out

PRINTOUT RESUMED BY /GOP

ACTIVE COORDINATE SYSTEM SET TO     0  (CARTESIAN)

*GET  s_x     FROM  NODE   3516  ITEM=LOC  X    VALUE= -28.2400000

*GET  s_z     FROM  NODE   3516  ITEM=LOC  Z    VALUE=  21.4600000

NODE    3517  KCS=  0  X,Y,Z=  28.240     0.00000E+00  21.460

SPECIFIED CONSTRAINT UY   FOR SELECTED NODES      3517 TO    3517 BY      1
REAL= 0.000000000E+00   IMAG= 0.000000000E+00

SPECIFIED CONSTRAINT UZ   FOR SELECTED NODES      3517 TO    3517 BY      1
REAL= 0.000000000E+00   IMAG= 0.000000000E+00

SELECT      FOR ITEM=LOC  COMPONENT=Y    BETWEEN-0.10000E-01 AND   1.0000
 KABS=  0.   TOLERANCE= 0.000000E+00

  192  NODES (OF   3517  DEFINED) SELECTED BY  NSEL  COMMAND.

RESELECT     FOR ITEM=LOC  COMPONENT=X    BETWEEN  22.900     AND   23.010
 KABS=  0.   TOLERANCE= 0.000000E+00

  15  NODES (OF   3517  DEFINED) SELECTED BY  NSEL  COMMAND.
```

```
USE COMMAND MACRO R_BEAM
ARGS= 3517.0    1.0000    3.0000    3.0000

MATERIAL NUMBER SET TO    1

REAL CONSTANT NUMBER=    3

ELEMENT TYPE SET TO    3

UNSELECT    FOR ITEM=NODE COMPONENT=
 IN RANGE   3517 TO    3517 STEP      1

   15 NODES (OF   3517 DEFINED) SELECTED BY  NSEL  COMMAND.

DEFINITION OF COMPONENT = C_N      ENTITY=NODE

DEFINITION OF COMPONENT = C_NN     ENTITY=NODE

*GET ncnt    FROM NODE ITEM=COUN     VALUE= 15.0000000

*DO LOOP ON PARAMETER= II     FROM 1.0000    TO 15.000    BY 1.0000

*GET ndmx    FROM NODE ITEM=NUM MAX  VALUE= 1835.00000

ALSO SELECT  FOR ITEM=NODE COMPONENT=
 IN RANGE   3517 TO    3517 STEP      1

   16 NODES (OF   3517 DEFINED) SELECTED BY  NSEL  COMMAND.

ELEMENT  2606   3517  1835    0

SELECT     COMPONENT C_NN

UNSELECT    FOR ITEM=NODE COMPONENT=
 IN RANGE   3517 TO    3517 STEP      1

   15 NODES (OF   3517 DEFINED) SELECTED BY  NSEL  COMMAND.

UNSELECT    FOR ITEM=NODE COMPONENT=
 IN RANGE   1835 TO    1835 STEP      1

   14 NODES (OF   3517 DEFINED) SELECTED BY  NSEL  COMMAND.

DEFINITION OF COMPONENT = C_NN     ENTITY=NODE

*ENDDO INDEX= II

SELECT     COMPONENT C_N

ALSO SELECT  FOR ITEM=NODE COMPONENT=
 IN RANGE   3517 TO    3517 STEP      1
```

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```
 16 NODES (OF  3517 DEFINED) SELECTED BY NSEL COMMAND.

MAT NUMBERING KEY = 1

NUMBER KEY SET TO 1 -1=NONE 0=BOTH 1=COLOR 2=NUMBER

AUTOMATIC SCALING FOR WINDOW 1
  DISTANCE AND FOCUS POINT AUTOMATICALLY CALCULATED

PRODUCE ELEMENT PLOT IN DSYS = 0

SELECT ALL ENTITIES OF TYPE= ALL AND BELOW

ALL SELECT  FOR ITEM=VOLU COMPONENT=
 IN RANGE     1 TO     8 STEP     1

  8 VOLUMES (OF    8 DEFINED) SELECTED BY VSEL COMMAND.

ALL SELECT  FOR ITEM=AREA COMPONENT=
 IN RANGE     1 TO    52 STEP     1

  52 AREAS (OF   52 DEFINED) SELECTED BY ASEL COMMAND.

ALL SELECT  FOR ITEM=LINE COMPONENT=
 IN RANGE     1 TO    94 STEP     1

  94 LINES (OF   94 DEFINED) SELECTED BY LSEL COMMAND.

ALL SELECT  FOR ITEM=KP  COMPONENT=
 IN RANGE     1 TO    54 STEP     1

  54 KEYPOINTS (OF   54 DEFINED) SELECTED BY KSEL COMMAND.

ALL SELECT  FOR ITEM=ELEM COMPONENT=
 IN RANGE     1 TO  2620 STEP     1

 2620 ELEMENTS (OF  2620 DEFINED) SELECTED BY ESEL COMMAND.

ALL SELECT  FOR ITEM=NODE COMPONENT=
 IN RANGE     1 TO  3517 STEP     1

 3517 NODES (OF  3517 DEFINED) SELECTED BY NSEL COMMAND.

DESTROY ASSOCIATIVITY OF FINITE ELEMENT MODEL AND SOLID MODEL
   NUMBER OF MESH ITEMS DISCONNECTED FROM NODES AND ELEMENTS =    154

ACTIVE COORDINATE SYSTEM SET TO     1 (CYLINDRICAL)

SELECT     FOR ITEM=ENAM COMPONENT=
 IN RANGE    45 TO    45 STEP     1
```

```
 2484 ELEMENTS (OF  2620 DEFINED) SELECTED BY ESEL COMMAND.

SELECT    ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

 3515 NODES (OF  3517 DEFINED) SELECTED FROM
 2484 SELECTED ELEMENTS BY NSLE COMMAND.

RESELECT   FOR ITEM=LOC COMPONENT=Y   BETWEEN -41.000   AND -39.000
 KABS= 0. TOLERANCE= 0.000000E+00

  95 NODES (OF  3517 DEFINED) SELECTED BY NSEL COMMAND.

MODIFY ALL SELECTED NODES IN COORDINATE SYSTEM   1
NEW COORDS=   Y= -39.00

SELECT    ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

 3515 NODES (OF  3517 DEFINED) SELECTED FROM
 2484 SELECTED ELEMENTS BY NSLE COMMAND.

*GET r_o    FROM NODE ITEM=MXLO X   VALUE= 23.0000000

RESELECT   FOR ITEM=LOC COMPONENT=X   BETWEEN 22.900   AND  24.000
 KABS= 0. TOLERANCE= 0.000000E+00

 555 NODES (OF  3517 DEFINED) SELECTED BY NSEL COMMAND.

RESELECT   FOR ITEM=LOC COMPONENT=Y   BETWEEN -66.000   AND -38.000
 KABS= 0. TOLERANCE= 0.000000E+00

  90 NODES (OF  3517 DEFINED) SELECTED BY NSEL COMMAND.

COORDINATE SYSTEM   12 DEFINITION. TYPE= 0 (CARTESIAN)
 XC,YC,ZC= 0.00000E+00 0.00000E+00 0.00000E+00
 ANGLES= -52.00  0.00  0.00 PARAMETERS= 1.000 1.000
 ORIENTATION= 0.62 -0.79 0.00 0.79 0.62 0.00 0.00 0.00 1.00

ACTIVE COORDINATE SYSTEM SET TO   12 (CARTESIAN)

MODIFY ALL SELECTED NODES IN COORDINATE SYSTEM   12
NEW COORDS=   X= 22.38

SELECT    FOR ITEM=TYPE COMPONENT=
 IN RANGE   4 TO   4 STEP   1

  69 ELEMENTS (OF  2620 DEFINED) SELECTED BY ESEL COMMAND.

DELETE ALL SELECTED ELEMENTS.

DELETE ELEMENT TYPES FROM   4 TO   4 BY   1

CURRENT NODAL DOF SET IS UX  UY  UZ  ROTX ROTY ROTZ
```

Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

```
THREE-DIMENSIONAL MODEL

SELECT ALL ENTITIES OF TYPE= ALL  AND BELOW

ALL SELECT   FOR ITEM=VOLU COMPONENT=
 IN RANGE     1 TO     8 STEP     1

   8 VOLUMES (OF    8 DEFINED) SELECTED BY  VSEL  COMMAND.

ALL SELECT   FOR ITEM=AREA COMPONENT=
 IN RANGE     1 TO    52 STEP     1

  52  AREAS (OF   52  DEFINED) SELECTED BY ASEL COMMAND.

ALL SELECT   FOR ITEM=LINE COMPONENT=
 IN RANGE     1 TO    94 STEP     1

  94  LINES (OF   94  DEFINED) SELECTED BY LSEL COMMAND.

ALL SELECT   FOR ITEM=KP   COMPONENT=
 IN RANGE     1 TO    54 STEP     1

  54  KEYPOINTS (OF   54  DEFINED) SELECTED BY  KSEL  COMMAND.

ALL SELECT   FOR ITEM=ELEM COMPONENT=
 IN RANGE     1 TO   2620 STEP     1

 2551  ELEMENTS (OF  2551  DEFINED) SELECTED BY  ESEL  COMMAND.

ALL SELECT   FOR ITEM=NODE COMPONENT=
 IN RANGE     1 TO   3517 STEP     1

 3517  NODES (OF  3517  DEFINED) SELECTED BY  NSEL  COMMAND.


***** ROUTINE COMPLETED *****  CP =      570.773



*** NOTE ***                    CP=   570.781   TIME= 22:00:07
A total of 353 warnings and errors written to ftube.err.

*****  ANSYS SOLUTION ROUTINE  *****

ACEL=   0.00000E+00 0.00000E-00  1.0000

*****  ANSYS SOLVE    COMMAND  *****

*** NOTE ***                    CP=   570.789   TIME= 22:00:07
There is no title defined for this analysis.

*** NOTE ***                    CP=   571.820   TIME= 22:00:08
```

Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

```
The model data was checked and warning messages were found.
Please review output or errors file ( ftube.err ) for these warning
messages.

          SOLUTION OPTIONS

PROBLEM DIMENSIONALITY.............3-D
DEGREES OF FREEDOM...... UX  UY  UZ  ROTX ROTY ROTZ
ANALYSIS TYPE.................STATIC (STEADY-STATE)

*** NOTE ***              CP=   572.055  TIME= 22:00:08
Present time 0 is less than or equal to the previous time.
 Time will default to 1.
** Reordering still in progress **
** Reordering still in progress **

          LOAD STEP OPTIONS

LOAD STEP NUMBER................   1
TIME AT END OF THE LOAD STEP.......... 1.0000
NUMBER OF SUBSTEPS...............   1
STEP CHANGE BOUNDARY CONDITIONS ........  NO
INERTIA LOADS              X       Y       Z
  ACEL............ 0.00000E+00 0.00000E+00  1.0000
PRINT OUTPUT CONTROLS .............NO PRINTOUT
DATABASE OUTPUT CONTROLS............ALL DATA WRITTEN
                                FOR THE LAST SUBSTEP

Element Formation Element= 10 Cum.  Iter.= 1 CP= 573.242
 Time= 1.0000 Load Step= 1 Substep= 1 Equilibrium Iteration= 1.
Element Formation Element= 1810 Cum.  Iter.= 1 CP= 582.734
 Time= 1.0000 Load Step= 1 Substep= 1 Equilibrium Iteration= 1.


     ***** CENTROID, MASS, AND MASS MOMENTS OF INERTIA *****

CALCULATIONS ASSUME ELEMENT MASS AT ELEMENT CENTROID

TOTAL MASS =  86871.

              MOM. OF INERTIA       MOM. OF INERTIA
  CENTROID          ABOUT ORIGIN        ABOUT CENTROID

XC = 0.63009E-02   IXX =  0.1862E+08    IXX =  0.3957E+07
YC = -12.992     IYY =  0.1969E+08   IYY =  0.1969E+08
ZC = 0.00000E+00   IZZ =  0.3831E+08   IZZ =  0.2365E+08
             IXY =  -3448.      IXY = -0.1056E+05
             IYZ =  0.0000E+00   IYZ =  0.0000E+00
             IZX =  0.0000E+00   IZX =  0.0000E+00
ONLY THE X-DIRECTION MASS TERMS ARE USED FOR MASS21   ELEMENTS.
```

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```
*** MASS SUMMARY BY ELEMENT TYPE ***

TYPE    MASS
  5  86871.0

Range of element maximum matrix coefficients in global coordinates
Maximum= 2.061031631E+10 at element 2596.
Minimum= 7637221.94 at element 1754.

 *** ELEMENT MATRIX FORMULATION TIMES
 TYPE NUMBER  ENAME    TOTAL CP  AVE CP

   1  2484  SOLID45    13.250   0.005
   3    30  BEAM4       0.039   0.001
   5    37  MASS21      0.008   0.000
Time at end of element matrix formulation CP= 586.632813.

Estimated number of active DOF= 10452.
Maximum wavefront= 397.

Equation Solution Element= 500 Cum. Iter.= 1 CP= 592.461
 Time= 1.0000 Load Step= 1 Substep= 1 Equilibrium Iteration= 1.
Equation Solution Element= 1920 Cum. Iter.= 1 CP= 601.836
 Time= 1.0000 Load Step= 1 Substep= 1 Equilibrium Iteration= 1.
Time at end of matrix triangularization CP= 605.734375.
Equation solver maximum pivot= 2.1605637E+11 at node 3517 ROTY.
Equation solver minimum pivot= 159079.15 at node 74 UX.
Element Output Element= 900 Cum. Iter.= 1 CP= 611.555
 Time= 1.0000 Load Step= 1 Substep= 1 Equilibrium Iteration= 1.

 *** ELEMENT RESULT CALCULATION TIMES
 TYPE NUMBER  ENAME    TOTAL CP  AVE CP

   1  2484  SOLID45     8.453   0.003
   3    30  BEAM4       0.047   0.002
   5    37  MASS21      0.000   0.000

 *** NODAL LOAD CALCULATION TIMES
 TYPE NUMBER  ENAME    TOTAL CP  AVE CP

   1  2484  SOLID45     0.664   0.000
   3    30  BEAM4       0.008   0.000
   5    37  MASS21      0.008   0.000
*** LOAD STEP   1  SUBSTEP   1 COMPLETED.  CUM ITER =   1
*** TIME =  1.00000      TIME INC =  1.00000     NEW TRIANG MATRIX


 *** PROBLEM STATISTICS
 ACTUAL NO. OF ACTIVE DEGREES OF FREEDOM =  10452
 R.M.S. WAVEFRONT SIZE =  305.2
```

```
*** ANSYS BINARY FILE STATISTICS
 BUFFER SIZE USED= 8192
    13.031 MB WRITTEN ON ELEMENT MATRIX FILE: ftube.emat
     9.063 MB WRITTEN ON ELEMENT SAVED DATA FILE: ftube.esav
    24.563 MB WRITTEN ON TRIANGULARIZED MATRIX FILE: ftube.tri
     4.344 MB WRITTEN ON RESULTS FILE; ftube.rst

FINISH SOLUTION PROCESSING


***** ROUTINE COMPLETED ***** CP =    617.820


*** NOTE ***              CP=   617.828  TIME= 22:01:01
A total of 355 warnings and errors written to ftube.err.

      ***** ANSYS RESULTS INTERPRETATION (POST1) *****

ENTER /SHOW,DEVICE-NAME  TO ENABLE GRAPHIC DISPLAY
ENTER  FINISH          TO LEAVE POST1

*** NOTE ***              CP=   617.828  TIME= 22:01:01
An active coordinate system is not zero.
 RSYS= 0 CSYS= 12 DSYS= 0.

SELECT ALL ENTITIES OF TYPE= ALL  AND BELOW

ALL SELECT   FOR ITEM=VOLU COMPONENT=
 IN RANGE      1 TO      8 STEP      1

   8  VOLUMES (OF     8 DEFINED) SELECTED BY  VSEL  COMMAND.

ALL SELECT   FOR ITEM=AREA COMPONENT=
 IN RANGE      1 TO     52 STEP      1

  52  AREAS (OF    52 DEFINED) SELECTED BY ASEL COMMAND.

ALL SELECT   FOR ITEM=LINE COMPONENT=
 IN RANGE      1 TO     94 STEP      1

  94  LINES (OF    94 DEFINED) SELECTED BY LSEL COMMAND.

ALL SELECT   FOR ITEM=KP   COMPONENT=
 IN RANGE      1 TO     54 STEP      1

  54  KEYPOINTS (OF    54 DEFINED) SELECTED BY  KSEL  COMMAND.

ALL SELECT   FOR ITEM=ELEM COMPONENT=
 IN RANGE      1 TO   2620 STEP      1
```

Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

```
 2551 ELEMENTS (OF 2551 DEFINED) SELECTED BY ESEL COMMAND.

ALL SELECT FOR ITEM=NODE COMPONENT=
 IN RANGE 1 TO 3517 STEP 1

 3517 NODES (OF 3517 DEFINED) SELECTED BY NSEL COMMAND.

***** SUMMATION OF TOTAL FORCES AND MOMENTS IN GLOBAL COORDINATES *****
 FX = -0.4228059E-07
 FY = 0.4213598E-07
 FZ = -86871.00
 MX = 1128610.
 MY = 547.3622
 MZ = -0.1312711E-05

SUMMATION POINT= 0.00000E+00 0.00000E+00 0.00000E+00

DISPLAYS PUT ON PLOT FILE kbasin.plt - VECTOR MODE.

TITLE=
K Basin Pail Ring Lift Analysis

DEVICE VECTOR KEY SET TO 1

HIDDEN DISPLAY (PRECISE) IN WINDOW 1

NUMBER KEY SET TO -1 -1=NONE 0=BOTH 1=COLOR 2=NUMBER

view point for window 1 1.0000 1.0000 1.0000

PRODUCE ELEMENT PLOT IN DSYS = 0

CUMULATIVE DISPLAY NUMBER 1 WRITTEN TO FILE kbasin.plt - VECTOR MODE.
DISPLAY TITLE=
K Basin Pail Ring Lift Analysis

*** NOTE *** CP= 618.758 TIME= 22:01:01
CUMULATIVE DISPLAY NUMBER 1 WRITTEN TO FILE kbasin.plt - VECTOR MODE.
 DISPLAY TITLE= K Basin Pail Ring Lift Analysis.

NUMBER KEY SET TO 2 -1=NONE 0=BOTH 1=COLOR 2=NUMBER

SELECT FOR ITEM=ENAM COMPONENT=
 IN RANGE 45 TO 45 STEP 1

 2484 ELEMENTS (OF 2551 DEFINED) SELECTED BY ESEL COMMAND.

SELECT ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

 3515 NODES (OF 3517 DEFINED) SELECTED FROM
 2484 SELECTED ELEMENTS BY NSLE COMMAND.
```

AUTOMATIC SCALING FOR WINDOW 1
 DISTANCE AND FOCUS POINT AUTOMATICALLY CALCULATED

view point for window 1 1.0000 -1.0000 1.0000

VIEW UP DIRECTION FOR WINDOW 1 IS GCS Z AXIS

ACTIVE COORDINATE SYSTEM SET TO 1 (CYLINDRICAL)

RESELECT FOR ITEM=LOC COMPONENT=Y BETWEEN -161.00 AND -29.000
 KABS= 0. TOLERANCE= 0.000000E+00

2565 NODES (OF 3517 DEFINED) SELECTED BY NSEL COMMAND.

SELECT ONLY ELEMENTS COMPLETELY CONTAINED WITHIN NODE SET.

1821 ELEMENTS (OF 2551 DEFINED) SELECTED FROM
2565 SELECTED NODES BY ESLN COMMAND.

DISPLAY NODAL SOLUTION. ITEM=S COMP=EQV

CUMULATIVE DISPLAY NUMBER 2 WRITTEN TO FILE kbasin.plt - VECTOR MODE.
DISPLAY TITLE=
K Basin Pail Ring Lift Analysis

*** NOTE *** CP= 623.000 TIME= 22:01:06
CUMULATIVE DISPLAY NUMBER 2 WRITTEN TO FILE kbasin.plt - VECTOR MODE.
DISPLAY TITLE= K Basin Pail Ring Lift Analysis.

DISPLAY COORDINATE SYSTEM SET TO 1 (CYLINDRICAL)

LIST ALL SELECTED NODES IN RANGE 2221 TO 2630 STEP 409 DSYS= 1

NODE	X	Y	Z	THXY	THYZ	THZX
2221	23.000	-30.000	22.571	0.00	0.00	0.00
2630	20.625	-30.000	22.505	0.00	0.00	0.00

DISPLAY COORDINATE SYSTEM SET TO 0 (CARTESIAN)

DEFINE A PATH FOR SUBSEQUENT CALCULATIONS THROUGH NODES:
 2221 2630

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

***** POST1 LINEARIZED STRESS LISTING *****
INSIDE NODE = 2221 OUTSIDE NODE = 2630

LOAD STEP 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

```
        ** MEMBRANE **
  SX      SY      SZ      SXY     SYZ     SXZ
-580.5  -34.39  -135.5  -495.1  -521.9  -219.9
  S1      S2      S3      SINT    SEQV
495.5   -139.9  -1106.   1602.   1397.

        ** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
  SX      SY      SZ      SXY     SYZ     SXZ
I -1002.   -2782.   725.8   -2057.   0.1180E+05  6852.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  1002.    2782.  -725.8    2057.  -0.1180E+05 -6852.
  S1      S2      S3      SINT    SEQV
I 0.1217E+05  336.0  -0.1556E+05 0.2773E+05 0.2410E+05
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 0.1556E+05 -336.0  -0.1217E+05 0.2773E+05 0.2410E+05

        ** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
  SX      SY      SZ      SXY     SYZ     SXZ
I -1583.   -2816.   590.3   -2552.   0.1128E+05  6632.
C -580.5   -34.39  -135.5   -495.1  -521.9   -219.9
O  421.6    2747.  -861.3    1562.  -0.1233E+05 -7072.
  S1      S2      S3      SINT    SEQV
I 0.1130E+05  331.6  -0.1544E+05 0.2675E+05 0.2329E+05
C  495.5   -139.9   -1106.   1602.   1397.
O 0.1571E+05 -351.2  -0.1305E+05 0.2876E+05 0.2496E+05

        ** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
  SX      SY      SZ      SXY     SYZ     SXZ
I -7.176   -27.64   27.29   164.2   704.6   376.9
C  23.07    13.26  -10.07  -130.4  -546.0  -291.8
O -105.5    115.3   158.7   118.8   1143.   611.4
  S1      S2      S3      SINT    SEQV
I  875.7   -145.4  -737.8   1614.   1414.
C  573.9    127.5  -675.1   1249.   1096.
O  1458.   -155.0  -1135.   2593.   2268.

        ** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
  SX      SY      SZ      SXY     SYZ     SXZ
I -1590.   -2844.   617.6   -2388.   0.1199E+05  7009.
C -557.5   -21.13  -145.6   -625.5  -1068.   -511.7
O  316.2    2862.  -702.6    1681.  -0.1118E+05 -6461.
  S1      S2      S3      SINT    SEQV    TEMP
I 0.1215E+05  172.9  -0.1614E+05 0.2829E+05 0.2459E+05 0.0000E+00
C  994.9   -7.545   -1712.   2706.   2370.
O 0.1459E-05 -503.0  -0.1161E+05 0.2621E+05 0.2278E+05 0.0000E+00

DISPLAY COORDINATE SYSTEM SET TO    1 (CYLINDRICAL)

LIST ALL SELECTED NODES IN RANGE  2272 TO  2596 STEP  324 DSYS=  1

 NODE    X     Y     Z    THXY  THYZ  THZX
```

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```
2272  23.000  -30.000   20.857    0.00  0.00  0.00
2596  21.000  -30.000   20.808    0.00  0.00  0.00

DISPLAY COORDINATE SYSTEM SET TO  0 (CARTESIAN)

DEFINE A PATH FOR SUBSEQUENT CALCULATIONS THROUGH NODES:
  2272 2596

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND.  DSYS= 0

   ***** POST1 LINEARIZED STRESS LISTING *****
   INSIDE NODE =  2272    OUTSIDE NODE =  2596

LOAD STEP    1  SUBSTEP=    1
TIME=   1.0000      LOAD CASE=  0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

     ** MEMBRANE **
   SX      SY      SZ      SXY     SYZ     SXZ
 -85.87   123.4   -109.4   36.11   -141.8   16.32
   S1      S2      S3      SINT    SEQV
  192.8   -78.97  -185.7   378.6   338.1

     ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
   SX      SY      SZ      SXY     SYZ     SXZ
I -805.1   -2385.   694.7   -1732.   0.1237E+05  7148.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  805.1   2385.   -694.7   1732.   -0.1237E+05 -7148.
   S1      S2      S3      SINT    SEQV
I 0.1304E+05  300.4  -0.1584E+05 0.2888E+05 0.2507E+05
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 0.1584E+05 -300.4  -0.1304E+05 0.2888E+05 0.2507E+05

     ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
   SX      SY      SZ      SXY     SYZ     SXZ
I -891.0   -2262.   585.3   -1696.   0.1223E+05  7164.
C -85.87   123.4   -109.4   36.11   -141.8    16.32
O  719.3   2508.   -804.1   1769.   -0.1251E+05 -7132.
   S1      S2      S3      SINT    SEQV
I 0.1291E+05  238.6  -0.1572E+05 0.2863E+05 0.2485E+05
C  192.8   -78.97   -185.7   378.6    338.1
O 0.1596E+05 -363.8  -0.1318E+05 0.2914E+05 0.2530E+05

     ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
   SX      SY      SZ      SXY     SYZ     SXZ
I -87.16   49.86   -35.67   61.27   -332.3   -208.0
C  88.30   -44.07   34.19   -55.73   289.7    180.8
O  8.675   58.61   -34.08   82.29   -545.0   -343.0
   S1      S2      S3      SINT    SEQV
I  412.0   -103.1   -381.9   793.9   697.6
C  335.4   100.5   -357.5   692.9   610.3
```

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```
O  690.9   -51.34   -606.3    1297.    1127.

        ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
   SX       SY      SZ      SXY      SYZ      SXZ
I -978.2   -2212.   549.6   -1635.   0.1190E+05  6956.
C  2.434    79.34   -75.23  -19.62   148.0     197.1
O  727.9    2567.   -838.2   1851.   -0.1306E+05 -7475.
   S1       S2      S3      SINT     SEQV      TEMP
I 0.1253E+05  132.6   -0.1531E+05 0.2784E+05 0.2416E+05 0.0000E+00
C  222.1    67.78   -283.3    505.5    448.7
O 0.1665E+05 -414.2   -0.1378E+05 0.3043E+05 0.2642E+05 0.0000E+00

DISPLAY COORDINATE SYSTEM SET TO    1 (CYLINDRICAL)

LIST ALL SELECTED NODES IN RANGE  1847  TO  2392  STEP   545  DSYS=  1

 NODE     X        Y        Z       THXY   THYZ   THZX
 1847   23.000   -30.000   26.000    0.00   0.00   0.00
 2392   21.000   -30.000   26.000    0.00   0.00   0.00

DISPLAY COORDINATE SYSTEM SET TO    0 (CARTESIAN)

DEFINE A PATH FOR SUBSEQUENT CALCULATIONS THROUGH NODES:
   1847  2392

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND.  DSYS= 0

     ***** POST1 LINEARIZED STRESS LISTING *****
    INSIDE NODE =  1847    OUTSIDE NODE =  2392

 LOAD STEP    1  SUBSTEP=    1
 TIME=   1.0000       LOAD CASE=  0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

        ** MEMBRANE **
   SX       SY      SZ      SXY      SYZ      SXZ
 -7607.    3503.   363.6   -5999.   -173.8   -111.5
   S1       S2      S3      SINT     SEQV
  6126.    364.1   -0.1023E+05 0.1636E+05 0.1437E+05

        ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
   SX       SY      SZ      SXY      SYZ      SXZ
I -1499.   -901.0   291.0   -1803.   4276.    2445.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  1499.    901.0   -291.0   1803.   -4276.   -2445.
   S1       S2      S3      SINT     SEQV
I  4107.    207.5   -6423.   0.1053E+05  9221.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  6423.    -207.5  -4107.   0.1053E+05  9221.

        ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
```

```
   SX      SY      SZ      SXY     SYZ     SXZ
I -9106.   2602.   654.6   -7802.  4102.   2334.
C -7607.   3503.   363.6   -5999.  -173.8  -111.5
O -6108.   4404.   72.61   -4196.  -4449.  -2557.
   S1      S2      S3      SINT    SEQV
I  7612.   613.4   -0.1407E+05 0.2169E+05 0.1917E+05
C  6126.   364.1   -0.1023E+05 0.1636E+05 0.1437E+05
O  7597.   92.87   -9321.  0.1692E+05 0.1468E+05

      ** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
   SX      SY      SZ      SXY     SYZ     SXZ
I  876.0   -973.1  -48.63  567.5   -78.35  -45.63
C -746.5   822.2   41.84   -489.3  -6.043  -3.962
O  1430.   -1641.  -76.63  877.8   -816.9  -479.6
   S1      S2      S3      SINT    SEQV
I  1040.   -48.89  -1137.  2177.   1886.
C  962.4   41.85   -886.6  1849.   1601.
O  1906.   -87.07  -2106.  4013.   3475.

      ** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
   SX      SY      SZ      SXY     SYZ     SXZ
I -8230.   1629.   605.9   -7235.  4023.   2288.
C -8353.   4325.   405.4   -6488.  -179.9  -115.5
O -4678.   2763.   -4.011  -3318.  -5266.  -3037.
   S1      S2      S3      SINT    SEQV    TEMP
I  6640.   552.4   -0.1319E+05 0.1983E+05 0.1759E+05 0.0000E+00
C  7059.   405.9   -0.1109E+05 0.1815E+05 0.1590E+05
O  6886.   29.11   -8834.  0.1572E+05 0.1365E+05 0.0000E+00

DISPLAY COORDINATE SYSTEM SET TO    1 (CYLINDRICAL)

LIST ALL SELECTED NODES IN RANGE   129 TO   742 STEP   613 DSYS= 1

 NODE    X       Y        Z       THXY   THYZ   THZX
  129  23.000  -160.00  26.000    0.00   0.00   0.00
  742  21.000  -160.00  26.000    0.00   0.00   0.00

DISPLAY COORDINATE SYSTEM SET TO    0 (CARTESIAN)

DEFINE A PATH FOR SUBSEQUENT CALCULATIONS THROUGH NODES:
   129  742

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND. DSYS= 0

    ***** POST1 LINEARIZED STRESS LISTING *****
    INSIDE NODE =   129   OUTSIDE NODE =   742

LOAD STEP   1  SUBSTEP=   1
TIME=   1.0000     LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.
```

```
        ** MEMBRANE **
   SX      SY      SZ      SXY      SYZ      SXZ
 -5907.   3233.   524.1   8449.   -317.2    27.93
   S1      S2      S3      SINT     SEQV
 8277.    518.5  -0.1095E+05 0.1922E+05 0.1675E+05

        ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
    SX      SY      SZ      SXY      SYZ      SXZ
 I -1151.  -4246.   678.9   3276.    5389.   -1959.
 C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
 O  1151.   4246.  -678.9  -3276.   -5389.    1959.
    S1      S2      S3      SINT     SEQV
 I  4146.   596.9  -9460.   0.1361E+05 0.1222E+05
 C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
 O  9460.  -596.9  -4146.   0.1361E+05 0.1222E+05

        ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
    SX      SY      SZ      SXY      SYZ      SXZ
 I -7058.  -1013.   1203.   0.1173E+05 5072.  -1931.
 C -5907.   3233.   524.1   8449.   -317.2    27.93
 O -4756.   7478.  -154.8   5173.   -5707.    1986.
    S1      S2      S3      SINT     SEQV
 I  9192.   1263.  -0.1732E+05 0.2651E+05 0.2357E+05
 C  8277.   518.5  -0.1095E+05 0.1922E+05 0.1675E+05
 O 0.1141E+05 -179.6  -8659.  0.2007E+05 0.1745E+05

        ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
    SX      SY      SZ      SXY      SYZ      SXZ
 I  668.7  -895.9  -128.2  -1043.   -102.5    44.28
 C -560.1   769.4   116.5   889.1   -6.203   -2.096
 O  1181.  -1382.  -145.3  -1702.   -1052.    408.8
    S1      S2      S3      SINT     SEQV
 I  1195.  -129.8  -1421.   2616.    2266.
 C  1215.   116.4  -1006.   2220.    1923.
 O  2327.  -180.2  -2493.   4820.    4176.

        ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
    SX      SY      SZ      SXY      SYZ      SXZ
 I -6389.  -1909.   1075.   0.1068E+05 4970.  -1886.
 C -6467.   4002.   640.5   9338.   -323.4    25.83
 O -3576.   6097.  -300.1   3472.   -6759.    2395.
    S1      S2      S3      SINT     SEQV     TEMP
 I  7960.   1119.  -0.1630E+05 0.2426E+05 0.2167E+05 0.0000E+00
 C  9481.   635.3  -0.1194E+05 0.2142E+05 0.1865E+05
 O 0.1058E+05 -306.3  -8056.  0.1864E+05 0.1622E+05 0.0000E+00

 DISPLAY COORDINATE SYSTEM SET TO    1 (CYLINDRICAL)

 LIST ALL SELECTED NODES IN RANGE   231 TO   912 STEP   681 DSYS=  1

  NODE     X       Y       Z      THXY   THYZ   THZX
   231   23.000  -160.00  24.286   0.00   0.00   0.00
```

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Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

```
 912  21.000  -160.00   24.260     0.00  0.00   0.00

DISPLAY COORDINATE SYSTEM SET TO     0 (CARTESIAN)

DEFINE A PATH FOR SUBSEQUENT CALCULATIONS THROUGH NODES:
   231  912

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND.  DSYS=  0

     ***** POST1 LINEARIZED STRESS LISTING *****
     INSIDE NODE =   231     OUTSIDE NODE =    912

 LOAD STEP     1  SUBSTEP=     1
 TIME=   1.0000        LOAD CASE=  0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

        ** MEMBRANE **
   SX        SY        SZ        SXY       SYZ       SXZ
 -1014.    -1129.     122.4     1802.     -879.5     192.2
   S1        S2        S3        SINT      SEQV
  1028.     12.69    -3062.     4090.     3689.

        ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
   SX        SY        SZ        SXY       SYZ       SXZ
I -533.2    -5151.     392.5     2619.    0.1423E+05 -5183.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  533.2     5151.    -392.5    -2619.   -0.1423E+05  5183.
   S1        S2        S3        SINT      SEQV
I 0.1257E+05  609.8  -0.1847E+05 0.3104E+05 0.2712E+05
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 0.1847E+05 -609.8   -0.1257E+05 0.3104E+05 0.2712E+05

        ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
   SX        SY        SZ        SXY       SYZ       SXZ
I -1548.    -6280.     514.9     4420.    0.1335E+05 -4991.
C -1014.    -1129.     122.4     1802.    -879.5      192.2
O -481.0     4022.    -270.1    -816.9   -0.1511E+05  5375.
   S1        S2        S3        SINT      SEQV
I 0.1103E+05  767.7  -0.1911E+05 0.3014E+05 0.2655E+05
C  1028.     12.69    -3062.     4090.     3689.
O 0.1808E+05 -490.7   -0.1432E+05 0.3240E+05 0.2816E+05

        ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
   SX        SY        SZ        SXY       SYZ       SXZ
I  35.60    -96.44     6.536    -261.1    -410.3     160.0
C -12.28     87.01     2.268     217.0     333.9    -129.7
O  230.0    -113.0     67.51    -501.1    -858.1     338.7
   S1        S2        S3        SINT      SEQV
I  541.0    -117.2    -478.1     1019.     894.9
C -399.4     110.0    -432.4     831.8     731.4
O  1199.    -106.7    -908.2     2108.     1843.
```

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Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

```
      ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
   SX       SY       SZ       SXY       SYZ       SXZ
I -1512.   -6377.   521.4    4159.    0.1294E+05 -4831.
C -1027.   -1042.   124.6    2019.    -545.5     62.50
O -251.0    3909.   -202.6   -1318.   -0.1597E+05 5714.
   S1       S2       S3       SINT      SEQV      TEMP
I 0.1062E+05  617.2  -0.1861E+05 0.2923E+05 0.2573E+05 0.0000E+00
C  1108.    58.80   -3111.    4219.    3804.
O 0.1915E+05 -614.9  -0.1508E+05 0.3422E+05 0.2976E+05 0.0000E+00

DISPLAY COORDINATE SYSTEM SET TO    1 (CYLINDRICAL)

LIST ALL SELECTED NODES IN RANGE   333 TO   861 STEP   528 DSYS=  1

 NODE    X        Y        Z      THXY  THYZ  THZX
  333  23.000  -160.00   20.857    0.00  0.00  0.00
  861  21.000  -160.00   20.808    0.00  0.00  0.00

DISPLAY COORDINATE SYSTEM SET TO    0 (CARTESIAN)

DEFINE A PATH FOR SUBSEQUENT CALCULATIONS THROUGH NODES:
    333  861

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND.  DSYS=  0

    ***** POST1 LINEARIZED STRESS LISTING *****
    INSIDE NODE =   333    OUTSIDE NODE =   861

 LOAD STEP    1  SUBSTEP=    1
 TIME=   1.0000       LOAD CASE=  0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

      ** MEMBRANE **
   SX       SY       SZ       SXY       SYZ       SXZ
 49.17     356.0    202.7    -89.04    -343.9     162.0
   S1       S2       S3       SINT      SEQV
 678.5     42.77   -113.5    792.0     726.6

      ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
   SX       SY       SZ       SXY       SYZ       SXZ
I -624.6   -6017.   -294.8    2703.    0.1426E+05 -5234.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  624.6    6017.    294.8   -2703.   -0.1426E+05  5234.
   S1       S2       S3       SINT      SEQV
I 0.1186E+05  483.7  -0.1928E+05 0.3114E+05 0.2730E+05
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 0.1928E-05 -483.7  -0.1186E-05 0.3114E+05 0.2730E+05

      ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
   SX       SY       SZ       SXY       SYZ       SXZ
```

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```
I -575.4   -5661.   -92.14    2614.   0.1392E+05 -5073.
C  49.17    356.0    202.7   -89.04   -343.9     162.0
O  673.8    6372.    497.5   -2792.   -0.1460E+05 5396.
   S1       S2       S3      SINT     SEQV
I 0.1177E+05  510.1  -0.1860E+05 0.3037E+05 0.2659E+05
C  678.5    42.77   -113.5    792.0    726.6
O 0.1996E+05 -457.0  -0.1196E+05 0.3192E+05 0.2800E+05

        ** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
   SX       SY       SZ      SXY      SYZ      SXZ
I -103.8    184.7    59.17   -72.21   -403.3    142.6
C  102.7   -162.2   -42.38    62.65    349.7.  -125.1
O -18.55    268.4    173.9   -132.9   -694.2    233.2
   S1       S2       S3      SINT     SEQV
I  563.0   -115.5   -307.4    870.4    792.1
C  273.2    110.4   -485.4    758.6    691.7
O  982.8   -69.48   -489.7    1472.    1314.

        ** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
   SX       SY       SZ      SXY      SYZ      SXZ
I -679.3   -5476.   -32.97    2542.   0.1351E+05 -4930.
C  151.9    193.8    160.3   -26.39    5.800     36.85
O  655.2    6641.    671.4   -2925.   -0.1530E+05 5630.
   S1       S2       S3      SINT     SEQV     TEMP
I 0.1146E+05 393.9  -0.1804E+05 0.2951E+05 0.2582E+05 0.0000E+00
C  210.2    183.8    112.0    98.13    87.95
O 0.2094E+05 -526.6  -0.1244E+05 0.3338E+05 0.2930E+05 0.0000E+00

DISPLAY COORDINATE SYSTEM SET TO    1 (CYLINDRICAL)

LIST ALL SELECTED NODES IN RANGE  1367 TO  1486 STEP  119 DSYS= 1

 NODE    X        Y        Z      THXY  THYZ  THZX
 1367  20.000  -160.00  6.3900    0.00  0.00  0.00
 1486  22.375  -160.00  6.7500    0.00  0.00  0.00

DISPLAY COORDINATE SYSTEM SET TO    0 (CARTESIAN)

DEFINE A PATH FOR SUBSEQUENT CALCULATIONS THROUGH NODES:
   1367  1486

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND.  DSYS= 0

     ***** POST1 LINEARIZED STRESS LISTING *****
     INSIDE NODE =  1367   OUTSIDE NODE =  1486

LOAD STEP   1 SUBSTEP=   1
TIME=  1.0000      LOAD CASE=  0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

        ** MEMBRANE **
```

Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

```
  SX      SY       SZ      SXY      SYZ      SXZ
 1146.   -4760.   860.1   -792.8    658.2   -301.0
  S1      S2       S3      SINT     SEQV
 1504.   672.4    -4930.   6433.    6061.

        ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
  SX      SY       SZ      SXY      SYZ      SXZ
I -819.4  -0.1003E+05 -1645.  2069.  -8455.  3117.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 819.4   0.1003E+05 1645.  -2069.   8455.  -3117.
  S1      S2       S3      SINT     SEQV
I 4154.   -608.0   -0.1604E+05 0.2020E+05 0.1829E+05
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 0.1604E+05 608.0  -4154.  0.2020E+05 0.1829E+05

        ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
  SX      SY       SZ      SXY      SYZ      SXZ
I 326.6   -0.1479E+05 -784.6  1276.  -7797.   2816.
C 1146.   -4760.   860.1   -792.8   658.2   -301.0
O 1966.   5274.    2505.   -2862.   9113.   -3418.
  S1      S2       S3      SINT     SEQV
I 3940.   -635.5   -0.1856E+05 0.2250E+05 0.2059E+05
C 1504.   672.4    -4930.   6433.    6061.
O 0.1464E+05 519.0  -5412.  0.2005E+05 0.1784E+05

        ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
  SX      SY       SZ      SXY      SYZ      SXZ
I 39.71   -959.9   -333.7  -504.1   456.3   -169.1
C -81.94  842.7    198.3   440.1    -335.1   117.0
O 159.9   -1212.   -115.4  -612.8   380.2   -131.2
  S1      S2       S3      SINT     SEQV
I 414.4   -358.3   -1310.  1724.    1496.
C 1102.   221.7    -364.3  1466.    1278.
O 509.5   -161.4   -1515.  2025.    1787.

        ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
  SX      SY       SZ      SXY      SYZ      SXZ
I 366.3   -0.1575E+05 -1118.  772.2  -7341.   2647.
C 1064.   -3917.   1058.   -352.7   323.1   -183.9
O 2125.   4062.    2389.   -3475.   9494.   -3549.
  S1      S2       S3      SINT     SEQV     TEMP
I 3479.   -1027.   -0.1896E+05 0.2244E+05 0.2056E+05 0.0000E+00
C 1289.   877.4    -3961.  5250.    5057.
O 0.1471E+05 180.8  -6315.  0.2103E+05 0.1865E+05 0.0000E+00

DISPLAY COORDINATE SYSTEM SET TO    1 (CYLINDRICAL)

LIST ALL SELECTED NODES IN RANGE  1373 TO  1492 STEP  119 DSYS=  1

 NODE    X        Y        Z       THXY   THYZ   THZX
 1373  20.000  -130.00   6.3900   0.00   0.00   0.00
 1492  22.375  -130.00   6.7500   0.00   0.00   0.00
```

Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

```
DISPLAY COORDINATE SYSTEM SET TO     0 (CARTESIAN)

DEFINE A PATH FOR SUBSEQUENT CALCULATIONS THROUGH NODES:
   1373  1492

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND.  DSYS= 0

    ***** POST1 LINEARIZED STRESS LISTING *****
    INSIDE NODE =  1373    OUTSIDE NODE =  1492

 LOAD STEP   1 SUBSTEP=   1
 TIME=  1.0000     LOAD CASE= 0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

      ** MEMBRANE **
   SX      SY      SZ      SXY     SYZ     SXZ
  3316.   -1474.   446.1   -419.9   9.073   8.458
   S1      S2      S3      SINT    SEQV
  3353.   446.1   -1510.   4863.   4238.

      ** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
   SX      SY      SZ      SXY     SYZ     SXZ
I  5315.   552.2   1411.   -2029.  -7795.   9465.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -5315.   -552.2  -1411.   2029.   7795.   -9465.
   S1      S2      S3      SINT    SEQV
I 0.1596E+05  509.3   -9191.   0.2515E-05 0.2197E+05
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  9191.   -509.3  -0.1596E+05 0.2515E+05 0.2197E+05

      ** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
   SX      SY      SZ      SXY     SYZ     SXZ
I  8632.   -921.7   1857.   -2449.  -7786.   9474.
C  3316.   -1474.   446.1   -419.9   9.073   8.458
O -1999.   -2026.   -964.5   1609.   7804.   -9457.
   S1      S2      S3      SINT    SEQV
I 0.1770E+05  674.1   -8811.   0.2652E-05 0.2327E+05
C  3353.   446.1   -1510.   4863.   4238.
O 0.1006E+05 -435.7  -0.1461E+05 0.2467E+05 0.2144E+05

      ** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
   SX      SY      SZ      SXY     SYZ     SXZ
I  993.2   -635.4   -27.00   147.8   471.2   -545.9
C -900.8   600.9    9.365   -119.7  -358.9   403.4
O  1341.   -907.5   19.10    157.7   430.4   -475.4
   S1      S2      S3      SINT    SEQV
I  1232.   74.52   -975.6   2207.   1912.
C  818.8   -55.31  -1054.   1873.   1623.
O  1494.   78.64   -1120.   2615.   2267.
```

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Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

```
      ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
   SX      SY      SZ      SXY     SYZ     SXZ
I  9625.   -1557.  1830.   -2301.  -7314.  8928.
C  2416.   -872.9  455.4   -539.6  -349.8  411.8
O  -657.9  -2934.  -945.4  1767.   8234.   -9932.
   S1      S2      S3      SINT    SEQV    TEMP
I 0.1743E+05  869.3  -8407.  0.2584E+05 0.2267E+05 0.0000E+00
C  2602.   410.8   -1015.  3617.   3156.
O 0.1091E+05 -279.0  -0.1517E+05 0.2607E+05 0.2266E+05 0.0000E+00

DISPLAY COORDINATE SYSTEM SET TO    1  (CYLINDRICAL)

LIST ALL SELECTED NODES IN RANGE  3082 TO  3201 STEP  119 DSYS=  1

 NODE    X       Y        Z      THXY   THYZ   THZX
 3082  20.000  -45.000  6.3900   0.00   0.00   0.00
 3201  22.375  -45.000  6.7500   0.00   0.00   0.00

DISPLAY COORDINATE SYSTEM SET TO    0  (CARTESIAN)

DEFINE A PATH FOR SUBSEQUENT CALCULATIONS THROUGH NODES:
   3082  3201

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND.  DSYS=  0

    ***** POST1 LINEARIZED STRESS LISTING *****
    INSIDE NODE =  3082   OUTSIDE NODE =  3201

 LOAD STEP    1  SUBSTEP=   1
 TIME=   1.0000      LOAD CASE=  0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

      ** MEMBRANE **
   SX      SY      SZ      SXY     SYZ     SXZ
  2926.   -2054.   463.8   408.5   240.6   229.0
   S1      S2      S3      SINT    SEQV
  2984.   458.5   -2106.   5090.   4408.

      ** BENDING **  I=INSIDE C=CENTER O=OUTSIDE
   SX      SY      SZ      SXY     SYZ     SXZ
I  3497.   -700.0  926.7   1137.   -9210.  -9286.
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O  -3497.  700.0   -926.7  -1137.  9210.   9286.
   S1      S2      S3      SINT    SEQV
I 0.1500E+05  261.1  -0.1154E+05 0.2654E+05 0.2303E+05
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O 0.1154E+05 -261.1  -0.1500E+05 0.2654E+05 0.2303E+05

      ** MEMBRANE PLUS BENDING **  I=INSIDE C=CENTER O=OUTSIDE
   SX      SY      SZ      SXY     SYZ     SXZ
I  6423.   -2754.  1390.   1546.   -8969.  -9057.
```

```
C  2926.   -2054.   463.8    408.5    240.6    229.0
O  -571.3  -1354.   -462.8   -728.9   9450.    9515.
   S1        S2      S3       SINT     SEQV
I 0.1593E+05  377.1   -0.1125E+05 0.2718E+05 0.2362E+05
C  2984.    458.5   -2106.    5090.    4408.
O 0.1235E+05 -236.5   -0.1451E+05 0.2686E+05 0.2328E+05

        ** PEAK **  I=INSIDE C=CENTER O=OUTSIDE
   SX       SY       SZ       SXY      SYZ      SXZ
I  956.3   -790.1   -83.09   -8.789   551.9    540.9
C  -877.5   729.3    46.03   -2.945   -417.7   -400.1
O  1311.   -1088.   -16.65    21.06    497.8    470.4
   S1       S2       S3       SINT     SEQV
I  1210.    1.856   -1129.    2340.    2026.
C  944.0   -6.025   -1040.    1984.    1719.
O  1473.    26.55   -1293.    2766.    2396.

        ** TOTAL **  I=INSIDE C=CENTER O=OUTSIDE
   SX       SY       SZ       SXY      SYZ      SXZ
I  7379.   -3544.    1307.    1537.   -8417.   -8516.
C  2048.   -1325.    509.8    405.5   -177.1   -171.1
O  739.6   -2442.   -479.5   -707.9    9948.    9985.
   S1       S2       S3       SINT     SEQV     TEMP
I 0.1554E+05  489.1   -0.1089E+05 0.2642E+05 0.2296E+05 0.0000E+00
C  2119.    500.0   -1386.    3505.    3038.
O 0.1318E+05 -153.4   -0.1521E+05 0.2839E+05 0.2460E+05 0.0000E+00

DISPLAY COORDINATE SYSTEM SET TO   1 (CYLINDRICAL)

LIST ALL SELECTED NODES IN RANGE  2184 TO  2474 STEP  290 DSYS= 1

 NODE     X        Y        Z       THXY   THYZ   THZX
 2184   22.550   -44.860   23.714    0.00   0.00   0.00
 2474   21.000   -45.000   23.680    0.00   0.00   0.00

DISPLAY COORDINATE SYSTEM SET TO   0 (CARTESIAN)

DEFINE A PATH FOR SUBSEQUENT CALCULATIONS THROUGH NODES:
   2184  2474

PRINT LINEARIZED STRESS THROUGH A SECTION DEFINED BY LPATH COMMAND.  DSYS= 0

     ***** POST1 LINEARIZED STRESS LISTING *****
     INSIDE NODE =  2184   OUTSIDE NODE =  2474

 LOAD STEP   1  SUBSTEP=   1
 TIME=   1.0000      LOAD CASE=  0

THE FOLLOWING X,Y,Z STRESSES ARE IN GLOBAL COORDINATES.

        ** MEMBRANE **
   SX       SY       SZ       SXY      SYZ      SXZ
```

Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

```
-3637.   414.0   -17.31   -1318.   -1045.   -606.1
  S1      S2      S3      SINT     SEQV
1361.   -384.1   -4218.   5580.    4944.

      ** BENDING ** I=INSIDE C=CENTER O=OUTSIDE
   SX       SY       SZ      SXY      SYZ      SXZ
I 1528.   -1088.    1616.   20.35    9201.    0.1008E+05
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
O -1528.   1088.   -1616.   -20.35   -9201.   -0.1008E+05
   S1       S2       S3      SINT     SEQV
I 0.1470E+05 95.24  -0.1274E+05 0.2744E+05 0.2378E+05
C 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E-00 0.0000E+00
O 0.1274E+05 -95.24  -0.1470E+05 0.2744E+05 0.2378E+05

      ** MEMBRANE PLUS BENDING ** I=INSIDE C=CENTER O=OUTSIDE
   SX       SY       SZ      SXY      SYZ      SXZ
I -2109.   -673.8    1599.   -1297.    8156.    9470.
C -3637.    414.0   -17.31   -1318.   -1045.   -606.1
O -5166.    1502.   -1634.   -1338.   -0.1025E+05 -0.1068E+05
   S1       S2       S3      SINT     SEQV
I 0.1211E+05 0.5126  -0.1329E+05 0.2540E+05 0.2200E+05
C 1361.    -384.1   -4218.    5580.    4944.
O 0.1275E+05 -416.6  -0.1763E+05 0.3037E+05 0.2638E-05

      ** PEAK ** I=INSIDE C=CENTER O=OUTSIDE
   SX       SY       SZ      SXY      SYZ      SXZ
I -550.5    195.6   -231.3   -120.9   -470.6   -362.5
C 378.6    -134.0    159.8    82.16    337.7    270.9
O -536.7    188.8   -402.3   -119.4   -943.0   -875.8
   S1       S2       S3      SINT     SEQV
I 508.6    -178.7   -916.0    1425.    1234.
C 654.7     115.0   -365.2    1020.    883.7
O 1021.    -106.8   -1665.    2686.    2336.

      ** TOTAL ** I=INSIDE C=CENTER O=OUTSIDE
   SX       SY       SZ      SXY      SYZ      SXZ
I -2660.   -478.1    1368.   -1418.    7685.    9107.
C -3259.    280.0    142.5   -1236.   -707.1   -335.2
O -5702.    1691.   -2036.   -1457.   -0.1119E+05 -0.1156E+05
   S1       S2       S3      SINT     SEQV     TEMP
I 0.1126E+05 18.89  -0.1305E+05 0.2432E+05 0.2108E+05 0.0000E+00
C 1055.    -169.2   -3722.    4777.    4298.
O 0.1375E+05 -509.1  -0.1929E+05 0.3304E+05 0.2870E+05 0.0000E+00

DISPLAYS PUT ON PLOT FILE xxx          - RASTER MODE.

/SHOW SET WITH DRIVER NAME= WIN32 , RASTER MODE, GRAPHIC PLANES = 8

HIDDEN DISPLAY (FACE SORT) IN WINDOW 1
```

APPENDIX C
List of Files on 3.5" Diskette

There a a total of 2 pages in Appendix C.

NAC INTERNATIONAL	Performed by: MY	Date: 11-11-96	Calculation No. 457-2003.3 Revision 0
	Checked by: JRO	Date: 11-11-96	Page C1 of 2

Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

```
 Volume in drive A is EF4572003_3
 Volume Serial Number is 0000-0000

 Directory of A:\

07/17/96  03:25p            1,242 MAS21.MAC
11/06/96  02:57p              421 R_BEAM.MAC
11/07/96  09:59p            3,588 k_pail.mac
11/01/96  01:20p              100 MABBR.MAC
11/07/96  05:48p              577 NDIS.MAC
11/07/96  09:36p              863 TEST1.MAC
11/07/96  10:01p           75,593 kbasl.out
              15 File(s)     828,116 bytes
                             627,200 bytes free
```

APPENDIX D
ANSYS Software Verification

There a a total of 12 pages in Appendix D.

Provided in Attachment D is the software verification package for ANSYS 5.2 on DEC-ALPHA XL266 Computer Serial No. 02207. The verification test runs are listed in a table provided on page 11. Due to the enormous number output pages, actual computer run documentation has not been included with this appendix. Computer run documentation is maintained in files located at NAC International in Norcross, Georgia.

NAC INTERNATIONAL	Performed by: MY	Date: 11-11-96	Calculation No. 457-2003.3 Revision 0
	Checked by: JRO	Date: 11-11-96	Page D1 of 12

Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

NAC INTERNATIONAL

Work Request and Report

Date of Request: 11-Mar-96	Work Request Log No.: 1008
Subject/Project: UMS Design, Analysis and Licensing	Requested By: Norm Meinert

Description of Work to be Performed:

Complete structural and thermal verification calculations for each element type expected to be used during the UMS cask system design analysis and the checking of other partners analyses. Evaluate according to NAC Quality Assurance Procedure Manual, the agreement of the ANSYS Revision 5.2 solutions generated on NAC computer platforms to the results in the ANSYS Revision 5.2 Verification Manual. Perform evaluation using the same input data as in the ANSYS in the ANSYS Revision 5.2 Verification Manual.

Man-hours
ADM @ 32
TAK @ 32
TAD @ 4

To be performed with 5.2 Software on New Computers. Schedule slips until hardware & Software is operational.

Requested Completion Date: 29-Mar-96

Reference Codes/Specifications:

EDS Document NO. 850-S-01 - UMS™ Design Specification, Dated January 23, 1996

QAM 22.1 - Software Control, Rev 2, Dated Feburary 15, 1995

	Estimated Charges	Budget Charges (optional)	Actual Work Charges	Actual Review Charges
Work Man-hours (hr.)	58			
Review Man-hours (hr.)	10			
Computer (SUA) (if required)				
Other (if required)				
Complete Date:				

Charge Number: EA7901006 - ANSYS 5.2 computer code verification

Functional Manager Approval: [signature] **Project Manager Approval:** W.Jt. [signature]

Results Synopsis (Complete and Detailed work Attached)

Performed By:	Independent Review By:	Approved by Functional Manager:	Approved by Project Manager:
TAK	ADM	[signature]	[signature] Norm Meinert
Date: ~~5/10/96~~ 6/10/96 TAK	Date: ~~5/15/96~~ 6/11/96 ADM	Date: 6/28/96	Date: 16 SEP 96

Rev. 4, 12-7-89

c:\ums-proj\workreq\1008.doc

NAC INTERNATIONAL	Calculation No. 457-2003.3 Revision 0
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Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

DESIGN REVIEW CHECKLIST

Work Request Number: 10060

Scope of Analysis File: ANSYS Verification

Review Methodology: Check of Calculations: ✓
Alternate Analysis:
Others (explain):

Confirm that the Work Request and Report Includes:

1. Statement of Purpose ✓
2. Defined Method of Analysis ✓
3. Listing of Assumptions ✓
4. Detailed Analysis Record ✓
5. Statement of Conclusions with appropriate recommendations as applicable ✓

Step	Activities	Verification Yes	No	N/A	Comments
1	For the scope of the defined analyses: • Are the required input data complete? • Material Properties • Geometry (Drawing Reference) • Loading/Source Term — If a supporting analysis is required to define the load state, has it been verified? • Are Boundary conditions acceptable?	✓			
2	Is the method of analysis adequate for the defined scope?	✓			
3	Is the worst case loading/configuration documented?			✓	
4	Are the acceptance criteria defined and complete?	✓			
5	Has all concurrent loading been considered?			✓	
6	Are analyses consistent with previous WRR for method and approach?			✓	
7	Are the records for Input and Output complete?			✓	
8	Is traceability to validated software complete?			✓	
9	Is the Statement of Conclusions and recommendations complete and acceptable for the project and objectives of the defined purpose?			✓	

Anthony D. Moore — 6/11/96 ADM
[signature] — ~~5/16/96~~

Reviewer (Name/Signature) — Date

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Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

COMPUTER RESOURCES MANUAL

Category: (1) 2 (Circle Applicable Category) Project No:

Computer Program Name: Ansys, Version 5.2

Author: Ansys, Inc

Responsible Program Engineer: N/A

Hardware System(s) where installed:

DEC - Alpha XL266
(Serial no 02207)

Program Description:

A general purpose finite element code applicable to problems in statics, dynamics, heat transfer; magnetics, fluidflow and acoustics.

User's Guide Document No: N/A.

Approved By:

[signature]

Manager, Design and Analysis

NAC INTERNATIONAL

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Revision 0
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CERTIFICATE OF VERIFICATION/VALIDATION

✓ Verification ____ Validation

Title of Program: ANSYS

Revision/Version: 5.2 Level: ____

Origin of Program: ANSYS, INC, HOUSTON, PA.

Brief Description of Program: ANSYS IS A GENERAL PURPOSE FINITE ELEMENT CODE APPLICABLE TO PROBLEMS IN STATICS, DYNAMICS, HEAT TRANSFER, MAGNETICS, FLUID FLOW, ACOUSTICS,

Tested For Which Application: STRUCTURAL + THERMAL

Method Used To Verify/Validate Program: USED UNEDITED INPUT DATA FROM THE ANSYS VERIFICATION ~~MANUAL~~ MANUAL TO OBTAIN ANSYS SOLUTIONS AND THEN COMPARED RESULTS TO THOSE IN THE ANSYS VERIF. MANUAL FOR AGREEMENT.

References/Documents To Support Verification/Validation

1. ANSYS VERIFICATION MANUAL (REV. 5.2)
2. ANSYS USERS MANUAL, VOL III (REV. 5.2
3. UMD NUMBER UMD-1006

Title of User's Manual: ANSYS USERS MANUAL

Description of Benchmark Tests/Alternate Calculations: N/A

Performed By: [signature] Date: ~~5~~ 6/10/96 TJ

Checked By: [signature] Date: ~~5/15/96~~ 6/11/96

Approved By: [signature] Date: 6/28/96

Manager, Design and Analysis

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ANSYS, REVISION 5.2, COMPUTER CODE VERIFICATION ON DEC-ALPHA XL-266 COMPUTER; SERIAL NO: 02207

Prepared By: TS Date: 06/10/1996 WRR No:1006a

Checked By: ADM Date: 6/11/96 Page 1 of 543

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Prepared By: [signature] Date: 06/10/1996 WRK No:1006a

Checked By: ADM Date: 6/11/96 Page 2 of 543

NAC INTERNATIONAL

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Revision 0

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1.0 OVERVIEW

ANSYS, Revision 5.2 (ANSYS), an unpublished, general purpose finite element computer code developed by ANSYS, Inc., is currently installed on two DEC-ALPHA, XL-266 computer workstations serial numbers 02207 and 02209. ANSYS is delievered to NAC *precompiled, with inaccessible source codes and sufficiently thorough guidelines on installation and computer hardware requirements.* The ANSYS code on DEC-ALPHA, XL-266 computer platform serial number 02207 is verified in this work request for structural and thermal disciplines in accordance with NAC International Quality Assurance procedures.

2.0 OBJECTIVE

ANSYS, Inc. documented the verification of a wide range of ANSYS elements and capabilities in the ANSYS Verification Manual (Ref. 1) for straightforward problems with classical or readily-available theoretical solutions. The verification of the program, according to ANSYS Inc, is conducted in line with written procedure that form part of an overall Quality Assurance program at ANSYS, Inc. The main objective of this package, therefore, is to *further* verify the quality of ANSYS solutions obtained on DEC-ALPHA XL-266 computer platform serial number 02207 to similar ANSYS solutions documented in the ANSYS Verification Manual (Ref. 1).

3.0 METHODOLOGY

A set of thermal and structural elements (Appendix A) that are commonly used for structural and heat transfer analyses in the EDS group are selected from the ANSYS Revision 5.2 element library for verification. The ANSYS Verification Manual (Ref.1) demonstrates a wide range of ANSYS elements and capabilities in simple problems which have classical or readily obtainable theoretical solutions, and it demonstrates, futhermore, the close agreement of the ANSYS solutions to the theoretical results i.e., texbooks or technical publications. The applicable problems documented in the ANSYS Verification Manual serve as the basis for *additional* verification and qualification of ANSYS capabilities for structural and heat transfer applications on the DEC-ALPHA XL-266 computer platform serial number 02207.

The selected ANSYS elements and capabilities that are specific to EDS engineering applications are verified using the input data from the ANSYS Verification Manual for all applicable elements. *The relevant input data used for the verification were extracted from the ANSYS Verification Manual database (Ref. 2), and executed for ANSYS solution without any modification to the input data.* The ANSYS solution obtained on the DEC-ALPA XL266 computer platform serial number 02207 for selected ANSYS elements and capabilities were then compared to similar solutions documented in the ANSYS Verification Manual. Total of 50 structural and heat transfer test cases, some involving more than one element type in a single analysis pass, were examined.

4.0 RESULT COMPARISON

The verification of the ANSYS code on DEC-ALPHA XL266 computer platform serial number 02209 is completed and documented in work request number UMS-1006 (Ref. 3). The verification package in work request number UMS 1006 compares analyses solutions from the DEC-ALPHA XL266 computer platform serial number 02209 to similar solutions in the ANSYS Verification Manual and presented the result in terms of percentage differences between the two ANSYS solution outputs. The DEC-ALPHA XL266 computer platform serial number 02207 upon which the ANSYS verification is performed in this work request is identical to the DEC-ALPHA XL266 computer serial number 02209 upon which ANSYS is verified in work request number UMS 1006. It follows, therefore, that the ANSYS solutions obtained from DEC-ALPHA XL266 serial number 02207 in this work request (WRR 1006a) must be identical to the ANSYS solution obtained from DEC-ALPHA XL266 computer serial number 02209 in work request number UMS-1006 (Ref. 3), given identical problems and hierachy of ANSYS commands in the analysis input streams. This is the corollary upon which the verification of the ANSYS code on DEC-ALPHA XL266 computer serial number 02209 in this work request is based. In line with the asserted corollary, the verification test case and result table below shows that there is no difference in the ANSYS solution in this package for DEC-ALPHA XL266 computer platform

Prepared By: [signature] Date: 06/10/1996 WRR No: 1006a

Checked By: ADM Date: 6/11/96 Page 6 of 543 serial number 02207 *and* the ANSYS solution in the analysis package number UMS-1006 for DEC-ALPHA XL266 computer platform serial number 02209.

5.0 CONCLUSION

ANSYS, Revision 5.2 finite element computer code that is currently installed on the DEC-ALPHA XL266 computer platform, serial number 02207, gives solution that are in agreement with the ANSYS solution documented in the ANSYS Verification Manual for all related identified NAC verification test cases.

Appendix A9.2.2 Immersion Pail Calculation 457-2003.3 (Continued)

VERIFICATION TEST CASES AND RESULTS TABLE
(DEC-ALPHA XL266 COMPUTER SERIAL # 02207)

Test Case Number (WRR No 1006a)	Page Location in WRR Pkg.	ANSYS Element Type(s)	ANSYS VM Case #	Result Ratio[1]
1	1	LINK1	1	1.0
2	4	COMB14-COMB40	9[2]	1.0
3	12	SHELL51	13	1.0
4	15	BEAM 54	14	1.0
5	19	SHELL41	41	1.0
6	22	BEAM4	21	1.0
7	28	PLANE13[3]-CONT48	23	1.0
8	36	BEAM 23	24	1.0
9	46	PLANE82	25	1.0
10	57	LINK1-CONT12	27	1.0
11	64	LINK10	31	1.0
12	68	PLANE55	32	1.0
13	75	SHELL63	34	1.0
14	90	SHELL91	35	1.0
15	95	BEAM4-COMB40[3]	36	1.0
16	104	SOLID45-SOLID72-SOLID73	37	1.0
17	124	PLANE25	43	1.0
18	132	SHELL61	44	1.0
19	145	PLANE35-SURF19[3]	58	1.0
20	150	PLANE82-PLANE2-CONT26	63	1.0
21	159	SHELL99-SOLID46	82	1.0
22	170	LINK32-LINK34	92	1.0
23	174	SOLID70-LINK33-LINK34	95	1.0
24	181	SOLID87	96	1.0
25	186	SHELL57-LINK34	97	1.0
26	192	LINK31	106	1.0
27	195	PLANE75	108	1.0
28	198	MASS71-LINK34	109	1.0
29	206	PLANE77	112	1.0
30	210	BEAM3	127	1.0
31	215	BEAM24	134	1.0
32	229	PLANE83	140	1.0
33	242	PLANE2-PLANE82-SHELL93-MATRIX50[3]-PLANE145	141	1.0
34	261	SOLID45-SOLID95-PLANE82	143	1.0
35	277	SOLID64	145	1.0
36	281	SOLID65-LINK8[3]-LINK1	146	1.0
37	289	COMB39[3]-MASS21	156	1.0
38	311	MASS71-LINK34-COMB37[3]	159	1.0
39	328	SOLID90	161	1.0
40	332	PLANE13[3]-COMB14[3]	171	1.0
41	334	COMB7[3]-BEAM4	179	1.0
42	340	PLANE42-CONT48-SOLID45-CONT49	191	1.0
43	357	HYPE56-CONT26-HYPE74-CONT48-HYPE58-SHELL63	201	1.0
44	376	SHELL28	202	1.0
45	376	PLANE42-PLANE82	5	1.0
46	384	SOLID45-SHELL43	7	1.0
47	406	MASS21	131	1.0
48	409	SOLID5-SOLID92-SOLID98[3]	184	1.0
49	432	COMB7[3]-COMB14[3]-LINK11	195	1.0
50	441	SHELL93	203	1.0

Note:

[1] The ratio of ANSYS solution in this package to the ANSYS solution in Ref. 3 (WRR UMS-1006)
[2] The ratio of ANSYS solution in this package to the ANSYS solution in Ref. 1 (ANSYS Verification Manual)
[3] These elements are not included in the work request package in Ref. 3 (WRR UMS-1006). They are, therefore, considered irrelevant

Prepared By: Rp Date: 06/10/1996 WRR No:1006a

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REFERENCES

1.0 ANSYS Revision 5.2 Verification Manual, ANSYS, Inc.

2.0 DEC-ALPHA XL266 Computer Platform; D:\ansys52\data\verif\
(Computer Serial No 02207)

3.0 "ANSYS Revision 5.2 Verification" DEC-ALPHA XL266 Computer; Serial No. 02209,
WRR No. UMS-1006, Dated 5/2/96, Prepared By Anthony Moore.

Prepared By: TLS Date: 06/10/1996 WRR No:1006a

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Appendix A9.2.3 Support Structure Calculation 457-2005.2

NAC INTERNATIONAL	CALCULATION PACKAGE COVER SHEET	Work Request/Calc No: 457-2005.2
PROJECT NAME: K Basin Operations Equipment	CLIENT: Hanford (Transnuclear, Inc.)	

CALCULATION TITLE:

Immersion Pail Stand

PROBLEM STATEMENT OR OBJECTIVE OF THE CALCULATION:

This calculation evaluates the immersion pail stand utilizing the load factor requirements defined in ANSI N14.6 (Reference 7.3). The immersion pail stand is part of the TN-WHC Cask and Transportation System to be used at the K-Basin Area of the Hanford site.

GEORGIA REGISTERED No. 16206 PROFESSIONAL ENGINEER NORMAN M. MEINERT

Revision	Affected Pages	Revision Description	Preparer Name, Initials, Date	Checker Name, Initials, Date	Project Manager Approval/Date
0	1 thru 22	Original Issue	Jeffrey R. Dargis 11-10-96	Ravi Singh 11-14-96	Thomas A. Danner 11-15-96
1	1, 3 thru 23	Revised method of calculating margin of safety.	Jeffrey R. Dargis JRD 12-2-96	Ravi Singh RS 12/2/96	Thomas A Danner 12/2/96

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Total Pages 23

Appendix A9.2.3 Support Structure Calculation 457-2005.2 (Continued)

INDEPENDENT DESIGN VERIFICATION CHECK SHEET

Work Request/Calculation No: 457-2005.2 Revision 0

Scope Of Analysis File: This calculation evaluates the immersion pail stand stand utilizing the load factor requirements defined in ANSI N14.6.

Review Methodology: Check Of Calculations RS
Alternate Analyses —
Other (Explain) —

Confirm That The Work Request / Calculation Package Reviewed Includes:

1. Statement of Purpose RS
2. Defined Method of Analysis RS
3. Listing of Assumptions RS
4. Detailed Analysis Record RS
5. Statement of Conclusions / Recommendations (if applicable) RS

Step	Activities	Verification Yes	No	N/A	Comments
1	For the scope of the defined analysis: A. Are the required data input complete? 1. Material properties 2. Geometry (drawing reference) 3. Loading source term *If a supporting analysis is required to define the load state, has it been defined?* B. Are boundary conditions acceptable?	✓ ✓ ✓ ✓			
2	Is the method of analysis adequate for the defined scope?	✓			
3	Is the worst case loading/configuration documented?	✓			
4	Are the acceptance criteria defined and complete?	✓			
5	Has all concurrent loading been considered?	✓			
6	Are analyses consistent with previous work for method and approach?			✓	NEW CALC PACKAGE.
7	Are the records for input and output complete?	✓			
8	Is traceability to verified software complete?			✓	NO SOFTWARE USED.
9	Is the statement of conclusions and recommendations complete and acceptable for the project and objectives of the defined purpose?				

RAVI SINGH [signature] 11/14/96
Reviewer (Name/Signature) Date

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Appendix A9.2.3 Support Structure Calculation 457-2005.2 (Continued)

INDEPENDENT DESIGN VERIFICATION CHECK SHEET

Work Request/Calculation No: 457-2005.2 Revision 1

Scope Of Analysis File: This calculation evaluates the immersion pail stand stand utilizing the load factor requirements defined in ANSI N14.6.

Review Methodology:
Check Of Calculations RS
Alternate Analyses —
Other (Explain) —

Confirm That The Work Request / Calculation Package Reviewed Includes:

1. Statement of Purpose RS
2. Defined Method of Analysis RS
3. Listing of Assumptions RS
4. Detailed Analysis Record RS
5. Statement of Conclusions / Recommendations (if applicable) RS

Step	Activities	Verification Yes	No	N/A	Comments
1	For the scope of the defined analysis: A. Are the required data input complete? 1. Material properties 2. Geometry (drawing reference) 3. Loading source term *If a supporting analysis is required to define the load state, has it been defined?* B. Are boundary conditions acceptable?	 ✓ ✓ ✓ ✓			
2	Is the method of analysis adequate for the defined scope?	✓			
3	Is the worst case loading/configuration documented?	✓			
4	Are the acceptance criteria defined and complete?	✓			
5	Has all concurrent loading been considered?	✓			
6	Are analyses consistent with previous work for method and approach?	✓			
7	Are the records for input and output complete?	✓			
8	Is traceability to verified software complete?			✓	NO SOFTWARE USED.
9	Is the statement of conclusions and recommendations complete and acceptable for the project and objectives of the defined purpose?	✓			

RAVI SINGH [signature] 12/2/96
Reviewer (Name/Signature) Date

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1.0 SYNOPSIS OF RESULTS

Summary of Stress Analysis

Drawing No.	Item No.	Component	Applied Load	Design Check	Calculated Loading	Allowable	M.S.
457-102	98, 99	frame stand assembly	5W	buckling	300 kips	1,064 kips	0.72
457-102	4, 7, 8, 9, 15, 16, 17, 18	tie plates	5W	compression	480 psi	694 psi	0.31
457-102	5	corner post	5W	buckling	72,500 lbs	75,000 lbs	0.03
457-109	4	lock pin	5W	double shear	49.0 ksi	81.0 ksi	0.40
457-109	10	guide assembly	5W	bearing	16.0 ksi	54 ksi	0.70

The immersion pail support structure design meets the criteria defined in Section 4.2.

2.0 INTRODUCTION / PURPOSE

This calculation evaluates the immersion pail stand utilizing the load factor requirements defined in Reference 7.3. The immersion pail stand configuration is part of the TN-WHC Cask and Transportation System to be used at the K-Basin Area of the Hanford site. The immersion pail stand design was initially evaluated in Reference 7.1.

3.0 METHOD OF ANALYSIS

Hand calculations using classic textbook solutions are used to structurally evaluate the immersion pail support structure. Per Reference 7.14, the design considers the entire pail resting weight will be distributed to two (2) of the four (4) corner column supports.

The design will be assessed using the load factors discussed in Section 4.2. The acceptance criteria defined in Reference 7.3 limits the lifting induced tensile stresses to the lesser of:

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(a) one-third material yield strength; or
(b) one-fifth the material ultimate strength.

Shear stresses will be limited to 0.6 times the tensile stress limits.

Buckling loads will be determined based on a load factor of 5.0. The critical buckling load will be determined per Reference 7.10.

The following evaluations are documented within this calculation.

- Frame Stand Buckling Evaluation;
- Tie Plate Evaluation;
- Corner Post Assembly Buckling Evaluation;
- Guide Assembly Evaluation; and
- Base Assembly - Upper Assembly Joint Evaluation.

3.1 Frame Stand Buckling Evaluation

This evaluation will determine the critical buckling load for the stand assembly as a single unit, (simultaneous buckling of the entire assembly using the combined cross section of all eight tube steel columns, tie plates excluded). The buckling criteria of Reference 7.10.2 will be used. The applied load will be 5 x the dead weight loading.

To evaluate net stand buckling, the following steps are performed:

- The net cross section properties are determined;
- The kl/r parameter is determined;
- The maximum allowable section axial stress is determined;
- The critical buckling load is determined; and
- The applied axial load (5W) is compared to the critical buckling load.

3.2 Tie Plate Evaluation

Tie plates are used to reduce the buckling potential of the corner assemblies by making the mid-section (upper-to-lower stand section joint) behave as a frame unit and to assist in the installation/fabrication of the stand.

The tie plates are concentrated at the mid stand height to ensure the midpoint can be treated as an inflection point (pinned-pinned end condition, no tendency for lateral movement under load) for the corner assembly buckling evaluation (See Section 3.3).

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The following steps are performed:

- The size of the tie plates is determined;
- The required spacing between tie plates is determined;
- The tie plate design load is determined;
- The compression load on the tie plates is evaluated; and
- The tie plate welds are evaluated.

3.3 Upper Frame Corner Post Assembly Buckling Evaluation

Each corner post assembly is composed of two 4x4 tubing sections connected by corner plates. The corner plates are installed in pairs of two.

The buckling capacity is evaluated by determining the critical buckling length of the 4x4 tubing only. The length determined is then compared to the existing maximum length available to buckle in the critical mode.

The buckling length is determined by the following steps:

- The tube cross section properties are determined;
- The axial load is determined; and
- The maximum allowable load is determined and compared to the axial load.

3.4 Guide Assembly Evaluation

The guide assembly is comprised of a solid block element and a slide lock pin arrangement. By inspection the solid block guide and lock pin flange (with bolting) are adequate. Only the lock pin requires evaluation. For the lock pin, bearing and double shear design checks are evaluated.

3.5 Base Assembly-Upper Assembly Joint Evaluation

The base and upper stand assemblies are connected by a solid connector plug inserted within the 4x4 column tubing. The connector is full penetration welded to the base side tubing. The load path under loading conditions is through bearing at the tube steel-to-tube steel interface. The connector and its weldment serve alignment and connectivity functions only. No structural evaluation is required.

4.0 ASSUMPTIONS / DESIGN INPUTS

4.1 Assumptions

There are no unverified assumptions within this calculation.

4.2 Design Criteria

4.2.1 Tensile Stresses

Calculated tensile stress (based on load factor of 3) $< S_{yield}$ (Ref. 7.3)
Calculated tensile stress (based on load factor of 5) $< S_{ultimate}$ (Ref. 7.3)

4.2.2 Shear Stresses

Calculated shear stress (based on load factor of 3) $< 0.6 \times S_{yield}$
Calculated shear stress (based on load factor of 5) $< 0.6 \times S_{ultimate}$

4.2.3 Bearing stresses

Calculated bearing stress $< 1.5 \times S_y$ (Ref. 7.7.3)

4.2.4 Buckling Design

Calculated buckling load (based on load factor of 5) $< P_{cr}$

4.2.5 Material Properties / Stress Design Checks

All components evaluated within this WRR are made of A500, A36 or A654 carbon steel.

Poison's ratio = 0.3
Modulus of Elasticity , E = 28.3×10^6 psi (Ref. 7.7)

Normalizing the material yield and ultimate strengths by the Reference 7.3 load factors yields the following (See Section 4.2.1 for load factors):

A500 GR B Carbon Steel
(Reference 7.10.7)
Fy: 46 ksi
Fu: 58 ksi
$F_y/3$ = 46,000 / 3 = 15,333 psi
$F_u/5$ = 58,000 / 5 = 11,600 psi

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ASTM A36 Carbon Steel
(Reference 7.10.8)
Fy: 36 ksi
Fu: 58 ksi
$F_y/3$ = 36,000/3 = 12,000 psi
$F_u/5$ = 58,000/5 = 11,600 psi

ASTM A564 Carbon Steel
Guide Pin Only
(Reference 7.15)
Fy: 105 ksi
Fu: 135 ksi
$F_y/3$ = 105,000/3 = 35,000 psi
$F_u/5$ = 135,000/5 = 27,000 psi

Based on the above comparisons of yield and ultimate allowables for the three (3) materials, comparing a factor (LF) of 5 against ultimate is more restrictive. Only the limiting condition is evaluated within this WRR.

4.3 Design Conditons

Load: 60,000 lbs
Temperature: Ambient, 100 °F
Lifting: Two Point Lift (set) condition is design controlling per Reference 7.14.

4.4 Component Properties

4.4.1 Tube steel
(Reference 7.10.1)
size: 4 x 4 x 0.5
I: 12.3 in^4
r: 1.39 in
area: 6.36 in^2
matl: A36

4.4.2 Tie Plates
size: 1/2" plate

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4.5 Elevations of the Fuel Pit (Reference 7.1)

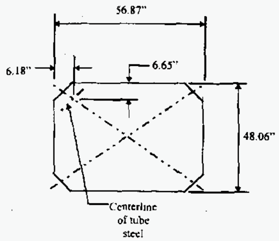
Pit floor elevation:	- 25'-9"
Fuel floor elevation:	- 20'-9"
Load pit floor elevation:	0'-0"
Top of pit wall elevation:	+ 2'-0"
Water elevation:	- 4'-9"

5.0 ANALYSIS DETAIL

5.1 Frame Stand Buckling Evaluation

5.1.1 Net Cross Section Properties

The frame stand consists of eight (8) vertical 4" x 4" x 0.5" tube steel members. Since the I and r of a tube are the same for any orientation, consider the effective section as follows (Reference 7.6.2):



Per Reference 7.6.2:

L_1 = 56.87" - (2 x 6.18")
= 44.51 in
L_2 = 48.06" - (2 x 6.65")
= 34.76 in

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The moment of inertia of the effective section, I , is:

$$I = \Sigma Ay^2 + \Sigma I$$
$$= [(8 \times 6.36) \times (34.76 / 2)^2] + [8 \times (12.3)]$$
$$= 15{,}467 \text{ in}^4$$

$$r = \sqrt{\frac{I}{A}}$$

$$= \sqrt{\frac{15{,}467}{8 \times 6.36}}$$

$$= 17.44$$

5.1.2 <u>kl/r Parameter</u>

Due to the location of struts at each corner assembly of the upper stand, consider k = 0.8 (Reference 7.10.3). The length, l , is:

l = 160" + 156.5" (Reference 7.6.2)
= 316.5"
≅ 317 in

Therefore:

kl/r = 0.8 x (317) / 17.44
= 14.54

5.1.3 <u>Maximum Allowable Section Axial Stress</u>

Per Reference 7.10.2 and conservatively using the A36 allowable in lieu of the A500 Gr B allowable (i.e., A500 Gr B has a yield strength of 42 ksi compared to 36 ksi for A36):

at kl/r = 14.54,

F_a = 20.92 ksi

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5.1.4 Critical Buckling Load

P_{cr} = F_a x A
= 20,920 x (8 x 6.36)
= 1,064,410 lbs

5.1.5 Axial Load (5W, for buckling considerations)

Axial load = 5 x 60,000

= 300,000 lbs

The axial load is less than the critical buckling load, P_{cr}:

300,000 lbs < 1,064,410 lbs

The stand will not buckle as a frame assembly if the tie plate bracing is demonstrated to be adequate (Section 5.2).

5.2 Tie Plate Evaluation

5.2.1 Sizing Of Tie Plates

The frame will be braced using 1/2" tie plates on all four (4) sides. The upper frame (stand) assembly is designed with one (1) open side for placement and removal of the immersion pail.

The tie plate requirements per Reference 7.10.9 are:

"... the end tie plates shall have a length of not less than the distance between the lines of fasteners or welds connecting them to the components of the member. Intermediate tie plates shall have a length not less than 1/2 of this distance. The thickness of tie plates shall not be less than 1/50 of the distance between the lines of fasteners or welds connecting them to the components of the member."

L_1 = maximum distance between welds of tie plates.
= 44 in

L_2 = minimum width of end tie plates
= L_1
= 44 in

L_3 = minimum width of intermediate tie plates
= $1/2\ L_1$
= 22 in

t = minimum thickness of tie plates
= $1/50\ L_1$
= 0.88 in

Tie plates used in this design are 0.5 in thick. Note that this is in violation of the requirements stated in the AISC Code. However, the AISC allows exception to these requirements, provided that stress allowable reduction factors for slender compression elements are applied (See Section 5.2.4).

5.2.2 Spacing Between Tie Plates

The tie plate spacing requirements per Reference 7.10.9 are:

"Compression members composed of two or more shapes separated by intermittent fillers shall be connected at these fillers at intervals such that the slenderness ratio *kl/r* of either shape, between the fasteners, does not exceed 3/4 times the governing slenderness ratio of the built-up member. The least radius of gyration *r* shall be used in computing the slenderness ratio of each component part."

$kl/r_{composite}$ = kl/r of composite section from 5.1.2
= 14.54

$kl/r_{component}$ = kl/r of component section

Per Reference 7.10.9:

$kl/r_{component} < 0.75 \times kl/r_{composite}$

r = radius of gyration of component section
= 1.39

k = effective length factor for component section
= 1.0

$l_{component}$ = maximum length of component section (i.e., distance between tie plates)
= 0.75 x 14.54 x 1.39
= 15.15 in

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Therefore, the maximum permissible spacing between tie plates is 15".

5.2.3 Tie Plate Design Load

The tie plates are not subject to any side loads, therefore they will be designed to the load requirements of Reference 7.10.9:

"...resist a shearing stress normal to the axis of the member equal to 2% of the total compressive stress in the member."

W = Load on frame.
= 60,000 lbs

LF = Load factor for ultimate.
= 5

f = Two point lift criteria reduction factor
= 2

F_{design} = Frame Design Load
= 60,000 x 5 x 2
= 600.000 lbs

$F_{tie\ plate}$ = Tie Plate Design Load
= $0.02 \times F_{design}$
= 0.02 x 600,000
= 12,000 lbs

5.2.4 Tie Plate Evaluation

For the evaluation of a tie plate of minimum width equal to 22" and maximum width equal to 50", both with a thickness of 1/2", the AISC Code (Reference 7.10, page 5-36) contains the following limitations:

$$b/t \leq \frac{95}{\sqrt{F_y}} \leq \frac{95}{\sqrt{36}} \leq 16$$

For 50" plate:

b/t = 100

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Appendix A9.2.3 Support Structure Calculation 457-2005.2 (Continued)

For 22" plate:

$b/t = 44$

Since $b/t > 16$ in both cases, a stress reduction factor must be applied. Note that this falls in line with thickness conclusion in Section 5.2.1 of this calculation.

The stress reduction factor is calculated per Equation A-B5-4 of AISC Code:

when: $b/t > \dfrac{195}{\sqrt{\dfrac{F_y}{k_c}}} > \dfrac{195}{\sqrt{\dfrac{F_y}{\dfrac{4.05}{(h/t)^{0.46}}}}}$

where: $k_c = 4.05/(h/t)^{0.46}$ for $h/t > 70$; and

$k_c = 1.0$ for $h/t \le 70$.

$h = b$

then: $Q_s =$ stress reduction factor
$= 26{,}200\ k_c / [F_y \times (b/t)^2]$

For 50" plate: $\dfrac{195}{\sqrt{\dfrac{36}{\dfrac{4.05}{(100)^{0.46}}}}} = 22.7$

For 22" plate: $\dfrac{195}{\sqrt{\dfrac{36}{1.0}}} = 32.5$

Since b/t is greater for both size plates, for the 50" plate

$Q_{s50} = 26{,}200\ k_c / [F_y \times (b/t)^2]$
$= 0.036$

For the 22" plate:

$Q_{s22} = 26{,}200\ k_c / [F_y \times (b/t)^2]$
$= 0.376$

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For 22" plate:

b/t = 44

Since b/t > 16 in both cases, a stress reduction factor must be applied. Note that this falls in line with thickness conclusion in Section 5.2.1 of this calculation.

The stress reduction factor is calculated per Equation A-B5-4 of AISC Code:

when: $b/t > \dfrac{195}{\sqrt{\dfrac{F_y}{k_c}}} > \dfrac{195}{\sqrt{\dfrac{F_y}{\dfrac{4.05}{(h/t)^{0.46}}}}}$

where: $k_c = 4.05/(h/t)^{0.46}$ for $h/t > 70$; and

$k_c = 1.0$ for $h/t \leq 70$.

$h = b$

then: $Q_s =$ stress reduction factor

$= 26{,}200\ k_c / [F_y \times (b/t)^2]$

For 50" plate: $\dfrac{195}{\sqrt{\dfrac{36}{\dfrac{4.05}{(100)^{0.46}}}}} = 22.7$

For 22" plate: $\dfrac{195}{\sqrt{\dfrac{36}{1.0}}} = 32.5$

Since b/t is greater for both size plates, for the 50" plate

$Q_{s50} = 26{,}200\ k_c / [F_y \times (b/t)^2]$
$= 0.036$

For the 22" plate:

$Q_{s22} = 26{,}200\ k_c / [F_y \times (b/t)^2]$
$= 0.376$

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From Reference 7.10, page 5-101,

$$Q = Q_{s50} = 0.036$$

$$= Q_{s22} = 0.376$$

$$C'_{c50} = \sqrt{\frac{2 \times \pi^2 \times E}{Q \times F_y}}$$

$$= \sqrt{\frac{2 \times \pi^2 \times 29E3}{0.036 \times 36}}$$

$$= 647$$

$$C'_{c22} = \sqrt{\frac{2 \times \pi^2 \times E}{Q \times F_y}}$$

$$= \sqrt{\frac{2 \times \pi^2 \times 29E3}{0.376 \times 36}}$$

$$= 205$$

For a plate with both ends welded:

k = 0.65

l = L_1
= 44 in

r = 0.289 x t (Reference 7.10)
= 0.289 x 0.5
= 0.1445

kl/r = .65 x 44 / .1445
= 198

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Since kl/r < C'_c for both the 50" and 22" plates:

F_{a50} = Stress allowable in compression, 50" plate

$$= \frac{Q \times \left[1 - \frac{\left(\frac{k \times l}{r}\right)^2}{2 \times C'^2_c}\right] \times F_y}{\frac{5}{3} + \frac{3 \times \left(\frac{k \times l}{r}\right)}{8 \times C'_c} - \frac{\left(\frac{k \times l}{r}\right)^3}{8 \times C'^3_c}}$$

$$= \frac{0.036 \times \left[1 - \frac{(198)^2}{2 \times (647)^2}\right] \times 36}{\frac{5}{3} + \frac{3 \times (198)}{8 \times 647} - \frac{(198)^3}{8 \times (647)^3}}$$

= 0.694 ksi

F_{a22} = Stress allowable in compression, 22" plate

$$= \frac{0.376 \times \left[1 - \frac{(198)^2}{2 \times (205)^2}\right] \times 36}{\frac{5}{3} + \frac{3 \times (198)}{8 \times 205} - \frac{(198)^3}{8 \times (205)^3}}$$

= 3.769 ksi

The actual axial stresses are:

$\sigma_{axial\ 50}$ = 12,000 / (50 x 0.5)
= 480 psi

$\sigma_{axial\ 22}$ = 12,000 / (22 x 0.5)
= 1091 psi

Both actual stresses are less than the allowable, therefore the plates ranging from 22" to 50" wide with a 1/2" thickness are acceptable.

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	Checked by: *TRS*	Date: *11/25/96*	Page 17 of 23

Appendix A9.2.3 Support Structure Calculation 457-2005.2 (Continued)

Since kl/r < C'_c for both the 50" and 22" plates:

F_{a50} = Stress allowable in compression, 50" plate

$$= \frac{Q \times \left[1 - \frac{\left(\frac{k \times l}{r}\right)^2}{2 \times C'^2_c}\right] \times F_y}{\frac{5}{3} + \frac{3 \times \left(\frac{k \times l}{r}\right)}{8 \times C'_c} - \frac{\left(\frac{k \times l}{r}\right)^3}{8 \times C'^3_c}}$$

$$= \frac{0.036 \times \left[1 - \frac{(198)^2}{2 \times (647)^2}\right] \times 36}{\frac{5}{3} + \frac{3 \times (198)}{8 \times 647} - \frac{(198)^3}{8 \times (647)^3}}$$

= 0.694 ksi

F_{a22} = Stress allowable in compression, 22" plate

$$= \frac{0.376 \times \left[1 - \frac{(198)^2}{2 \times (205)^2}\right] \times 36}{\frac{5}{3} + \frac{3 \times (198)}{8 \times 205} - \frac{(198)^3}{8 \times (205)^3}}$$

= 3.769 ksi

The actual axial stresses are:

$\sigma_{axial\ 50}$ = 12,000 / (50 x 0.5)
= 480 psi

$\sigma_{axial\ 22}$ = 12,000 / (22 x 0.5)
= 1091 psi

Both actual stresses are less than the allowable, therefore the plates ranging from 22" to 50" wide with a 1/2" thickness are acceptable.

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5.2.5 Tie Plate Weld Evaluation

The plates will be welded on both edges with double line fillet welds. For 50" plate, the weld length is ≅ 34", which is twice the AISC Code requirement of 1/3 the plate width = 50/3 = 16.7". Similarly, the 22" plate weld length is 14", which is twice the AISC Code requirement of 22/3 = 7.3".

Therefore, the weld design is adequate.

5.3 Corner Post Assembly Buckling Evaluation

5.3.1 Tube Cross Section Properties

Per Section 4.4.1:
Tube steel
size = 4 x 4 x 0.5
I = 12.3 in^4
r = 1.39 in
area = 6.36 in^2

5.3.2 Axial Load

Per Reference 7.16, the maximum lift load for Condition I and IV is < 58,000 lbs. For eight tube columns, the axial load per column is:

F_{column} = LF x W x 2 / 8 (2 point set)
= 5 x 58,000 x 2 / 8
= 72,500 lbs

5.3.3 Buckling Load Evaluation

The bracing configuration was designed to ensure the stand will effectively behave as a frame assembly. However, due to the non braced section on the upper frame assembly, a localized buckling evaluation is performed. The upper / lower frame assembly connection will serve as a pinned connection point (k = 1.0 applies).

Per drawing Reference 7.6.2, the maximum actual length, L_{max},

L_{max} = 156 in
= 13.0 ft

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Per Reference 7.10.6, with kl = 1.0 x 13 = 13.0:

The maximum allowable concentric load is = 75 kips.

Since the applied load is less than the maximum allowable concentric load, the corner tube will not buckle and is adequately designed against buckling failure.

5.4 Guide Assembly Evaluation

5.4.1 Bearing Check

The pin bearing area is;

Consider lock pin extends 90% thru guide, therefore extension length per item 98 of Reference 7.6.4,

L = [0.9 x (10.58 - 0.5 end pin chamfer)] - 1.5 (gap)
= 7.572 in

Pin bearing width, W , is

W = 1.5 - 2 (0.13).
= 1.24 in

Bearing area = L x W
= 7.572 x 1.24
= 9.39 in^2

Therefore, the bearing stress (guide assembly is A36 material, pin is 17-4PH) is:

$Stress_{bearing}$ = LF x (W / 2) / area
= 5 x (60,000 / 2)/ 9.39
= 15,974 psi

Safety Margin = 1 - (stress / (1.5 x S_y))
= 1 - (16.0 / (1.5 x 36))
= 0.70

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5.4.2 Double shear of the Lock Pin

shear area = W^2
= 1.24 x 1.24
= 1.53 in^2

shear stress = LF x (W / 2) / (2 x shear area)
= 5 x (60,000 / 2) / (2 x 1.53)
= 49,020 psi

Safety Margin = 1 - (shear stress / (0.6 x S_u))
= 1 - (49.0 / (0.6 x 135))
= 1 - (49.0 / 81.0)
= 0.40

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6.0 SUMMARY OF RESULTS/CONCLUSIONS

Summary of Stress Analysis

Drawing No.	Item No.	Component	Applied Load	Design Check	Calculated Loading	Allowable	M.S.
457-102	98, 99	frame stand assembly	5W	buckling	300 kips	1,064 kips	0.72
457-102	4, 7, 8, 9, 15, 16, 17, 18	tie plates	5W	compression	480 psi	694 psi	0.31
457-102	5	corner post	5W	buckling	72,500 lbs	75,000 lbs	0.03
457-109	4	lock pin	5W	double shear	49.0 ksi	81.0 ksi	0.40
457-109	10	guide assembly	5W	bearing	16.0 ksi	54 ksi	0.70

The immersion pail support structure design meets the criteria defined in Section 4.2.

7.0 REFERENCES

7.1 Preliminary Design Analysis Report For The TN-WHC Cask and Transporation System
Project 3035
Transnuclear, Inc.

7.2 Not Used.

7.3 ANSI N14.6
American National Standard for Radioactive Materials
"special lifting devices for shipping containers weighing 10,000 lbs (4,500 kg) or more"

7.4 Roark's Formulas for Stress and Strain, 3rd edition.

7.5 Hanford ECN 191402.

7.6 K Basin Immersion Pail Assembly TN WHC Transport Cask Drawings.
- 7.6.1 Project 457, Drawing 101, sheet 1 / 1.
- 7.6.2 Project 457, Drawing 102, sheets 1, 2 / 2.
- 7.6.3 Project 457, Drawing 103, sheets 1, 2 / 2.
- 7.6.4 Project 457, Drawing 109, sheet 1 / 1.

7.7 ASME Boiler & Pressure Vessel Code, 1995 edition.
- 7.7.1 Section II-D, page 99, Table 1A.
- 7.7.2 Section I-D, page 6, Table 1A.
- 7.7.3 Section III, NB-3227.1(a).
- 7.7.4 Section II-D, page 432, 496.

7.8 Blodgett's Design Of Welded Structures, 1966.
- 7.8.1 Page 3.2-16
- 7.8.2 Page 3.2-1
- 7.8.3 Page 3.2-14

7.9 Not Used.

7.10 AISC Manual Of Steel Construction, 9th edition.
- 7.10.1 Page 1-96
- 7.10.2 Page 3-16
- 7.10.3 Page 5-135
- 7.10.4 Page 5-37 (Section B7) and 5-42
- 7.10.5 Page 1-103
- 7.10.6 Page 3-43
- 7.10.7 Page 1-92
- 7.10.8 Page 1-7
- 7.10.9 Page 5-43

7.11 Not Used.

7.12 Machinery's Handbook, 22nd Edition.
- 7.12.1 Page 287

7.13 Mark's Standard Handbook for Mechanical Engineers.
- 7.13.1 Page 5-30

7.14 Meeting Minutes, NAC/TN, September 1996.

7.15 ASTM Annual Book of ASTM Standards.
Volume 01.01, Page 404
1010 Drawn Tubing.

7.16 WRR-457-2003.2.

Appendix A9.2.4 Lift Beam Calculation 457-2005.3

NAC INTERNATIONAL	CALCULATION PACKAGE COVER SHEET	Work Request/Calc No: 457-2005.3
PROJECT NAME: K Basin Operations Equipment	CLIENT: Hanford (Transnuclear, Inc.)	

CALCULATION TITLE:

Lift Beam Evaluation

GEORGIA REGISTERED No. 5706 PROFESSIONAL ENGINEER NORMAN M. MEINERT

PROBLEM STATEMENT OR OBJECTIVE OF THE CALCULATION:

This calculation evaluates the lift beam utilizing the load factor requirements defined in ANSI N14.6 (Reference 7.3). The lift beam is part of the TN-WHC Cask and Transportation System to be used at the K-Basin Area of the Hanford site.

Revision	Affected Pages	Revision Description	Preparer Name, Initials, Date	Checker Name, Initials, Date	Project Manager Approval/Date
0	1 thru 13	Original Issue	Jeffrey R. Dargis 11-13-96	Ravi Singh 11-14-96	Thomas A. Danner 11-15-96
1	1, 3 thru 14	Revised method of calculating margin of safety.	Jeffrey R. Dargis JRD 11-25-96	Ravi Singh RS 11/25/96	[signature] 11/25/96

1 Total Pages 14

Appendix A9.2.4 Lift Beam Calculation 457-2005.3 (Continued)

INDEPENDENT DESIGN VERIFICATION CHECK SHEET

Work Request/Calculation No: 457-2005.3 Revision 0

Scope Of Analysis File: This calculation structurally evaluates the lift beam utilizing the load factor requirements defined in ANSI N14.6.

Review Methodology: Check Of Calculations RS
Alternate Analyses –
Other (Explain) –

Confirm That The Work Request / Calculation Package Reviewed Includes:

1. Statement of Purpose RS
2. Defined Method of Analysis RS
3. Listing of Assumptions RS
4. Detailed Analysis Record RS
5. Statement of Conclusions / Recommendations (if applicable) RS

Step	Activities	Verification Yes	No	N/A	Comments
1	For the scope of the defined analysis: A. Are the required data input complete? 1. Material properties 2. Geometry (drawing reference) 3. Loading source term *If a supporting analysis is required to define the load state, has it been defined?* B. Are boundary conditions acceptable?	 ✓ ✓ ✓ ✓			
2	Is the method of analysis adequate for the defined scope?	✓			
3	Is the worst case loading/configuration documented?	✓			
4	Are the acceptance criteria defined and complete?	✓			
5	Has all concurrent loading been considered?	✓			
6	Are analyses consistent with previous work for method and approach?			✓	NEW CALC PACKAGE
7	Are the records for input and output complete?	✓			
8	Is traceability to verified software complete?			✓	NO SOFTWARE USED.
9	Is the statement of conclusions and recommendations complete and acceptable for the project and objectives of the defined purpose?	✓			

RAVI SINGH [signature] 11/14/96
Reviewer (Name/Signature) Date

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Appendix A9.2.4 Lift Beam Calculation 457-2005.3 (Continued)

INDEPENDENT DESIGN VERIFICATION CHECK SHEET

Work Request/Calculation No: 457-2005.3 Revision 1

Scope Of Analysis File: This calculation structurally evaluates the lift beam utilizing the load factor requirements defined in ANSI N14.6.

Review Methodology:
Check Of Calculations RS
Alternate Analyses —
Other (Explain) —

Confirm That The Work Request / Calculation Package Reviewed Includes:

1. Statement of Purpose RS
2. Defined Method of Analysis RS
3. Listing of Assumptions RS
4. Detailed Analysis Record RS
5. Statement of Conclusions / Recommendations (if applicable) RS

Step	Activities	Verification Yes	No	N/A	Comments
1	For the scope of the defined analysis: A. Are the required data input complete? 1. Material properties 2. Geometry (drawing reference) 3. Loading source term *If a supporting analysis is required to define the load state, has it been defined?* B. Are boundary conditions acceptable?	 ✓ ✓ ✓ ✓ ✓			
2	Is the method of analysis adequate for the defined scope?	✓			
3	Is the worst case loading/configuration documented?	✓			
4	Are the acceptance criteria defined and complete?	✓			
5	Has all concurrent loading been considered?	✓			
6	Are analyses consistent with previous work for method and approach?	✓			
7	Are the records for input and output complete?	✓			
8	Is traceability to verified software complete?			✓	
9	Is the statement of conclusions and recommendations complete and acceptable for the project and objectives of the defined purpose?	✓			

RAVI SINGH [signature] 11/25/96
Reviewer (Name/Signature) Date

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	Checked by: RS	Date: 11/25/96	Page 4 of 14

Appendix A9.2.4 Lift Beam Calculation 457-2005.3 (Continued)

1.0 SYNOPSIS OF RESULTS

Summary of Stress Analysis

Drawing No.	Item No.	Component	Applied Load	Design Check	Calculated Loading	Allowable	M.S.
457-112	1	weldment	180 kips (plate)	beam bending	25,447 psi	30,000 psi	0.15
			150 kips (trunnion)	beam shear	2,769 psi	18,000 psi	0.85
				trunnion shear	11,933 psi	40,200 psi	0.70
457-112	10	eye plate	180 kips	tension	14,400 psi	30,000 psi	0.52
				bearing	10,650 psi	45,000 psi	0.76

The lift beam design meets the criteria defined in Section 4.2.

2.0 INTRODUCTION / PURPOSE

This calculation evaluates the lift beam utilizing the load factor requirements defined in ANSI N14.6 (Reference 7.3). The lift beam is part of the TN-WHC Cask and Transportation System to be used at the K-Basin Area of the Hanford site.

3.0 METHOD OF ANALYSIS

Hand calculations using classic textbook solutions are used to structurally evaluate the lift beam.

The design will be assessed using the load factors discussed in Section 4.2. The acceptance criteria defined in Reference 7.3 limits the lifting induced tensile stresses to the lesser of:

(a) one-third material yield strength; or
(b) one-fifth the material ultimate strength.

The following evaluations are documented within this calculation.

- Design Load Development;
- Lift Beam Evaluation; and
- Pad Eye Evaluation.

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4.0 ASSUMPTIONS / DESIGN INPUTS

4.1 Assumptions

There are no unverified assumptions within this calculation.

4.2 Design Criteria

4.2.1 Tensile Stresses

Calculated tensile stress (based on load factor of 3) $< F_{yield}$ (Ref. 7.3)
Calculated tensile stress (based on load factor of 5) $< F_{ultimate}$ (Ref. 7.3)

4.2.2 Shear Stresses

Calculated shear stress (based on load factor of 3) $< 0.6 \times F_{yield}$
Calculated shear stress (based on load factor of 5) $< 0.6 \times F_{ultimate}$

4.2.3 Bearing stresses

Calculated bearing stress $< 1.5 \times F_{yield}$.

4.2.4 Material Properties / Stress Design Checks

All components evaluated within this calculation are made of A516 GR55 or A588 GR A carbon steel.

Poison's ratio = 0.3
Modulus of Elasticity , $E = 28.3 \times 10^6$ psi (Ref. 7.7)

Normalizing the material yield and ultimate strengths by the Reference 7.3 load factors yields the following (See Section 4.2.1 for load factors):

A516 GR 55 Carbon Steel
(Reference 7.10)
Fy: 30 ksi
Fu: 55 ksi
$F_y/3$ = 30,000 / 3 = 10,000 psi
$F_u/5$ = 55,000 / 5 = 11,000 psi

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ASTM A588 GR A Carbon Steel
(Reference 7.10)

F_y: 46 ksi
F_u: 67 ksi
$F_y/3$ = 46,000/3 = 15,333 psi
$F_u/5$ = 67,000/5 = 13,400 psi

Based on the comparisons of yield and ultimate allowables for the two (2) materials, comparing a factor (LF) of 3 against yield is more restrictive for A516, while using a factor (LF) of 5 against ultimate is more restrictive for A588. Only the limiting condition is evaluated within this calculation.

5.0 ANALYSIS DETAIL

5.1 Design Load Development

The design loads, F, for the lift beam and trunnion are as follows:

$F_{lift\ beam}$ = 60,000 x 3

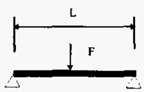
= 180,000 lbs

$F_{trunnion}$ = (60,000 / 2) x 5

= 150,000 lbs

5.2 Lift Beam Evaluation

The load is applied by the eye plate to the lift beam as follows:



where:

L = 36.81 + ((3/2) x 2)
= 34.81 in

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Appendix A9.2.4 Lift Beam Calculation 457-2005.3 (Continued)

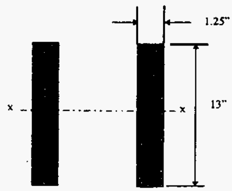
$$F = 180{,}000 \text{ lbs}$$

$$M = \frac{F \times L}{4}$$

$$= \frac{180{,}000 \times 39.81}{4}$$

$$= 1{,}791{,}450 \text{ in-lbs}$$

The effective cross section is:



$$I_x = \frac{2 \times b \times h^3}{12}$$

$$= \frac{2 \times 1.25 \times 13^3}{12}$$

$$= 457.7 \text{ in}^4$$

$$S_x = I / c$$

$$= 457.7 / (13 / 2)$$

$$= 70.4 \text{ in}^3$$

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The maximum bending stress is:

$\sigma_b = M / S_x$

$= 1{,}791{,}450 / 70.4$

$= 25{,}447$ psi

$MS = 1 - \frac{\sigma_b}{F_y}$

$= 1 - \frac{25{,}447}{30{,}000}$

$= 0.15$

The maximum shear stress is:

$\sigma_v = (F/2) / A_{shear}$

$= (180{,}000/2) / (13 \times 1.25 \times 2)$

$= 2{,}769$ psi

$MS = 1 - \frac{\sigma_v}{(0.6 \times F_y)}$

$= 1 - \frac{2{,}769}{(0.6 \times 30{,}000)}$

$= 0.85$

The maximum shear stress for the trunnion section:

$A_v = \pi \times r_{trunnion}^2$

$= \pi \times (2)^2$

$= 12.57 \text{ in}^2$

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σ_v = F / (2 x A)

= 150,000 / (12.57)

= 11,933 psi

The maximum allowable shear stress is:

F_v = 0.6 x F_u

= 40,200 psi

The margin of safety is:

$$MS = 1 - \frac{\sigma_v}{F_v}$$

$$= 1 - \frac{11,933}{40,200}$$

$$= 0.70$$

5.2 Eye Plate Evaluation

Per Reference 7.6.1, the minimum tensile area of the eye plate is:

A_t = 5.00 x 2.50

= 12.5 in^2

The maximum tensile stress in the eye plate is:

$$\sigma_t = \frac{F}{A_t}$$

$$\sigma_t = \frac{180,000}{12.5}$$

= 14,400 psi

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The maximum allowable tensile stress is:

$F = F_y$

$= 30{,}000$ psi

The margin of safety is:

$$MS = 1 - \frac{\sigma_t}{F}$$

$$= 1 - \frac{14{,}400}{30{,}000}$$

$$= 0.52$$

The eye plate bearing area, $A_{bearing}$, is:

$A_{bearing}$ = 3.38 in x 5 in

= 16.9 in^2

The maximum bearing stress in the eye plate is:

$$\sigma_{bearing} = \frac{F}{A_{bearing}}$$

$$\sigma_{bearing} = \frac{180{,}000}{16.9}$$

$= 10{,}650$ psi

The maximum allowable bearing stress is 1.5 F_y:

$F = 1.5 \times F_y$

$= 45{,}000$ psi

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Appendix A9.2.4 Lift Beam Calculation 457-2005.3 (Continued)

The margin of safety is:

$$MS = 1 - \frac{\sigma_{bearing}}{F}$$

$$= 1 - \frac{10{,}650}{45{,}000}$$

$$= 0.76$$

NAC INTERNATIONAL	Performed by: JRO	Date: 11-25-96	Calculation No. 457-2005.3 Revision 1
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6.0 SUMMARY OF RESULTS/CONCLUSIONS

Summary of Stress Analysis

Drawing No.	Item No.	Component	Applied Load	Design Check	Calculated Loading	Allowable	M.S.
457-112	1	weldment	180 kips (plate)	beam bending	25,447 psi	30,000 psi	0.15
			150 kips (trunnion)	beam shear	2,769 psi	18,000 psi	0.85
				trunnion shear	11,933 psi	40,200 psi	0.70
457-112	10	eye plate	180 kips	tension	14,400 psi	30,000 psi	0.52
				bearing	10,650 psi	45,000 psi	0.76

The lift beam design meets the criteria defined in Section 4.2.

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7.0 REFERENCES

7.1 Preliminary Design Analysis Report For The TN-WHC Cask and Transporation System
Project 3035
Transnuclear, Inc.

7.2 Not Used.

7.3 ANSI N14.6
American National Standard for Radioactive Materials
"special lifting devices for shipping containers weighing 10,000 lbs (4,500 kg) or more"

7.4 Roark's Formulas for Stress and Strain, 3rd edition.

7.5 Hanford ECN 191402.

7.6 K Basin Immersion Pail Assembly TN WHC Transport Cask Drawings.
7.6.1 Project 457, Drawing 112, sheets 1, 2 / 2.

7.7 ASME Boiler & Pressure Vessel Code, 1995 edition.

7.8 Blodgett's Design Of Welded Structures, 1966.

7.9 AISC Manual Of Steel Construction, 9th edition.

7.10 ASTM Annual Book of ASTM Standards.
Volume 01.04.

Appendix A9.2.5 Cold Vacuum Drying Lid Calculation 457-2001.2

NAC INTERNATIONAL	CALCULATION PACKAGE COVER SHEET	Work Request/Calc No: 457-2001.2

PROJECT NAME: K Basin Operations Equipment	CLIENT: Hanford (Transnuclear, Inc.)

CALCULATION TITLE:

Cold Vacuum Drying Lid

GEORGIA REGISTERED No. 15706 PROFESSIONAL ENGINEER NORMAN W. MEINER

PROBLEM STATEMENT OR OBJECTIVE OF THE CALCULATION:

This calculation structurally evaluates the cold vacuum drying lid for internal pressure and lid lifting load conditions. The cold vacuum drying lid is used during the MCO vacuum drying operation in the conditioning facility immediately after the MCO is loaded. The internal pressure load is developed as a result of circulating hot water between the MCO outer surface and the inner surface of the cask. Once the cask is within the conditioning facility, the cask lid is removed and the cold vacuum drying lid installed. The lid provides pressure boundary (two seals) and pressure restraint during MCO draining/drying in addition to providing additional shielding during the streaming operation.

The cold vacuum drying lid is part of the TN-WHC Cask and Transportation System to be used at the K-Basin Area of the Hanford site.

Revision	Affected Pages	Revision Description	Preparer Name, Initials, Date	Checker Name, Initials, Date	Project Manager Approval/Date
0	1 thru 13	Original Issue	Jeffrey R. Dargis 11-10-96	Ravi Singh 11-14-96	Thomas A. Danner 11-15-96
1	1, 3 thru 14	Revised to incorporate change in lid terminology from conditioning lid to cold vacuum drying lid. Also, revised method of calculating margin of safety.	Jeffrey R. Dargis JRD 11-25-96	Ravi Singh RS 11/25/96	Thomas A. Danner [signature] 11/25/96

1 Total Pages 14

Appendix A9.2.5 Cold Vacuum Drying Lid Calculation 457-2001.2 (Continued)

INDEPENDENT DESIGN VERIFICATION CHECK SHEET

Work Request/Calculation No: 457-2001.2 Revision 0

Scope Of Analysis File: This calculation structurally evaluates the conditioning lid for internal pressure and lid lifting load conditions.

Review Methodology:

Check Of Calculations	RS
Alternate Analyses	—
Other (Explain)	—

Confirm That The Work Request / Calculation Package Reviewed Includes:

1. Statement of Purpose RS
2. Defined Method of Analysis RS
3. Listing of Assumptions RS
4. Detailed Analysis Record RS
5. Statement of Conclusions / Recommendations (if applicable) RS

Step	Activities	Verification Yes	No	N/A	Comments
1	For the scope of the defined analysis: A. Are the required data input complete? 1. Material properties 2. Geometry (drawing reference) 3. Loading source term *If a supporting analysis is required to define the load state, has it been defined?* B. Are boundary conditions acceptable?	✓ ✓ ✓ ✓			
2	Is the method of analysis adequate for the defined scope?	✓			
3	Is the worst case loading/configuration documented?	✓			
4	Are the acceptance criteria defined and complete?	✓			
5	Has all concurrent loading been considered?	✓			
6	Are analyses consistent with previous work for method and approach?			✓	NEW CALC PACKAGE
7	Are the records for input and output complete?	✓			
8	Is traceability to verified software complete?			✓	NO SOFTWARE USED.
9	Is the statement of conclusions and recommendations complete and acceptable for the project and objectives of the defined purpose?	✓			

RAVI SINGH [signature] 11/14/96

Reviewer (Name/Signature) Date

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Appendix A9.2.5 Cold Vacuum Drying Lid Calculation 457-2001.2 (Continued)

INDEPENDENT DESIGN VERIFICATION CHECK SHEET

Work Request/Calculation No: 457-2001.2 Revision 1

Scope Of Analysis File: This calculation structurally evaluates the cold vacuum drying lid for internal pressure and lid lifting load conditions.

Review Methodology:

Check Of Calculations RS
Alternate Analyses –
Other (Explain) –

Confirm That The Work Request / Calculation Package Reviewed Includes:

1. Statement of Purpose RS
2. Defined Method of Analysis RS
3. Listing of Assumptions RS
4. Detailed Analysis Record RS
5. Statement of Conclusions / Recommendations (if applicable) RS

Step	Activities	Verification Yes	Verification No	Verification N/A	Comments
1	For the scope of the defined analysis: A. Are the required data input complete? 1. Material properties 2. Geometry (drawing reference) 3. Loading source term *If a supporting analysis is required to define the load state, has it been defined?* B. Are boundary conditions acceptable?	✓ ✓ ✓ ✓			
2	Is the method of analysis adequate for the defined scope?	✓			
3	Is the worst case loading/configuration documented?	✓			
4	Are the acceptance criteria defined and complete?	✓			
5	Has all concurrent loading been considered?	✓			
6	Are analyses consistent with previous work for method and approach?	✓			
7	Are the records for input and output complete?	✓			
8	Is traceability to verified software complete?			✓	NO SOFTWARE USED.
9	Is the statement of conclusions and recommendations complete and acceptable for the project and objectives of the defined purpose?	✓			

RAVI SINGH [signature] 11/25/96
Reviewer (Name/Signature) Date

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NAC INTERNATIONAL	Performed by: JRO	Date: 11-25-96	Calculation No. 457-2001.2 Revision 1
	Checked by: RS	Date: 11/25/96	Page 4 of 14

1.0 SYNOPSIS OF RESULTS

Summary of Stress Analysis

Drawing No.	Item No.	Component	Applied Load	Design Check	Calculated Loading	Allowable	M.S.
457-106	1	lid flange	pressure	torsion	5,031 psi	16.7 ksi	0.70
457-106	2	bolt	pressure	tension	13,590 psi	16.7 ksi	0.19
457-106	8	lifting lug	3 times the weight	bearing	4,093 psi	30 ksi	0.86
				tension	4,093 psi	30 ksi	0.86
				shear	8,187 psi	18 ksi	0.55
457-106	Item 8 to Item 1	weld	3 times the weight	shear	620 psi	large compared to actual stress	large

Therefore the cold vacuum drying lid design meets the criteria defined in Section 4.2.

2.0 INTRODUCTION / PURPOSE

This calculation structurally evaluates the cold vacuum drying lid for internal pressure and lid lifting load conditions. The cold vacuum drying lid is used during the MCO vacuum drying operation in the conditioning facility immediately after the MCO is loaded. The internal pressure load is developed as a result of circulating hot water between the MCO outer surface and the inner surface of the cask. Once the cask is within the conditioning facility, the cask lid is removed and the cold vacuum drying lid installed. The lid is a "Z" shaped ring. The lower leg of the Z rests on the top of the cask. Three (3) lid bolts are used to join the cold vacuum drying lid to the cask. The upper Z leg bears against the MCO top surface. The lid provides pressure boundary (two seals) and pressure restraint during MCO draining/drying in addition to providing additional shielding during the streaming operation.

The cold vacuum drying lid is part of the TN-WHC Cask and Transportation System to be used at the K-Basin Area of the Hanford site. The cold vacuum drying lid was initially evaluated in Reference 7.1.

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3.0 METHOD OF ANALYSIS

Hand calculations using classic textbook solutions are used to structurally evaluate the cold vacuum drying lid design.

The lid design will be assessed utilizing a pressure loading of 60 psi (Reference 7.10). Only the lid bolting and the upper Z leg of the lid are influenced by pressure loading. The pressure induced bolt stress will be compared to the ASME Code Class 2/3 stress allowable, S. For upper Z leg flange rotation, the pressure induced torsional stress will also be limited to S.

The lifting lug acceptance criteria is to limit tension and bearing stresses to the lesser of:
(a) one-third material yield strength; or
(b) one-fifth the material ultimate strength.

Shear stresses will be limited to 0.6 times the tensile stress limits.

The following evaluations are documented within this calculation:

- Lid Hold Down Evaluation; and
- Lifting Lug Assessment.

3.1.1 Lid Hold Down Evaluation

The lid is connected to the cask by three (3) 1-1/2 6UNC fabricated bolts. The bolts attach the lower lid flange to the cask shell. The lid-to-shell contact is metal-to-metal. An O-ring seal is used to maintain the pressure boundary between the lid and the cask. A silicone seal is also incorporated to maintain the pressure boundary between the cold vacuum drying lid and the MCO shell. The MCO seal is located on the vertical leg of the Z cold vacuum drying lid design. Sealing is achieved by pressurizing the silicon seal internally.

To evaluate the lid hold down, the following steps will be performed:

- The net pressure cross section and pressure load will be determined;
- The lid bolt load will be determined; and
- The maximum upper flange stress due to rotation under pressure loading will be determined.

3.1.2 Lifting Lug Evaluation

The lid has three (3) lifting lugs attached to the top surface of the lid. These lugs are used to install/remove the lid to/from the cask. The lug bearing stress, net tension and shear pull out will be assessed. The lifting criteria of Reference 7.3 will be used to

NAC INTERNATIONAL	Performed by: gRO	Date: 11-25-96	Calculation No. 457-2001.2 Revision 1
	Checked by: RS	Date: 11/25/96	Page 6 of 14

determine the adequacy of the lug design. The lug-to-lid weld will also be assessed.

4.0 ASSUMPTIONS / DESIGN INPUTS

4.1 Assumptions

There are no unverified assumptions within this calculation.

4.2 Design Criteria

4.2.1 Bolt and Flange Bending Evaluation

Calculated bolt tensile stress (due to pressure)	$< S$	(Ref. 7.7)
Calculated flange torsional stress (due to pressure)	$< S$	(Ref. 7.7)

4.2.2 Lift Lug Evaluation

Calculated tensile stress (based on load factor of 3)	$< S_{yield}$	(Ref. 7.3)
Calculated tensile stress (based on load factor of 5)	$< S_{ultimate}$	(Ref. 7.3)
Calculated shear stress (based on load factor of 3)	$< 0.6S_{yield}$	
Calculated shear stress (based on load factor of 5)	$< 0.6S_{ultimate}$	
Calculated bearing stress (based on load factor of 3)	$< S_{yield}$	
Calculated bearing stress (based on load factor of 5)	$< S_{ultimate}$	

4.3 Design Conditions

Pressure: 60 psi (Reference 7.10)
Temperature: Ambient, 100 °F

4.4 Component Properties

Bolts: (Reference 7.6.1)

Size:	1.22" diameter	
Material:	A276 TP304 SS	
Area:	$= \pi \times D^2 / 4$	
	$= 1.17 \text{ in}^2$	
Threading:	1-1/2 6UNC-2A	(Reference 7.6.1)

NAC INTERNATIONAL	Performed by: gRO	Date: 11-25-96	Calculation No. 457-2001.2 Revision 1
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Lid flange:	(Reference 7.6.1)	
(upper leg)	Size:	3.5" thick
	$D_{i\ flg}$:	18.48 in
	$D_{o\ flg}$:	31.5 in
	Material:	ASTM A240, Type 304
Lid flange:	(Reference 7.6.1)	
(vertical leg)	Size:	11 - 3.5 - 4 = 3.5 axial length
	$D_{i\ flg}$:	25.5 in
	$D_{o\ flg}$:	31.5 in
	Material:	ASTM A240, Type 304
Lid flange:	(Reference 7.6.1)	
(lower leg)	Size:	4.0" thick
	$D_{i\ flg}$:	25.5 in
	$D_{o\ flg}$:	39.81 in
	Material:	ASTM A240, Type 304
Lift Lug:	(Reference 7.6.1)	
	Thickness:	0.375 in
	D_{lug}:	2.0 in
	D_{hole}:	1.0 in
	Material:	ASTM A240, Type 304

Lid Weight: W = 1535 lbs. (Reference 7.6.1)

O-ring: Diameter: 31.8 in (Reference 7.6.1)

4.5 Material Properties

- ASTM A240 (Reference 7.7.1, 7.7.2)
  (Note: use SA240, Type 304 SS properties)
  Fy: 30 ksi
  Fu: 75 ksi (100°)

- SA276 TP304 (Reference 7.5)
  Fy: 30 ksi
  Fu: 75 ksi

- SA240, Type 304 (Reference 7.7.4)
  S: 16,700 psi (at 200 degrees)

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	Checked by: RS	Date: 11/25/96	Page 8 of 14

5.0 ANALYSIS DETAIL

5.1 Lid Hold Down Evaluation

5.1.1 Lid Bolt Pressure Load Evaluation

The o-ring diameter is used as the pressure load development area. This area , A, is:

$$A = \Pi / 4 \left(D_{o\text{-ring}}^{2} \right)$$

$$A = \Pi / 4 \, (31.8^2)$$

$$A = 795 \text{ in}^2$$

The net pressure load, F, with no reduction for the weight of the MCO is;

F = pressure x area

= 60 x 795

= 47,700 lbs.

The lid bolt load, F_{bolt} , is;

F_{bolt} = F / no. bolts
= F / 3
= 47,700 / 3
= 15,900 lbs.

The bolt tensile stress is:

Stress = F_{bolt} / area
= 15,900 / 1.17
= 13,590 psi

The bolt allowable stress, S is:

S = 16,700 psi

Safety Margin = 1 - (stress / S)
= 1 - (13,590 / 16,700)
= 0.19

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5.1.2 Lid Flange Pressure Stress Evaluation

Conservatively, consider the pressure load is reacted at the cold vacuum drying lid upper flange. The maximum lid stress will then be developed by the rotation of the upper flange. The reaction along the inner edge of the upper flange per circumferential inch, F_o, is:

$F_o = F / (2 \times \Pi \times R_{i\text{-upper flg}})$

$= 47{,}700 / (2 \times \Pi \times (18.48 / 2))$

$= 822$ lbs/in

The uniform torque about the upper flange center of gravity due to F_o is:

$T_o = F_o \times (R_{o\text{-upper flg}} - R_{i\text{-upper flg}})$

$= 822 \times [(31.5 / 2) - (18.48 / 2)]$

$= 5{,}351$ in-lbs / in

Per Reference 7.8.1, for a ring under distributed torque:

$\sigma_{torque} = T_o \times R / (I / c)$

where R is equal to the mean radius of the ring.

The effective section I/c is:

$I/c = (R_{o\text{-upper flg}} - R_{i\text{-upper flg}}) \times t^2 / 6$
$= ((31.5 / 2) - (18.48 / 2)) \times (3.5)^2 / 6$
$= 13.29\ in^3$

The torsional stress, σ_{torque}, is therefore:

$\sigma_{torque} = T_o \times R / (I / c)$
$= 5{,}351 \times ((31.5 + 18.48) / 4) / 13.29$
$= 5{,}031$ psi

Safety Margin = 1 - (stress / S)
= 1 - (5,031 / 16,700)
= 0.70

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5.2 Lifting Lug Evaluation

5.2.1 Bearing Check

The pin bearing area is:

Bearing area = $t \times D_{hole}$
= 0.375 x 1.0
= 0.375 in^2

To determine the most conservative load factor, the material yield and ultimate strengths will be normalized.

For SA240 Type 304 SS

$F_y / 3$ = 30,000 / 3 = 10,000 psi

$F_u / 5$ = 75,000 / 5 = 15,000 psi

Therefore, comparing a factor (LF) of 3 against yield is more restrictive.

The bearing stress is:

Stress = LF x (W / 3 lugs) / area
= 3 x (1,535 / 3) / 0.375
= 4,093 psi

The safety margin is:

Safety Margin = 1 - (stress / S_y)
= 1 - (4,093 / 30,000)
= 0.86

5.2.2 Net Tension

Area = $t\,(D_{lug} - D_{hole})$
= 0.375 (2.0 - 1.0)
= 0.375 in^2

NAC INTERNATIONAL	Performed by: gRD	Date: 11-25-96	Calculation No. 457-2001.2 Revision 1
	Checked by: RS	Date: 11/25/96	Page 11 of 14

The tensile stress is:

Stress = LF x (W / 3 lugs) / (Area)
= 3 x (1,535 / 3) / (0.375)
= 4,093 psi

The safety margin is:

Safety Margin = 1 - (stress / S_y)
= 1 - (4,093 / 30,000)
= 0.86

5.2.3 Shear Pull Out At 45 Degrees

Shear Area = t (R_{lug} - R_{hole})
= 0.375 (1.0 -0.5)
= 0.1875 in^2

The shear stress is:

Stress = LF x (W / 3 lugs) / (Shear Area)
= 3 x (1,535 / 3 lugs) / (0.1875)
= 8,187 psi

Safety Margin = 1 - (stress / (0.6 S_y))
= 1 - (8,187 / 18,000)
= 0.55

5.2.4 Lug To Lid Weld

The lug to lid is welded all-around with a 0.25" fillet. Consider the entire lug load is carried in shear along the vertical weld section:

A_{shear} = 2 x 0.707 x 0.25" x (11" - 4")
= 2.475 in^2

σ_{weld} = LF x (W / no. of lugs) / A_{shear}
= 3 x (1535 / 3) / 2.475
= 620 psi

Allowable is large compared to actual stress. Therefore, weld is adequate.

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	Checked by: TK	Date: 11/25/96	Page 12 of 14

6.0 SUMMARY OF RESULTS / CONCLUSIONS

Summary of Stress Analysis

Drawing No.	Item No.	Component	Applied Load	Design Check	Calculated Loading	Allowable	M.S.
457-106	1	lid flange	pressure	torsion	5,031 psi	16.7 ksi	0.70
457-106	2	bolt	pressure	tension	13,590 psi	16.7 ksi	0.19
457-106	8	lifting lug	3 times the weight	bearing	4,093 psi	30 ksi	0.86
				tension	4,093 psi	30 ksi	0.86
				shear	8,187 psi	18 ksi	0.55
457-106	Item 8 to Item 1	weld	3 times the weight	shear	620 psi	large compared to actual stress	large

Therefore the cold vacuum drying lid design meets the criteria defined in Section 4.2.

NAC INTERNATIONAL	Performed by: gRO	Date: 11-25-96	Calculation No. 457-2001.2 Revision 1
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Appendix A9.2.6 Seal Lid Calculation 457-2004.2

NAC INTERNATIONAL	CALCULATION PACKAGE COVER SHEET	Work Request/Calc No: 457-2004.2
PROJECT NAME: K Basin Operations Equipment	CLIENT: Hanford (Transnuclear, Inc.)	

CALCULATION TITLE:

Immersion Pail Lid

PROBLEM STATEMENT OR OBJECTIVE OF THE CALCULATION:

This calculation structurally evaluates the immersion pail seal lid for internal pressure and lid lifting load conditions. Maximum internal pressure is developed by the positive pressure anti-c water system. Additionally, the lid lifting lugs and welds are designed and evaluated to carry lid weight loading.

The immersion pail lid is part of the TN-WHC Cask and Transportation System to be used at K-basin area at the Hanford site.

Revision	Affected Pages	Revision Description	Preparer Name, Initials, Date	Checker Name, Initials, Date	Project Manager Approval/Date
0	1 thru 13	Original Issue	Jeffrey R. Dargis 11-10-96	Ravi Singh 11-14-96	Thomas A. Danner 11-15-96
1	1, 3 thru 14	Revised method of calculating margin of safety.	Jeffrey R. Dargis JRD 11-25-96	Ravi Singh RS 11/25/96	[signature] 11/25/96

1 Total Pages 14

Appendix A9.2.6 Seal Lid Calculation 457-2004.2 (Continued)

INDEPENDENT DESIGN VERIFICATION CHECK SHEET

Work Request/Calculation No: 457-2004.2 Revision 0

Scope Of Analysis File: This calculation structurally evaluates the immersion pail lid for internal pressure and lid lifting load conditions.

Review Methodology: Check Of Calculations RS
Alternate Analyses —
Other (Explain) —

Confirm That The Work Request / Calculation Package Reviewed Includes:

1. Statement of Purpose RS
2. Defined Method of Analysis RS
3. Listing of Assumptions RS
4. Detailed Analysis Record RS
5. Statement of Conclusions / Recommendations (if applicable) RS

Step	Activities	Verification Yes	No	N/A	Comments
1	For the scope of the defined analysis: A. Are the required data input complete? 1. Material properties 2. Geometry (drawing reference) 3. Loading source term *If a supporting analysis is required to define the load state, has it been defined?* B. Are boundary conditions acceptable?	✓ ✓ ✓ ✓			
2	Is the method of analysis adequate for the defined scope?	✓			
3	Is the worst case loading/configuration documented?	✓			
4	Are the acceptance criteria defined and complete?	✓			
5	Has all concurrent loading been considered?	✓			
6	Are analyses consistent with previous work for method and approach?			✓	NEW CALC. PACKAGE
7	Are the records for input and output complete?	✓			
8	Is traceability to verified software complete?			✓	NO SOFTWARE USED.
9	Is the statement of conclusions and recommendations complete and acceptable for the project and objectives of the defined purpose?	✓			

RAVI SINGH [signature]
Reviewer (Name/Signature)

11/14/96
Date

2

Appendix A9.2.6 Seal Lid Calculation 457-2004.2 (Continued)

INDEPENDENT DESIGN VERIFICATION CHECK SHEET

Work Request/Calculation No: 457-2004.2 Revision 1

Scope Of Analysis File: This calculation structurally evaluates the immersion pail lid for internal pressure and lid lifting load conditions.

Review Methodology: Check Of Calculations RS
Alternate Analyses —
Other (Explain) —

Confirm That The Work Request / Calculation Package Reviewed Includes:

1. Statement of Purpose RS
2. Defined Method of Analysis RS
3. Listing of Assumptions RS
4. Detailed Analysis Record RS
5. Statement of Conclusions / Recommendations (if applicable) RS

Step	Activities	Verification Yes	No	N/A	Comments
1	For the scope of the defined analysis: A. Are the required data input complete? 1. Material properties 2. Geometry (drawing reference) 3. Loading source term *If a supporting analysis is required to define the load state, has it been defined?* B. Are boundary conditions acceptable?	✓ ✓ ✓ ✓			
2	Is the method of analysis adequate for the defined scope?	✓			
3	Is the worst case loading/configuration documented?	✓			
4	Are the acceptance criteria defined and complete?	✓			
5	Has all concurrent loading been considered?	✓			
6	Are analyses consistent with previous work for method and approach?	✓			
7	Are the records for input and output complete?	✓			
8	Is traceability to verified software complete?			✓	NO SOFTWARE USED.
9	Is the statement of conclusions and recommendations complete and acceptable for the project and objectives of the defined purpose?	✓			

RAVI SINGH [signature] 11/25/96
Reviewer (Name/Signature) Date

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Appendix A9.2.6 Seal Lid Calculation 457-2004.2 (Continued)

1.0 SYNOPSIS OF RESULTS

Summary of Stress Analysis

Drawing No.	Item No.	Component	Applied Load	Design Check	Calculated Loading	Allowable	M.S.
457-103	2	lid flange	pressure	bending	8,936 psi	25.05 ksi	0.64
457-103	20	bolt	pressure	tension	4,201 psi	16.7 ksi	0.75
457-103	3	lifting lug	3 times the weight	bearing	1600 psi	30 ksi	0.95
				tension	1600 psi	30 ksi	0.95
				shear	3200 psi	18 ksi	0.82

The immersion pail lid design meets the criteria defined in Section 4.2.

2.0 INTRODUCTION / PURPOSE

This calculation structurally evaluates the immersion pail seal lid for internal pressure and lid lifting load conditions. Maximum internal pressure load is developed as by the positive pressure anti-c water system. Additionally the lid lifting lugs and welds are designed and evaluated to carry lid weight loading.

The immersion pail lid is part of the TN-WHC Cask and Transportation System to be used at K-basin area at the Hanford site. The immersion pail system was initially evaluated in Reference 7.1.

3.0 METHOD OF ANALYSIS

Hand calculations using classic textbook solutions are used to structurally evaluate the immersion pail lid design.

The lid design will be assessed for an internal pressure loading of 5 psi (Reference 7.4). Only the lid bolting and adjacent flange are influenced by a pressure loading of this level. For the bolting, the pressure induced stress will be compared to the ASME Code Class 2/3 (Reference 7.7) bolting allowable, S. For flange bending, the pressure induced stress will be limited to 1.5 S.

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The lifting lug acceptance criteria is to limit tension and bearing stresses to the lesser of:

(a) one-third material yield strength; or
(b) one-fifth the material ultimate strength.

Shear stresses will be limited to 0.6 times the tensile stress limits

The following evaluations are documented within this calculation:

- Lid Hold Down Evaluation; and
- Lifting Lug Assessment.

3.1 Lid Hold Down Evaluation

The lid is connected to the upper flange of the pail shell by four (4) ¾-10 bolts. The bolts attach the lid flange to the pail shell flange. The lid-to-pail shell contact is metal-to-metal. Two (2) silicon seals are also used in the lid design. The seal at the outer lid diameter seals the lid-to-pail shell connection. The inner seal seals the lid-to-MCO canister joint. The sealing is achieved by pressurizing the seals internally.

To evaluate the lid hold down, the following steps will be performed:

- The net pressure cross section and pressure load will be determined;
- The lid bolt load will be determined; and
- The maximum lid flange bending stress due to pressure will be determined.

3.2 Lifting Lug Evaluation

The lid has three (3) lifting lugs attached to the top surface of the lid. These lugs are used to install/remove the lid to/from the immersion pail. The lug bearing stress, net tension and shear pull out will be assessed. The lifting criteria of Reference 7.3 will be used to determine the adequacy of the lug design.

4.0 ASSUMPTIONS / DESIGN INPUTS

4.1 Assumptions

There are no unverified assumptions within this calculation.

NAC INTERNATIONAL	Performed by: JRD	Date: 11-25-96	Calculation No. 457-2004.2 Revision 1
	Checked by: RS	Date: 11/25/96	Page 6 of 14

4.2 Design Criteria

4.2.1 Bolt and Flange Bending Evaluation

Calculated bolt tensile stress (due to pressure)	< S	(Reference 7.7)
Calculated flange bending stress (due to pressure)	< 1.5 x S	(Reference 7.7)

4.2.2 Lift Lug Evaluation

Calculated tensile stress (based on load factor of 3)	$< S_{yield}$	(Ref. 7.3)
Calculated tensile stress (based on load factor of 5)	$< S_{ultimate}$	(Ref. 7.3)
Calculated shear stress (based on load factor of 3)	$< 0.6S_{yield}$	
Calculated shear stress (based on load factor of 5)	$< 0.6S_{ultimate}$	
Calculated bearing stress (based on load factor of 3)	$< S_{yield}$	
Calculated bearing stress (based on load factor of 5)	$< S_{ultimate}$	

4.3 Design Conditions

Pressure: 5 psi (Reference 7.4)
Temperature: Ambient, 100 °F

4.4 Component Properties

Eye Bolts:	(Reference 7.6.3)		
	Size:	¾ - 10	
	Material:	Commercial SS	
	Area:	0.334 in^2	(Reference 7.9.1)
	Threading:	¾-10 UNC -2A	(Reference 7.6.3)
	Supplier:	McMaster-Carr	
		Part No. 8891T84	
Lid flange:	Size:	3/8 plate	
	$D_{i\ flg}$:	41.78 + (2 x 0.07) = 41.92 in	(Reference 7.6.3)
	$D_{o\ flg}$:	45.75 in	
	Material:	ASTM A240, Type 304	
Lift Lug:	(Reference 7.6.3)		
	Thickness:	0.375 in	
	D_{lug}:	2.0 in	
	D_{hole}:	1.0 in	
	Material:	ASTM A240, Type 304	

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Lid Weight: 600 lbs. (Reference 7.6.3)

4.5 Material Properties

- ASTM A240
  (Note: use SA240, Type 304 SS properties)
  (Reference 7.7.1, 7.7.2)
  Fy: 30 ksi
  Fu: 75 ksi (100°)

- SA240, Type 304
  (Reference 7.7.4)
  S: 16,700 psi (at 200 degrees)

- 304 SS, commercial grade
  (Note: SA240, Type 304 properties used.)

5.0 ANALYSIS DETAIL

5.1 Lid Hold Down Evaluation

5.1.1 Lid Bolt Pressure Load Evaluation

The lid pressure surface area , A, is:

$$A = \Pi / 4 \left(D_o^2 - D_i^2 \right)$$

$$A = \Pi / 4 \ (45.75^2 - 25.77^2)$$

$$A = 1{,}122 \text{ in}^2$$

The net pressure load, F, is;

$$F = \text{pressure x area}$$

$$= 5 \times 1122$$

$$= 5{,}610 \text{ lbs.}$$

The lid bolt load, F_{bolt} , is;

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F_{bolt} = F / no. bolts
= F / 4
= 5610 / 4
= 1,403 lbs.

The bolt tensile stress is:

Stress = F_{bolt} / area
= 1403 / 0.334
= 4,201 psi

The bolt allowable stress, S is:

S = 16,700 psi

The safety margin is:

Safety Margin = 1 - (stress / S)
= 1 - (4,201 / 16,700)
= 0.75

5.1.2 <u>Lid Flange Pressure Stress Evaluation</u>

The lid flange is a tab type extension from the center ring. The bending of the tab due to the pressure load is determined below.

Consider the tab as a cantilever beam of length L where;

$L = 0.5\,(D_{o\,flg} - D_{i\,flg})$

$= 0.5\,(45.75 - 41.92)$

$= 1.915$ in

$\cong 2.0$ in.

The bending moment , M, is (considering the bolt location at ½ L);

$M = F_{bolt} \times L/2$

$= 1403 \times 2/2$

$= 1403$ in-lbs

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Appendix A9.2.6 Seal Lid Calculation 457-2004.2 (Continued)

Only four bolts are used to connect the lid. The bending moment, M, is reacted by the effective flange arc length which is estimated to be ½ the geometric arc associated with each bolt.

Therefore the bolt arc angle is;

$$\text{arc}\angle = 38° - [(1.25 / (45.75 / 2)) \times (180° / \Pi)]$$
$$= 34.87°$$

Therefore the effective arc angle is:

$$\text{arc}\angle_{\text{effective}} = 34.87 / 2$$
$$= 17.44°$$

The arc length is:

$$\text{arc length} = r_{\text{bolt}} \times \text{arc}\angle_{\text{effectiv}}$$
$$= (44 / 2) \times (17.44 \times \Pi / 180°)$$
$$= 6.7 \text{ in}$$

The effective section I/c is:

$$I = bt^3/12$$
$$= 6.7(0.375)^3/12$$
$$= 0.0294 \text{ in}^4$$

$$I/c = bt^2/6$$
$$= 6.7\,(0.375)^2/6$$
$$= 0.157 \text{ in}^3$$

The bending stress, σ_b, is therefore:

$$\sigma_b = M \times c / I$$
$$= 1403 \times (1 / 0.157)$$
$$= 8{,}936 \text{ psi}$$

The safety margin is:

$$\text{Safety Margin} = 1 - (\text{stress} / (1.5 \times S))$$
$$= 1 - (8{,}936 / (1.5 \times 16{,}700))$$
$$= 0.64$$

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Appendix A9.2.6 Seal Lid Calculation 457-2004.2 (Continued)

Conservatively computing the deflection of the flange:

$\Delta = F_{bolt} \times (L/2)^3 / (3\ E\ I)$

$= 1403 \times (2/2)^3 / (3 \times 28.3 \times 10^6 \times 0.0294)$

$= 0.00056$ in

The deflection of the flange is negligible.

5.2 Lifting Lug Evaluation

5.2.1 Bearing Check

The pin bearing area is:

Bearing area $= t \times D_{hole}$
$= 0.375 \times 1.0$
$= 0.375\ in^2$

To determine the most conservative load factor, the material yield and ultimate strengths will be normalized.

For SA240 Type 304 SS

$F_y / 3 = 30{,}000 / 3 = 10{,}000$ psi

$F_u / 5 = 75{,}000 / 5 = 15{,}000$ psi

Therefore, comparing a factor (LF) of 3 against yield is more restrictive.

The bearing stress is:

Stress = LF x (W / 3 lugs) / area
= 3 x (600 / 3) / 0.375
= 1,600 psi

The safety margin is:

Safety Margin = $1 - (stress / S_y)$
= 1 - (1,600 / 30,000)
= 0.95

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5.2.2 Net Tension

Area = $t (D_{lug} - D_{hole})$
= 0.375 (2.0 -1.0)
= 0.375 in^2

The stress is:

Stress = LF x (W / 3 lugs) / (Area)
= 3 x (600 / 3) / (0.375)
= 1,600 psi

The safety margin is:

Safety Margin = 1 - (stress / S_y)
= 1 - (1,600 / 30,000)
= 0.95

5.2.3 Shear Pull Out At 45 Degrees

Shear Area = $t (R_{lug} - R_{hole})$
= 0.375 (1.0 -0.5)
= 0.1875 in^2

The shear stress is:

Stress = LF x (W / 3 lugs) / (Shear Area)
= 3 x (600 / 3lugs) / (0.1875)
= 3.200 psi

The safety margin is:

Safety Margin = 1 - (stress / (0.6 x S_y)
= 1 - (3,200 / (0.6 x 30,000))
= 0.82

5.2.4 Lug to Lid Weld

The lug to lid weld is a 0.25" all-around weld and is negligibly loaded. Allowable is very large compared to actual stress. Therefore, weld is adequate.

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Appendix A9.2.6 Seal Lid Calculation 457-2004.2 (Continued)

6.0 SUMMARY OF RESULTS / CONCLUSIONS

Summary of Stress Analysis

Drawing No.	Item No.	Component	Applied Load	Design Check	Calculated Loading	Allowable	M.S.
457-103	2	lid flange	pressure	bending	8,936 psi	25.05 ksi	0.64
457-103	20	bolt	pressure	tension	4,201 psi	16.7 ksi	0.75
457-103	3	lifting lug	3 times the weight	bearing	1600 psi	30 ksi	0.95
				tension	1600 psi	30 ksi	0.95
				shear	3200 psi	18 ksi	0.82

The immersion pail lid design meets the criteria defined in Section 4.2.

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Appendix A9.2.6 Seal Lid Calculation 457-2004.2 (Continued)

7.0 REFERENCES

7.1 Preliminary Design Analysis Report For The TN-WHC Cask and Transporation System
Project 3035
Transnuclear, Inc.

7.2 Not Used.

7.3 ANSI N14.6
American National Standard for Radioactive Materials
"special lifting devices for shipping containers weighing 10,000 lbs (4,500 kg) or more"

7.4 Memo to Project File From T. A. Danner, dated July 31, 1996.

7.5 Hanford ECN 191402.

7.6 K Basin Immersion Pail Assembly TN WHC Transport Cask drawings
- 7.6.1 Project 457 drawing 106 sheets 1, 2/2
- 7.6.2 Project 457 drawing 102 sheets 1, 2/2.
- 7.6.3 Project 457 drawing 103 sheets 1, 2/2.
- 7.6.4 Project 457 drawing 104 sheet 1/1

7.7 ASME Boiler & Pressure Vessel Code, 1995 edition.
- 7.7.1 Section II-D, page 530, Table Y-1
- 7.7.2 Section II-D, page 441,Table U
- 7.7.3 Section II-D, page 392 Table 3
- 7.7.4 Section II-D, page 432, 496

7.8 Shigley's Mechanical Engineering Design, McGraw Hill, 1963, Page 603

7.9 AISC Manual Of Steel Construction, 9th edition.
- 7.9.1 Page 4-147.

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Appendix A9.2.7 Loadout Pit Work Platform 457-2007.2

NAC INTERNATIONAL	CALCULATION PACKAGE COVER SHEET	Work Request/Calc No: 457-2007.2
PROJECT NAME: K Basin Operations Equipment	CLIENT: Hanford (Transnuclear, Inc.)	

CALCULATION TITLE:

Loadout Pit Work Platform

PROBLEM STATEMENT OR OBJECTIVE OF THE CALCULATION:

This calculation evaluates the loadout pit work platform for design loads based on OSHA requirements defined in Title 29 of the Code of Federal Regulations. The loadout pit platform is part of the TN-WHC Cask and Transportation System to be used at the K-Basin Area of the Hanford site.

Revision	Affected Pages	Revision Description	Preparer Name, Initials, Date	Checker Name, Initials, Date	Project Manager Approval/Date
0	1 thru 14	Original Issue	Jeffrey R. Dargis 11-10-96	Ravi Singh 11-14-96	Thomas A. Danner 11-15-96
1	1, 3 thru 15	Revised method of calculating margin of safety. Revised method of calculating weld allowable.	Jeffrey R. Dargis JRD 11-25-96	Ravi Singh RS 11/25/96	[signature] 11/25/96

1 Total Pages 15

Appendix A9.2.7 Loadout Pit Work Platform 457-2007.2 (Continued)

INDEPENDENT DESIGN VERIFICATION CHECK SHEET

Work Request/Calculation No: 457-2007.2 Revision 0

Scope Of Analysis File: This calculation evaluates the loadout pit work platform for design loads based on OSHA requirements defined in Title 29 of the CFR.

Review Methodology:
Check Of Calculations RS
Alternate Analyses –
Other (Explain) –

Confirm That The Work Request / Calculation Package Reviewed Includes:

1. Statement of Purpose RS
2. Defined Method of Analysis RS
3. Listing of Assumptions RS
4. Detailed Analysis Record RS
5. Statement of Conclusions / Recommendations (if applicable) RS

Step	Activities	Verification Yes	No	N/A	Comments
1	For the scope of the defined analysis: A. Are the required data input complete? 1. Material properties 2. Geometry (drawing reference) 3. Loading source term *If a supporting analysis is required to define the load state, has it been defined?* B. Are boundary conditions acceptable?	 ✓ ✓ ✓ ✓ ✓			
2	Is the method of analysis adequate for the defined scope?	✓			
3	Is the worst case loading/configuration documented?	✓			
4	Are the acceptance criteria defined and complete?	✓			
5	Has all concurrent loading been considered?	✓			
6	Are analyses consistent with previous work for method and approach?			✓	NEW CALC PACKAGE
7	Are the records for input and output complete?	✓			
8	Is traceability to verified software complete?			✓	NO SOFTWARE USED.
9	Is the statement of conclusions and recommendations complete and acceptable for the project and objectives of the defined purpose?	✓			

RAVI SINGH Ravindra Singh 11/14/96
Reviewer (Name/Signature) Date

2

Appendix A9.2.7 Loadout Pit Work Platform 457-2007.2 (Continued)

INDEPENDENT DESIGN VERIFICATION CHECK SHEET

Work Request/Calculation No: 457-2007.2 Revision 1

Scope Of Analysis File: This calculation evaluates the loadout pit work platform for design loads based on OSHA requirements defined in Title 29 of the CFR.

Review Methodology:
- Check Of Calculations RS
- Alternate Analyses —
- Other (Explain) —

Confirm That The Work Request / Calculation Package Reviewed Includes:

1. Statement of Purpose RS
2. Defined Method of Analysis RS
3. Listing of Assumptions RS
4. Detailed Analysis Record RS
5. Statement of Conclusions / Recommendations (if applicable) RS

Step	Activities	Verification Yes	No	N/A	Comments
1	For the scope of the defined analysis: A. Are the required data input complete? 1. Material properties 2. Geometry (drawing reference) 3. Loading source term *If a supporting analysis is required to define the load state, has it been defined?* B. Are boundary conditions acceptable?	 ✓ ✓ ✓ ✓			
2	Is the method of analysis adequate for the defined scope?	✓			
3	Is the worst case loading/configuration documented?	✓			
4	Are the acceptance criteria defined and complete?	✓			
5	Has all concurrent loading been considered?	✓			
6	Are analyses consistent with previous work for method and approach?	✓			
7	Are the records for input and output complete?	✓			
8	Is traceability to verified software complete?			✓	NO SOFTWARE USED.
9	Is the statement of conclusions and recommendations complete and acceptable for the project and objectives of the defined purpose?	✓			

RAVI SINGH [signature] 11/25/96

Reviewer (Name/Signature) Date

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1.0 SYNOPSIS OF RESULTS

Summary of Stress Analysis

Drawing No.	Item No.	Component	Applied Load	Design Check	Calculated Loading	Allowable	M.S.
457-111	4, 5, 3	brace, extension, brace	2000 lbs	tube bending shear	22,077 psi 2,000 psi	27,600 psi 18,400 psi	0.20 0.89
457-111	5 to 9	weld	2000 lbs	combined shear and tension	1,824 lbs / in	2,545 lbs / in	0.28
457-111	9 to 7	weld	2000 lbs	weld shear	0.133 ksi	14.4 ksi	0.99

The loadout pit work platform design meets the criteria defined in Section 4.2.

2.0 INTRODUCTION / PURPOSE

This calculation evaluates the loadout pit work platform against the criteria requirements listed in Section 4.2. The loadout pit work platform is part of the TN-WHC Cask and Transportation System to be used at the K-Basin Area of the Hanford site. The loadout pit work platform design was initially evaluated in Reference 7.1.

3.0 METHOD OF ANALYSIS

Hand calculations using classic textbook solutions are used to structurally evaluate the loadout pit work platform.

The design will be assesed using the design load developed in Section 5.1. The design loading considers OSHA requirements defined in Title 29 of the Code of Federal Regulations (Reference 7.5). The acceptance criteria limits the induced loads to the requirements of the AISC Code (Reference 7.7).

The work platform configuration consists of a tubing frame arrangement covered by steel decking. The frame is cantilevered off a wall plate and utilizes a brace for additional strength. The wall plate consists of three (3) plates welded in an inverted "U" configuration for suspension of the platform from the pit beam support structure. Drawing details are provided in Reference 7.6.

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The following evaluations are documented within this calculation.

- Design Load Development;
- Brace Evaluation;
- Extension / Brace Evaluation;
- Frame / Wall Plate Interface Weld Evaluation;
- Wall Plate Weld Evaluation; and
- Wall Plate Saddle Evaluation.

4.0 ASSUMPTIONS / DESIGN INPUTS

4.1 Assumptions

There are no unverified assumptions within this calculation.

4.2 Design Criteria

4.2.1 Loading

See Section 5.1.

4.2.2 Bending Stress Limits

Bending stress < 0.6 x S_y (Reference 7.7.2)

4.2.3 Shear Stress Limits

Shear stress < 0.4 x S_y (Reference 7.7)

4.2.4 Weld Limits

Weld Allowable Stress Limits < 0.4 x F_y of base metal (fillet, penetration) (Reference 7.7, AISC Table J2.5, page 5-70)

4.2.5 Platform Parameters (Reference 7.6.1)

Brace: Tube steel
2" x 4" x 0.25" x 45.50 in long
ASTM A500 GR B

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Extension:	Tube steel 2" x 4" x 0.25" x 14.22 in long ASTM A500 GR B
Brace:	Tube steel 2" x 4" x 0.25" x 15.33 in long ASTM A500 GR B
Wall Plate:	24" x 30" x 0.625 in ASTM A36
Toe Kick Plate / End Caps:	0.25 in thick ASTM A36
Decking Surface:	0.375" x 46.0" x 14.22 in diamond plate

4.2.6 Section Properties (Reference 7.7.3)

Tube Steel 2" x 4" x 0.25 in

Area = 2.59 in^2
I_{xx} = 4.69 in^4
S_x = 2.35 in^3
I_{yy} = 1.54 in^4
S_y = 1.54 in^3

4.2.7 Material Properties

ASTM A36 Carbon Steel
(Reference 7.7.4)
Fy: 32 ksi
Fu: 58 ksi

ASTM A500 GR B Carbon Steel
(Reference 7.7.5)
Fy: 46 ksi
Fu: 58 ksi

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5.0 ANALYSIS DETAIL

5.1 Design Load Development

The design load, F, is based on the larger of the following two (2) conditions:

Condition A: The heavy duty uniform loading of 29CFR1910 (Reference 7.5.2) multiplied by a load factor (LF) of four (4). The uniform distributed load, p, is 75 lbs / ft^2.

Condition B: Each platform section carrying a load equal to the maximum intended load multiplied by a load factor (LF) of four (4). The maximum intended load, P, shall be considered to be equal to two men, each weighing 250 lbs.

$$F_A = p \times (\text{area}) \times LF$$

$$= 75 \times \left(\frac{46.0 \times 14.22}{144}\right) \times 4$$

$$= 1363 \text{ lbs}$$

$$F_B = P \times 4$$

$$= (2 \times 250) \times 4$$

$$= 2000 \text{ lbs}$$

$$F = \text{Greater of } F_A \text{ or } F_B$$

$$= 2000 \text{ lbs}$$

5.2 Brace Evaluation

The critical brace stress is located at the interface point with the extension. The notch connection will develop the full capacity of the brace (i.e., interface weld is full penetration on top and bottom, fillet on sides).

5.2.1 Bending Stress Evaluation

Conservatively considering the brace as a cantilevered structure fixed at the extension interface with the design load applied as a concentrated load at the platform's edge:

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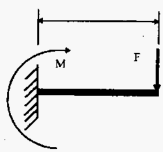

where:

$L = (46.0 - 12.0) / 2$

$= 17.0$ in

$F = 2000$ lbs

$M = L \times F$

$= 17.0 \times 2000$

$= 34,000$ in-lbs

The bending stress is:

$\sigma_b = M / S_y$

$= 34,000 / 1.54$

$= 22,077$ psi

The allowable bending stress is:

$F_b = 0.6 \times F_y$

$= 0.6 \times 46,000$

$= 27,600$ psi

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The margin of safety is:

$$MS = 1 - \frac{\sigma_b}{F_b}$$

$$= 1 - \frac{22{,}077}{27{,}600}$$

$$= 0.20$$

5.2.2 Shear Stress Evaluation

The shear stress is:

σ_v = F / (2 x area)

= 2000 / (2 x 0.25 x 2)

= 2000 psi

The allowable shear stress is:

$F_v = 0.4 \times F_y$

$= 0.4 \times 46{,}000$

= 18,400 psi

The margin of safety is:

$$MS = 1 - \frac{\sigma_v}{F_v}$$

$$= 1 - \frac{2{,}000}{18{,}400}$$

$$= 0.89$$

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5.2.3 Deflection Evaluation

Per Reference 7.4.1, the platform deflection, Δ, is:

$$\Delta = \frac{1}{3}\frac{F\,L^3}{(E)\,(I_{yy})}$$

$$= \frac{1}{3}\frac{(2000)\,(17.0)^3}{(28.3 \times 10^6)\,(1.54)}$$

$$= 0.075 \text{ in}$$

The platform deflection is insignificant.

5.3 Extension / Brace Evaluation

Two (2) extensions are cantilevered from the wall, each a distance 14.22". This is less than the distance of 17" previously evaluated in Section 5.1 for the brace. Therefore, the results from Section 5.1 are conservative for the extension pieces. No further evaluation is required.

5.4 Frame / Wall Plate Interface Weld Evaluation

The kicker is welded to the wall plate via a 0.25 in all-around fillet.

The shear stress in the weld is:

$$\sigma_v = F \;/\; L_{weld}$$

where:

$$L_{weld} = 2 + 2 + 4 + 4$$

$$= 12 \text{ in (per kicker)}$$

Therefore:

$$\sigma_v = 2000 \;/\; (2 \times 12)$$

$$= 83 \text{ lbs / in}$$

The tensile stress in the weld is:

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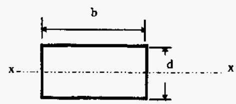
$\sigma_t = M / (2 \times S_w)$ (for both kickers)

where:

$M = 34{,}000$ in-lbs (from Section 5.2.1)



$S_w = b\,d + \dfrac{d^2}{3}$ (Reference 7.10)

$= (4 \times 2) + [(2)^2 / 3]$

$= 9.33\ in^2$

Therefore:

$\sigma_t = 34{,}000 / (2 \times 9.33)$

$= 1822$ lbs / in

The resultant weld stress, σ_r, is:

$\sigma_r = (\sigma_v{}^2 + \sigma_t{}^2)^{1/2}$

$= ((83)^2 + (1822)^2)^{1/2}$

$= 1{,}824$ lbs / in

The allowable weld stress per Section 4.2.4 is:

$F_w = 0.4 \times F_y \times l_{throat}$

$= 0.4 \times 36{,}000 \times (0.707 \times 0.25)$

$= 2{,}545$ lbs / in

The margin of safety is:

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$$MS = 1 - \frac{\sigma_r}{F_w}$$

$$= 1 - \frac{1,824}{2,545}$$

$$= 0.28$$

5.5 Wall Plate Weld Evaluation

The wall mounting plate is constructed by welding Items 7, 8, and 9. The 9 to 7 weld stress for the full penetration weld of a 0.625 in plate is as follows:

$$\sigma_v = F / A_{weld}$$

where:

t = plate thickness

= 0.625 in

l = weld length

= 24.0 in

$$A_{weld} = t \times l$$

$$= 0.625 \times 24.0$$

$$= 15.0 \text{ in}^2$$

$$\sigma_v = 2000 / 15.0$$

$$= 133 \text{ psi}$$

The weld stress is insignificant compared to the weld allowable, F_w :
F_w = 0.4 x F_y (base metal) = 14,400 psi.

5.6 Wall Plate Saddle Evaluation

The calculation performed under Section 5.5 demonstrates that the saddle itself will develop insignificant stresses.

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6.0 SUMMARY OF RESULTS/CONCLUSIONS

Summary of Stress Analysis

Drawing No.	Item No.	Component	Applied Load	Design Check	Calculated Loading	Allowable	M.S.
457-111	4, 5, 3	brace, extension, brace	2000 lbs	tube bending shear	22,077 psi 2,000 psi	27,600 psi 18,400 psi	0.25 0.89
457-111	5 to 9	weld	2000 lbs	combined shear and tension	1,824 lbs / in	2,545 lbs / in	0.28
457-111	9 to 7	weld	2000 lbs	weld shear	0.133 ksi	14.4 ksi	0.99

The loadout pit work platform design meets the criteria defined in Section 4.2.

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7.0 REFERENCES

7.1 Preliminary Design Analysis Report For The TN-WHC Cask and Transporation System
Project 3035
Transnuclear, Inc.

7.2 Not Used.

7.3 ASME Code Case N-71-16, Table 2.

7.4 Roark's Formulas for Stress and Strain, 3rd edition.
7.4.1 Table III, Case 1, page 100.

7.5 Code Of Federal Regulations
Title 29, Part 1910.28
Safety Requirements For Scaffolding
7.5.1 Page 114, (d)8, Tubular Welded Frame Scaffolds.
7.5.2 Page 112, Table D-9.

7.6 K Basin Immersion Pail Assembly TN WHC Transport Cask Drawings.
7.6.1 Project 457, Drawing 111, sheets 1, 2 / 2.

7.7 AISC Manual Of Steel Construction, 9th edition.
7.7.1 Table J2.5.
7.7.2 Page 5-45, Chapter F, Equation F1-1 (bending).
7.7.3 Page 1-103.
7.7.4 Page 1-7, Table 1.
7.7.5 Page 1-92, Table 3.
7.7.6 Page 5-135, Table C-C2.1.
7.7.7 Page 3-52.

7.8 ASME Boiler & Pressure Vessel Code, 1995 Edition, Section III, Division 1.

7.9 Hanford ECN 191402.

7.10 Blodgett's Design Of Welded Structures, 1966.

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Appendix A9.2.8 Trailer Work Platform 457-2002.2

NAC INTERNATIONAL	CALCULATION PACKAGE COVER SHEET	Work Request/Calc No: 457-2002.2
PROJECT NAME: K Basin Operations Equipment	CLIENT: Hanford (Transnuclear, Inc.)	
CALCULATION TITLE: Transport Trailer Work Platform		

GEORGIA REGISTERED No. 15706 PROFESSIONAL ENGINEER NORMAN M. MEINERT

PROBLEM STATEMENT OR OBJECTIVE OF THE CALCULATION:

This calculation evaluates the transport trailer work platform for design loads based on OSHA requirements defined in Title 29 of the Code of Federal Regulations. The acceptance criteria limits the induced loads to the requirements of the AISC Code.

The transport trailer work platform is part of the TN-WHC Cask and Transportation System to be used at the K-Basin Area of the Hanford site.

Revision	Affected Pages	Revision Description	Preparer Name, Initials, Date	Checker Name, Initials, Date	Project Manager Approval/Date
0	1 thru 12 A1 thru A4	Original Issue	Ravi Singh 11-11-96	Jeffrey R. Dargis 11-11-96	Thomas A. Danner 11-15-96
1	1, 3 thru 13	Revised method of calculating margin of safety.	Ravi Singh RS 11/25/96	Jeffrey R. Dargis JRD 11-25-96	[signature] 11/25/96

1 Total Pages 17

Appendix A9.2.8 Trailer Work Platform 457-2002.2 (Continued)

INDEPENDENT DESIGN VERIFICATION CHECK SHEET

Work Request/Calculation No: 457-2002.2 Revision 0

Scope Of Analysis File: This calculation evaluates the transport trailer platform for design loads based on OSHA requirements defined in Title 29 of the CFR.

Review Methodology:
- Check Of Calculations JRD
- Alternate Analyses N/A
- Other (Explain) N/A

Confirm That The Work Request / Calculation Package Reviewed Includes:

1. Statement of Purpose JRD
2. Defined Method of Analysis JRD
3. Listing of Assumptions JRD
4. Detailed Analysis Record JRD
5. Statement of Conclusions / Recommendations (if applicable) JRD

Step	Activities	Verification Yes	No	N/A	Comments
1	For the scope of the defined analysis: A. Are the required data input complete? 1. Material properties 2. Geometry (drawing reference) 3. Loading source term *If a supporting analysis is required to define the load state, has it been defined?* B. Are boundary conditions acceptable?	✓ ✓ ✓ ✓			
2	Is the method of analysis adequate for the defined scope?	✓			
3	Is the worst case loading/configuration documented?	✓			
4	Are the acceptance criteria defined and complete?	✓			
5	Has all concurrent loading been considered?	✓			
6	Are analyses consistent with previous work for method and approach?			✓	ORIGINAL DESIGN NO PREVIOUS ANALYSIS PERFORMED
7	Are the records for input and output complete?	✓			
8	Is traceability to verified software complete?			✓	COMPUTER SOFTWARE NOT USED
9	Is the statement of conclusions and recommendations complete and acceptable for the project and objectives of the defined purpose?	✓			

JEFFREY R DARGIS / Jeffrey R Dargis 11-11-96

Reviewer (Name/Signature) Date

2

Appendix A9.2.8 Trailer Work Platform 457-2002.2 (Continued)

INDEPENDENT DESIGN VERIFICATION CHECK SHEET

Work Request/Calculation No: 457-2002.2 Revision 1

Scope Of Analysis File: This calculation evaluates the transport trailer platform for design loads based on OSHA requirements defined in Title 29 of the CFR.

Review Methodology:
Check Of Calculations JRD
Alternate Analyses N/A
Other (Explain) N/A

Confirm That The Work Request / Calculation Package Reviewed Includes:

1. Statement of Purpose JRD
2. Defined Method of Analysis JRD
3. Listing of Assumptions JRD
4. Detailed Analysis Record JRD
5. Statement of Conclusions / Recommendations (if applicable) JRD

Step	Activities	Verification Yes	No	N/A	Comments
1	For the scope of the defined analysis: A. Are the required data input complete? 1. Material properties 2. Geometry (drawing reference) 3. Loading source term *If a supporting analysis is required to define the load state, has it been defined?* B. Are boundary conditions acceptable?	 ✓ ✓ ✓ ✓			
2	Is the method of analysis adequate for the defined scope?	✓			
3	Is the worst case loading/configuration documented?	✓			
4	Are the acceptance criteria defined and complete?	✓			
5	Has all concurrent loading been considered?	✓			
6	Are analyses consistent with previous work for method and approach?	✓			
7	Are the records for input and output complete?	✓			
8	Is traceability to verified software complete?			✓	Computer Software Not Used.
9	Is the statement of conclusions and recommendations complete and acceptable for the project and objectives of the defined purpose?	✓			

JEFFREY R. DAROIS / Jeffrey R Darois 11-25-96
Reviewer (Name/Signature) Date

3

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Appendix A9.2.8 Trailer Work Platform 457-2002.2 (Continued)

1.0 SYNOPSIS OF RESULTS

Summary of Stress Analysis

Drawing No.	Item No.	Component	Applied Load	Design Check	Calculated Loading	Allowable	M.S.
457-105	24	channel	125 lb/ft	bending	8,676 psi	21,000 psi	0.59
				shear	820 psi	14,000 psi	0.94
457-105	26	plank hook	591 lbs	bearing	1,182 psi	35,000 psi	0.97

The transport trailer work platform design meets the criteria defined in Section 4.2.

2.0 INTRODUCTION / PURPOSE

This calculation evaluates the transport trailer work platform for design loads based on OSHA requirements defined in Title 29 of the Code of Federal Regulations. The transport trailer work platform is part of the TN-WHC Cask and Transportation System to be used at the K-Basin Area of the Hanford site.

3.0 METHOD OF ANALYSIS

Hand calculations using classic textbook solutions are used to structurally evaluate the transport trailer work platform.

The design will be assessed using the design load developed in Section 5.1. The design loading considers OSHA requirements defined in Title 29 of the Code of Federal Regulations (Reference 7.5). The acceptance criteria limits the induced loads to the requirements of the AISC Code (Reference 7.7).

The work platform configuration evaluated herein consists of a plank 113.45" long and 29.29" wide supported by 4 x 0.180 aluminum channels. The channels will rest on the platform pipe when in use.

The framing components of the platform are standard catalog components supplied to the requirements of Reference 7.5. Maximum unbraced lengths in the design are limited to 6'-0" as specified in Reference 7.2 (Appendix A). Therefore, these items do not require specific stress evaluations. Drawing details are provided in Reference 7.6.1.

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The following evaluations are documented within this calculation.

- Design Load Development;
- Channel 4 x .180 Evaluation;
- Supporting Pipe Evaluation; and
- End Cap Evaluation.

4.0 ASSUMPTIONS / DESIGN INPUTS

4.1 Assumptions

There are no unverified assumptions within this calculation.

4.2 Design Criteria

4.2.1 Loading

See Section 5.1.

4.2.2 Stress Limits

Bending stress < 0.6 x S_y (Reference 7.7)

Shear stress < 0.4 x S_y (Reference 7.7)

4.2.3 Platform Parameters (Reference 7.6)

Channel: 4" x 0.180" x 113.45 in long
ASTM B308

Pipe: 1 1/2" NPS
ASTM A53

4.2.4 Material Properties

ASTM B308 Aluminum
(Reference 7.3)
Fy: 35 ksi
Fu: 38 ksi

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5.0 ANALYSIS DETAIL

5.1 Design Load Development

The design load, F, is the based on the larger of the following two (2) conditions:

Condition A: The light duty uniform loading of 29CFR1910 (Reference 7.5) multiplied by a load factor (LF) of four (4). The uniform distributed load, p, is 25 lbs / ft^2.

Condition B: Each platform section carrying a load equal to the maximum intended load multiplied by a load factor (LF) of four (4). The maximum intended load, P, shall be considered to be equal to two men, each weighing 250 lbs.

F_A = p x (area) x LF

= 25 x 113.45 x 29.29 x 4 / 144

= 2308 lbs

F_B = P x 4

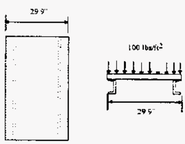
= (2 x 250) x 4

= 2000 lbs

F = Greater of F_A or F_B

= 2308 lbs

For the channel evaluation. an equivalent loading equal to 25 x 4 = 100 psf will be applied. Converting this to a linear loading per channel:



w = 100 psf x 29.9 in / [(12 in/ft) x 2 channels] = 125 lbs ft.

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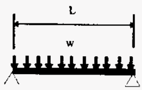
5.2 Channel Evaluation

The channel is supported by the scaffolding pipe at each end by caps, thus developing a simply supported beam loading configuration:



where:

L = 9.45 ft

w = 125 lbs/ft

$$M = \frac{wl^2}{8}$$

$$= \frac{125 \times 9.45^2}{8}$$

= 1,395 ft-lbs

= 16,744 in-lbs

The bending stress is:

σ_b = M / S_y

= 16,744 / 1.93 (use C4 x 5.4 section modulus from Reference 7.7)

= 8,676 psi

The allowable bending stress is:

F_b = 0.6 x F_y

= 0.6 x 35,000 psi

= 21,000 psi

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The margin of safety is:

$$MS = 1 - \frac{\sigma_b}{F_b}$$

$$= 1 - \frac{8,676}{21,000}$$

$$= 0.59$$

The shear stress is:

σ_v = (w x L) / (2 channels x width of channel web x web thickness)

= 125 x 9.45 / (2 x 4 x 0.18)

= 820 psi

The allowable shear stress is:

$F_v = 0.4 \times F_y$

$= 0.4 \times 35,000$ psi

$= 14,000$ psi

The margin of safety is:

$$MS = 1 - \frac{\sigma_v}{F_v}$$

$$= 1 - \frac{820}{14,000}$$

$$= 0.94$$

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5.2 Pipe Evaluation

10CFR29, Part 1910.28 specifies nominal two inch (2") O.D. tube for scaffolding. The drawing calls out 1.5 inch commercial pipe with a schedule 40 designation. The acceptance of the 1.5 inch pipe will be justified by comparing its sectional properties to those of the 2 inch tube.

PROPERTIES	2 IN TUBE	1.5 IN SCH 40 PIPE
Metal Area	0.7087 in^2	0.799 in^2
Section Modulus	0.314 in^3	0.326 in^3

This comparison shows that 1.5 inch schedule 40 pipe is slightly stronger than the two inch (2") tube with a maximum wall thickness of 0.120 inches. Therefore, the 1.5 inch schedule 40 pipe will perform as well as the two inch (2") tube.

The tube properties are based on 2" tube with a 0.120 inch wall thickness (Page 8-213 of Reference 7.4). The section modulus is based on the hollow circle formulas referenced on page 6-20 of Reference 7.7. The properties for 1.5 inch pipe are from page 1-93 of Reference 7.7.

5.4 End Cap Evaluation

The end cap is a 1/4 inch thick aluminum plate. Its basic loading scheme is in direct bearing.

$\sigma_v = F / A_{bearing}$

where:

$F = w \times L / 2$ channels
$= 125 \times 9.45 / 2$
$= 591$ lbs

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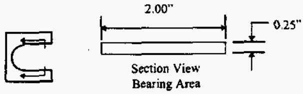

$$A_{bearing} = 2 \times 0.25$$
$$= 0.5 \text{ inch}^2$$

The bearing stress is:

$$\sigma_b = 591 / 0.5$$
$$= 1182 \text{ psi}$$

The allowable bearing stress is:

$$F_b = F_y$$
$$= 35{,}000 \text{ psi}$$

The margin of safety is:

$$MS = 1 - \frac{\sigma_b}{F_b}$$
$$= 1 - \frac{1{,}182}{35{,}000}$$
$$= 0.97$$

The plate is welded with 1/4 inch fillet weld on both sides. Therefore, the weld stress is insignificant. No further evaluation is required.

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Appendix A9.2.8 Trailer Work Platform 457-2002.2 (Continued)

6.0 SUMMARY OF RESULTS/CONCLUSIONS

Summary of Stress Analysis

Drawing No.	Item No.	Component	Applied Load	Design Check	Calculated Loading	Allowable	M.S.
457-105	24	channel	125 lb/ft	bending	8,676 psi	21,000 psi	0.59
				shear	820 psi	14,000 psi	0.94
457-105	26	plank hook	591 lbs	bearing	1,182 psi	35,000 psi	0.97

The transport trailer work platform design meets the criteria defined in Section 4.2.

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7.0 REFERENCES

7.1 Preliminary Design Analysis Report For The TN-WHC Cask and Transporation System
Project 3035
Transnuclear, Inc.

7.2 Kee Industrial Products.
Test Report: Ultimate Load Capacities of Set Screws.
(Provided in Appendix A)

7.3 1989 Annual Book of ASTM Standards, Volume 02.02, page 330.

7.4 Standard Handbook for Mechanical Engineers, Baumeister & Marks, 7th edition.

7.5 Code Of Federal Regulations
Title 29, Part 1910.28
Safety Requirements For Scaffolding

7.6 K Basin Immersion Pail Assembly TN WHC Transport Cask Drawings.
7.6.1 Project 457, Drawing 105.

7.7 AISC Manual Of Steel Construction, 9th edition.

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APPENDIX A

Kee Industrial Products Load Data

There a a total of 4 pages in Appendix A.

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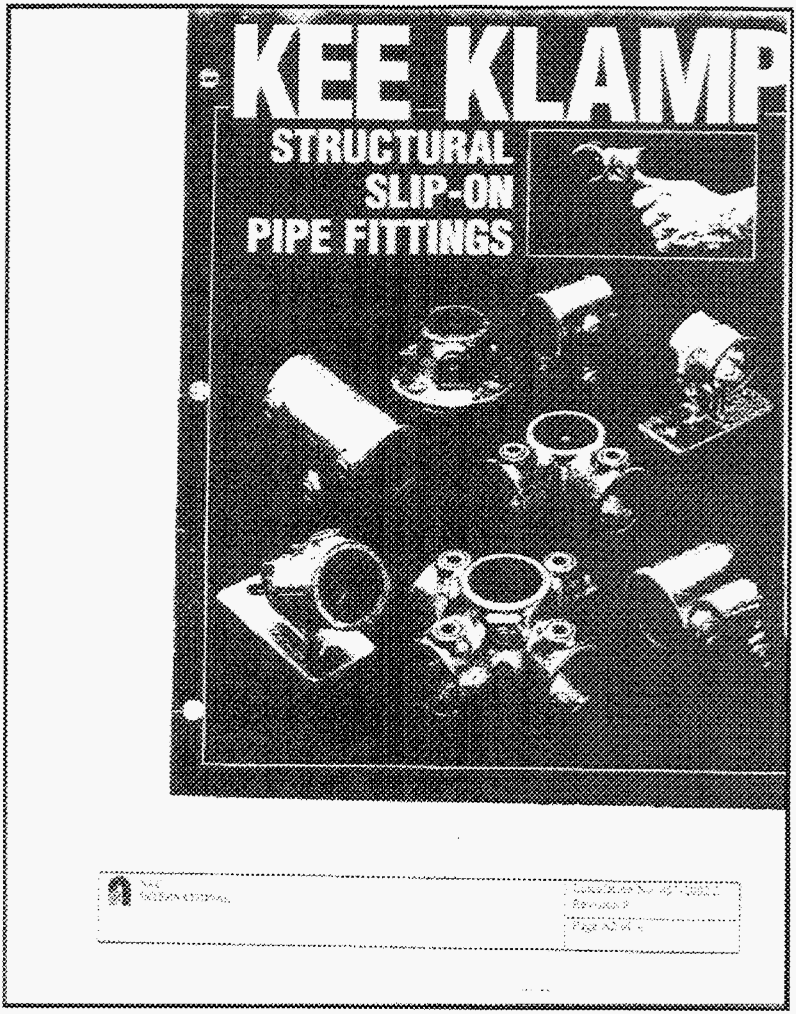
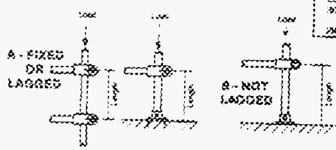


Appendix A9.2.8 Trailer Work Platform 457-2002.2 (Continued)

TABLE 2: UPRIGHT LOAD TABLES

Length Ft.	Pipe Size ¾" A	¾" B	1" A	1" B	1¼" A	1¼" B	1½" A	1½" B	2" A	2" B	Length Ft.
1'-0"	4090	3735	5730	5455	9270	6090	15605	10475	13920	16475	1'-0"
1'-3"	2719	3265	5085	5515	10000	5425	10470	9515	12270	14795	1'-3"
1'-6"	3255	2640	2216	5345	8425	7750	9910	5500	14065	14320	1'-6"
1'-9"	2985	3435	5410	4700	7288	7280	9480	6720	14370	15510	1'-9"
2'-0"	2565	1880	4880	4215	7430	6670	9000	6275	13885	13595	2'-0"
2'-3"	2115	1660	4480	3525	8640	9095	8505	7795	12270	12420	2'-3"
2'-6"	1865	1495	4040	3185	6545	5510	8005	7140	12710	11885	2'-6"
2'-9"	1843	1305	3560	2780	5085	5010	7460	6485	13135	[illegible]	2'-9"
3'-0"	1400		3165	2440	5405	4340	7045	5970	11670	10080	3'-0"
3'-3"	1270		3570	2155	5125	2865	6565	5285	11040	9725	3'-3"
3'-6"			2575	1885	4555	3630	6105	4835	10545	9050	3'-6"
3'-9"			2320		4170	3305	5715	4600	9855	8436	3'-9"
4'-0"			2060		5575	3575	5305	4080	9035	7760	4'-0"
4'-3"					2585	2625	4705	3760	9005	6590	4'-3"
4'-6"					2225	2430	4450	3305	8452	6606	4'-6"
4'-9"					2575		4155	3120	7215	6245	4'-9"
5'-0"					2725		3540	2900	7280	5835	5'-0"
5'-3"					2540		3370		6850	5295	5'-3"
5'-6"							3228		6535	5045	5'-6"
5'-9"							3040		6175	4725	5'-9"
6'-0"							2883		5835	4300	6'-0"
6'-3"									5430	4028	6'-3"
6'-6"									5155	3755	6'-6"
6'-9"									4755		6'-9"
7'-0"									4525		7'-0"
7'-3"									4300		7'-3"
7'-6"									4095		7'-6"
7'-9"									3905		7'-9"

These tables give an indication only of the safe load, in lbs. that may be carried between the restraints by a single pipe (standard schedule 40) when used as uprights.



TEST REPORT: Ultimate Load Capacities of Set Screws

Fitting Size	Ultimate Load - Lbs (Hand Tight)*
½"	2990**
¾"	2900
1"	2970
1¼"	3555
1½"	4175
2"	4150

*Hand Tight (Hex Key) = 10 Ft. Lb. Torque to set screw
**Pipe would bend before fitting would slip.

The test was carried out by an independent laboratory using the following method:

Standard schedule 40 pipe was clamped within the vertical barrel of each fitting and the set screw tightened to 10 Ft.Lb. Torque.

A 400,000 Lb. capacity universal testing machine was used to apply a vertical load to the fitting in an attempt to produce slippage.

These laboratory test figures show slippage point only. No safety factor is incorporated. When assessing weights and safety factors, we would advise the following:
1) Check pipe capacity above.
2) Divide test figures by two.
3) Take lowest of the two results.

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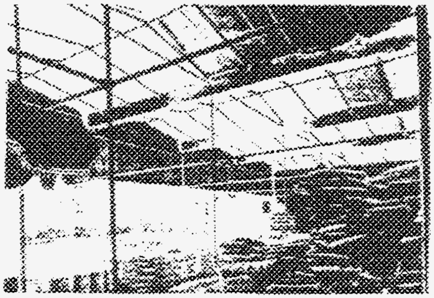

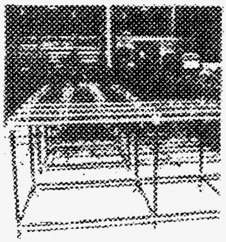

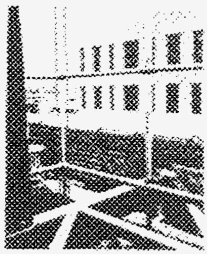

Kee Industrial Products

PART B: PACKAGE EVALUATION

B1.0 INTRODUCTION

B1.1 SAFETY EVALUATION METHODOLOGY

This section of the Design Analysis Report (DAR) presents the structural evaluation of the cask. This package evaluation describes the design features and presents the safety analyses which demonstrate that the cask complies with applicable requirements of the Hanford Specification[1].

Detailed structural analyses of various cask components subjected to individual loads are provided in the Appendix B4.5C. The limiting results from these analyses are used in Section B4.3 to quantify package performance in response to the normal condition of transport load combinations and Section B4.4 to quantify package performance in response to the accident condition of transport load combinations. Tables B4.3-1 and B4.4-1 provide an overview of the performance evaluations reported in each load combination subsection for normal and accident conditions, respectively. Each subsection provides the limiting structural analysis result for the affected cask component(s) in comparison to the established design criteria. This comparison permits the minimum margin of safety for a given component subjected to a given loading condition to be readily identified. In all cases, the acceptability of the cask design with respect to established criteria and consequently with respect to the Specification performance requirements is demonstrated.

Several other items should be noted. In the cask, thermal stresses occur due to the effects of differential thermal expansion. When evaluating stresses, these thermal stresses are conservatively treated as primary stresses and the combined stresses due to primary loads (like pressure) and differential expansion (such as heating from 70°F to hot thermal conditions) are evaluated as primary stresses. In addition, some individual load cases in Appendix B4.5C were performed for the corresponding unit load (1G) condition (like the end drop and side drop) and are factored for the normal and accident conditions.

The stress results for the individual load case tables reported in Appendix B4.5C are the maximum stresses for each individual load cases. Two or more individual load cases must be combined to determine the total stresses at the standard stress reporting locations for the various load combinations. This is accomplished using the ANSYS[2] postprocessor which algebraicly adds the stress components at each of the standard locations. The membrane stress intensity is then found from the membrane stress components and the inner and outer surface membrane plus bending stress intensities are determined from the membrane $\pm$ bending stress components.

Figure B4.3-1 shows the selected locations on the cask body where stress results for these analyses are reported. Detailed stresses are actually available at as many locations as there are nodes in the finite element model. However, for practical considerations, the reporting of stress results is limited to those locations shown on Figure B4.3-1. These locations were selected to be representative of the stress distribution in the cask body with special attention given to areas subject to high stresses. The maximum stress may occur at a different location for each individual load.

The shielding analysis of the cask is performed using industry standard codes and conservative modeling assumptions. An evaluation of the shielding performance of the cask was performed assuming dry cask conditions. This evaluation is based on the maximum source term payload. The bounding source term used for the shielding evaluation is the Mark IV fuel elements, 0.95 U-235 irradiation to 16% Pu-240, thirteen years after discharge from the N reactor.

The gamma and neutron analyses are performed using the one dimensional SAS1 module of SCALE-4, with the 27n-18g coupled cross-section library. This uses the codes XSDRNPM and XSDOSE to calculate surface flux and translate the flux into dose rates away from the cask surface. ANSI standard flux-to-dose factors, within SCALE-4, are used for the dose calculation at the selected points. The method in which the cask and its contents are modeled for the shielding analysis and the shielding analysis results are described in the Section B3.0.

The thermal evaluation is described in Section B5.0. The ANSYS computer code is used to performed the analysis. The design input for decay heat load, ambient conditions and MCO geometry were obtained from the Hanford Specification.

B1.2 EVALUATION SUMMARY AND CONCLUSIONS

Appendix B4.5C provides the detailed description of the structural analyses of the cask body. That appendix describes the detailed ANSYS model used to analyze various applied loads. Tables B4.3-2 and B4.4-2 identify the individual loads (IL) analyzed which are applicable to normal and accident conditions of transport.

Detailed stresses and displacements in the ANSYS model of the cask body are obtained and stored (on magnetic tape) for every node location for each individual load case. These stored results are postprocessed to printout the stresses at the standard stress reporting locations.

Since the individual load cases are linearly elastic, their results can be scaled and superimposed as required in order to perform the normal and hypothetical accident condition load combinations.

Shielding for the cask is provided mainly by the thick-walled cask body. This provides adequate shielding for both normal and accident conditions. Figures B3.3-1 and B3.3-2 illustrate the one-dimensional SAS1 models used for the analysis and Table B3.3-1 lists the compositions of the shielding materials.

The temperature distribution from the thermal analyses is used to evaluated the thermal stresses in the cask. The structural integrity of the cask is maintained during normal and accident thermal environments.

Normal Condition of Transport

The maximum stresses due to the 1 foot free drop event are presented in Section B4.3.4.3.5. In nearly all of the load cases, the maximum stresses are less than the membrane allowable stress with large margin of safety.

The lid bolt stresses do not exceed 2/3 times the yield strength during the 1 ft drop normal conditions as shown in Section B4.3.4.3.8.

The cask body is a solid stainless steel cylinder, the thermal stresses due to differential thermal expansion are insignificant. Thermal stresses of the cask body due to the differential thermal expansion under the hot and cold environment conditions are evaluated in Section B4.3.4.2.

From the analyses presented in Section 4.3, it can be shown that the normal structural and thermal loads will not result in any structural damage of the cask and the containment function of the MCO will be maintained.

Accident Condition of Transport

The maximum stresses due to the 30 foot drop event are also presented in Section B4.4-4.3. In nearly all of the load cases, the maximum stresses are less than the membrane allowable stress with large margins of safety.

The lid bolt stresses do not exceed the ultimate strength during the hypothetical 30 ft drop accidents as shown in Section B4.4.4.3.4.

During the 40 inch drop onto a 6.0 inch diameter puncture bar, the cask body may deform locally at the contact point. It has been shown by analysis (Section B4.4.4.3.5) that the cask will not be punctured and that the MCO will be confined.

The thermal stresses in the stainless steel cask body due to differential thermal expansion are insignificant. Thermal stress of the cask body due to the differential thermal expansion under the thermal accident conditions (between lid and lid bolts) is evaluated in Section B4.4.4.2.

From the analyses presented in Section 4.4, it can be shown that the accident structural and thermal loads will not impact the structural integrity of the cask, and the cask maintains the confinement function of the MCO.

References For B1.0

1. Performance Specification For TN-WHC Cask And Transportation System, WHC-S-0396, Rev. 1, September 1995.

2. ANSYS Engineering Analysis System, User's Manual Volumes 1&2, Rev. 5.2.

B2.0 CONTAINMENT EVALUATION

This Section will be written by DESH

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B2.2 CONTAINMENT SOURCE SPECIFICATION

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B3.0 SHIELDING EVALUATION

B3.1 INTRODUCTION

An evaluation of the shielding performance of the TN-WHC cask was performed assuming dry cask conditions. This evaluation is based on the maximum source term payload.

The most significant shielding design features of the cask are the thick walled forged carbon steel cask body and lid. The cask body has a minimum wall thickness of 7.25 inches and a bottom thickness of 6.13 inches. A minimum cask lid thickness of 3.0 inches was used. Additional shielding is provided by the fuel assemblies, the baskets, and the MCO. The cask design does not included separate neutron shielding because of the relatively low neutron source term in the spent fuel. The method in which the cask and its contents are modeled for the shielding analysis are described in the Sections B3.3 and B3.4.

The shielding analysis of the cask is performed using industry standard codes and conservative modeling assumptions. The expected dose rates for the cask have been evaluated for the design basis fuel.

B3.2 DIRECT RADIATION SOURCE SPECIFICATION

The bounding source term used for the shielding evaluation is the Mark IV fuel elements, 0.95 U-235 irradiation to 16% Pu-240, thirteen years after discharge from the N reactor. The source term, gamma spectra, and neutron spectra are provided in Reference 1.

B3.2.1 Gamma Source

Table B3.2-1 shows the gamma source spectra. The spectra from 0.35 to 2.25 MeV was used since these energy levels are the primary contributors to the dose rate. The gamma source spectra provided in Reference 1 was generated from the ORIGEN2 code. However, this spectra was converted into the gamma energy groups of the SCALE 27n-18γ library[2] by conserving energy. Appendix B3.7.1 details the conversion of the gamma source spectra for use in the SCALE code.

Table B3.2-1 Gamma Source Spectra

Average Energy Level (MeV)	Photon/sec/MCO	Fraction
2.25	8.88E+09	0.00000
1.83	6.828E+11	0.00024
1.495	1.009E+13	0.00348
1.165	2.415E+13	0.00833
0.9	3.727E+13	0.01286
0.7	9.045E+14	0.31211
0.5	1.868E+15	0.64458
0.35	5.300E+13	0.01829
Total	2.898E+15	0.99989

B3.2.2 Neutron Source

The Neutron Source for Mark IV Fuel 16% Pu 240 at 13 years decay was also provided in Reference 2. The spontaneous fission source is 7.317E+06 neutrons/sec/MCO with an (alpha,n) neutron source of 3.578E+06 neutrons/sec/MCO.

The neutron spectra for both sources were also provided in Reference 2. Similar to the gamma source spectra, this spectra must be converted into the proper neutron energy groups of the SCALE 28n-18γ library. This is accomplished by apportioning the provided spectra into the SCALE energy groups. This analysis and conversion is detailed in Appendix B3.7.2. The spectrum used for the analysis is provided in Table B3.2-2 below.

Table B3.2-2 Neutron Spectra

SCALE Group No	(alpha,n)	Spontaneous Fission	Combined
Group 1		0.02184	0.01463
Group 2	0.16137	0.22278	0.20251
Group 3	0.41486	0.22655	0.28869
Group 4	0.14594	0.12795	0.13389
Group 5	0.11620	0.15740	0.14380
Group 6	0.11214	0.15633	0.14175
Group 7	0.04767	0.08316	0.07145
Total:	0.99818	0.99601	0.99672

B3.3 SUMMARY OF SHIELDING PROPERTIES OF MATERIALS

One-dimensional SAS1 models (of the SCALE code[3]) were used for the gamma and neutron shielding calculations of the top, bottom, and side of the cask.

For the doses at the top and bottom of the cask, one-dimensional plane geometry XSDRNPM models are used. The fuel region is assumed to consist of uranium dioxide, zircaloy and steel basket. These are assumed to be homogenized throughout the fuel zone. The model assumes only the active fuel region. No consideration is given to the presence of a plenum or top fitting. The configurations of the top and bottom model are shown in Figure B3.3-1.

For the gamma and neutron doses on the side of the cask, a cylindrical one-dimensional model is used in XSDRMPM as shown in Figure B3.3-2. The central fuel region is considered to consist of uranium dioxide. The fuel cladding and steel basket are included in the homogenized fuel region. The fuel region is modeled as a cylinder with the actual cavity diameter. Subsequent regions are modeled as cylindrical shells corresponding to actual dimensions.

Materials and their densities used in the XSDRNPM models are provided in Table B3.3-1.

Figure B3.3-1 Axial Models

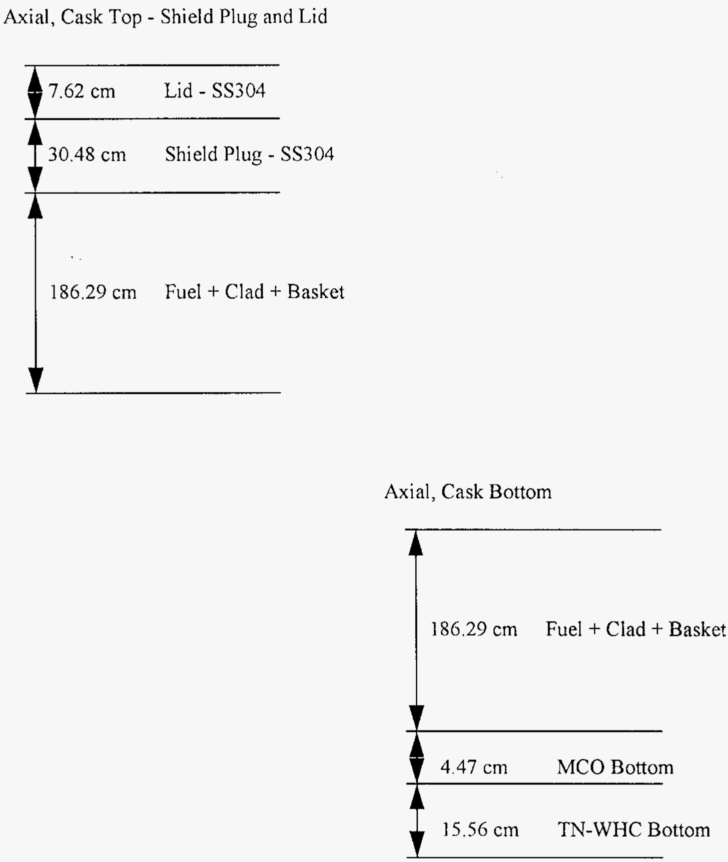


Figure B3.3-2 Radial Model

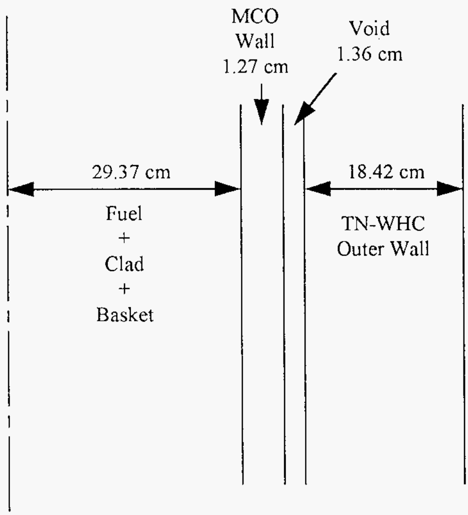


Table B3.3-1 Material Densities

Location	Material	Density (g/cc)
Fuel + Clad + Basket (assuming basket is 100% steel)	Uranium	6.28
	Zircaloy	0.41
	Steel (SS304)	0.338
Cask Wall	Steel (SS304)	7.92
Cask Lid	Steel (SS304)	7.92
Shield Plug	Steel (SS304)	7.92

B3.4 NORMAL TRANSFER CONDITIONS

B3.4.1 Conditions to be Evaluated

Under normal conditions the shielding of the cask is evaluated assuming an undamaged cask and the worst case fuel.

B3.4.2 Acceptance Criteria

The shielding acceptance criteria for normal conditions for the cask is the following:

-the maximum surface dose on the accessible surface of the cask shall be less than or equal to 100 mrem/hr [2]; and
-the dose rate 2 meters from the surface of the cask shall be less than or equal to 10 mrem/hr[2].

B3.4.3 Shielding Model

The gamma and neutron analyses are performed using the one dimensional SAS1 module of SCALE-4, with the 27n-18g coupled cross-section library. This uses the codes XSDRNPM and XSDOSE to calculate surface flux and translate the flux into dose rates away from the cask surface. ANSI standard flux-to-dose factors, within SCALE-4, are used for the dose calculation at the selected points.

For the axial calculations, the DISK geometry is chosen and buckling corrections, using the cask diameter, are used to correct for a finite dimension rather than an infinite plane.

Because of the irregular bottom in the MCO, the 3-dimensional QAD-CGGP[5] code was utilized to evaluate two models of the bottom; one with a cut-out and one without. Ratios of the calculated dose rates (1.32 @ contact and 1.01 @ 2 meters) were used to correct the SAS1 dose calculation for the bottom of the cask.

An additional dose rate calculation was performed to evaluate the dose rate at the drain port at the lower end of the cask. The 3-dimensional, monte carlo SAS4 module of the Scale-4 code was utilized to perform the calculation. Shielding from the quick connect coupling was conservatively neglected as shown in Figure B3.3-3.

The inputs for the SAS1 and SAS4 modules are included in Appendix B3.7.3.

B3.4.4 Shielding Calculations

Dose points, shown in Tables B3.4-1 and B3.4-1, are taken axially on the centerline of the cask and radially on the midplane.

Table B3.4-1 Summary of Maximum Dose Rates - Cask Surface
(mrem/hour)

	Sides	Top, Shield Plug	Top, Cask Lid & Shield Plug	Bottom*
Gamma	54.2	0.71	0.04	85.4
Neutron	5.10	2.39	1.31	7.26
Total	59.3	3.10	1.35	92.7

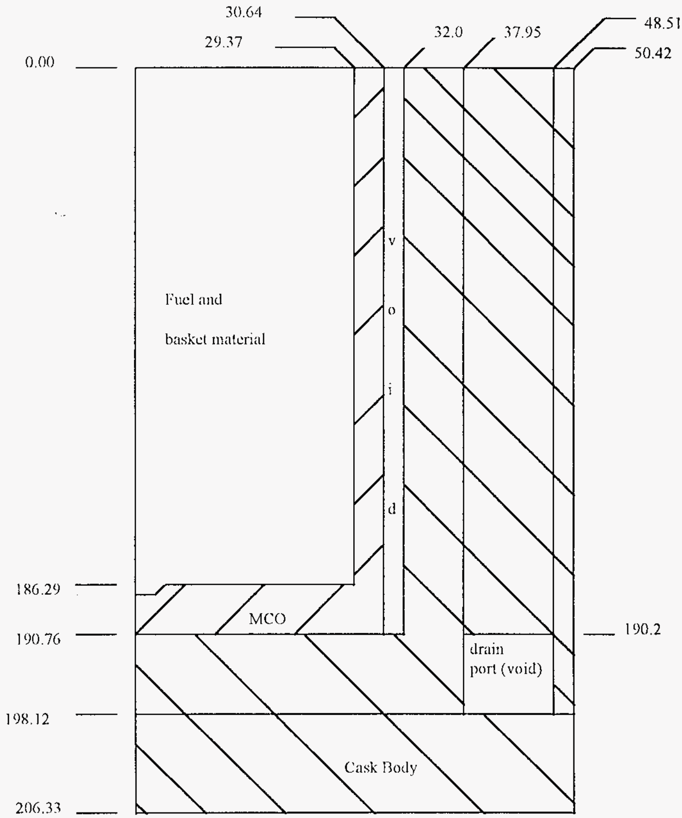
Table B3.4-2 Summary of Maximum Dose Rates - 2 meters from the Cask Surface
(mrem/hour)

	Sides	Top, Shield Plug	Top, Cask Lid & Shield Plug	Bottom*
Gamma	8.54	0.09	0.005	7.88
Neutron	0.61	0.12	0.06	0.28
Total	9.15	0.21	0.065	8.16

* - on cask centerline, below MCO sump (B3.4.3)

The dose rates on the drain port cover were calculated by SAS4 to be 167 mrem/hr γ and 2.5 mrem/hr neutron. At one foot from the drain port cover, the calculated dose rates were 62.7 mrem/hr and 1.1 mrem/hr γ and neutron respectively.

Figure B3.3-3 Drain Port Model



B3.5 ACCIDENT CONDITIONS

B3.5.1 Conditions To Be Evaluated

Briefly, the accidents to be evaluated are:

- Impact, the worst case credible impact for the packaging system may be simulated by a free drop of 30 ft. onto a concrete surface, the package shall impact in an orientation to cause maximum damage;

- Puncture, the worst case credible puncture is equivalent to a free drop of the packaging through a distance of 1 meter (40 in) in a position for which the maximum damage is expected; and

- Thermal, the exposure of the packaging system for not less than 30 minutes to a 800°C fire that has an emissivity coefficient of 0.9.

The impact, puncture and thermal scenarios will result in no loss of shielding. Therefore, the accident dose rates are the same as the normal conditions dose rates.

B3.5.2 Acceptance Criteria

The shielding acceptance criteria for accident conditions for the cask is the following:

- the dose rate 1 meter from the surface of the cask shall not exceed 1 rem/hr(2).

B3.5.3 Shielding Model

See Section B3.4.3 shielding model for normal conditions.

B3.5.4 Shielding Calculations

See Section B3.4.4 shielding calculations for normal conditions.

B3.6 SHIELDING EVALUATION AND CONCLUSIONS

Shielding for the cask is provided mainly by the thick-walled cask body. This provides adequate shielding for both normal and accident conditions. Figures B3.3-1 and B3.3-2 illustrate the one-dimensional SAS1 models used for the analysis and Table B3.3-1 lists the compositions of the shielding materials.

The expected dose rates were calculated using the source term provided in Reference 1 and the results of the shielding analyses are provided in Tables B3.4-1 and B3.4-2.

References For Section B3.0

1. Engineering Change Notice, ECN-191402, SNF Project, WHC-S-0396, Rev 1

2. Document Number WHC-SD-TP-SARP-017, Preliminary Safety Analysis Report for Packaging (On-Site) Multiple Canister Overpack Cask, Draft Rev. 0, April 12, 1996.

3. Performance Specification For TN-WHC Cask And Transportation System, WHC-S-0396, Rev. 1, September 1995.

4. SCALE-4: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation, ORNL/NUREG/CR-0200, U.S. Nuclear Regulatory Commission, Revision 4, February 1990.

5. QAD-CGGP - A Combinatorial Geometry Version of QAD-P5A, a Point Kernel Code System for Neutron and Gamma-Ray Shielding Calculation Using the GP Buildup Factor, CCC-495.

B3.7 APPENDIX

SHIELDING ANALYSIS

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Section **Page**

B3.7-1 DETERMINATION OF THE GAMMA SOURCE SPECTRA

The gamma source for the worst case fuel is provided in Reference 1. The gamma source spectra is shown below in Table B3.7-1.

Table B3.7-1 Photon Source for Mark IV Fuel 16% Pu 240 at 13 years decay

Energy (MeV)	Photons/sec/MCO
0.015	1.67E15
0.025	3.54E14
0.038	3.99E14
0.058	3.35E14
0.085	1.85E14
0.125	1.38E14
0.225	1.57E14
0.375	7.42E13
0.662	2.33E15
0.850	5.92E13
1.250	3.41E13
1.750	1.05E12
2.250	8.88E9
2.750	6.34E8
3.500	8.31E7
5.000	3.94E5
7.000	4.50E4
11.000	5.14E3
TOTAL	6.09E15

For the gamma source term, the energy levels from 0.375 to 2.25 MeV were used since these energy levels are the primary contributors to the gamma dose. The 0.662 MeV energy level was converted to the 0.575 MeV energy level:

0.662 MeV = 2.33E15 photon/sec/MCO (0.662/0.575) = 2.68E15 photon/second/MCO

The energy groups significant to the dose are from 0.375 MeV to 2.50 MeV. The table below summarizes these energy groups:

Table B3.7-2 Photon Source for Mark IV Fuel 16% Pu 240 at 13 years decay

ORIGEN2 Energy Range	ORIGEN2 Average Energy (MeV)	γ/sec/MCO
0.3 - 0.45	0.375	7.42E+13
0.45 - 0.7	0.575	2.68E+15
0.7 - 1.0	0.850	5.92E+13
1.0-1.5	1.250	3.41E+13
1.5-2.0	1.750	1.05E+12
2.0 -2.5	2.250	8.88E+09
	Subtotal:	2.85E+15

The energy groups from this ORIGEN2 output need to be translated into the appropriate energy groups for the SCALE 27n-18g library. This is done by conserving energy. The following calculations illustrate the conversion between the ORIGEN2 energy levels to the SCALE code energy levels.

Scale Group 35, 1.66 - 2.0:

$$= \frac{(2.0-1.66)}{(2.0-1.5)} * (\frac{1.75}{1.83}) * 1.05E{+}12$$
$$= 6.828E{+}11$$

Scale Group 36, 1.33 - 1.66 *MeV*:

$$= \frac{(1.66-1.5)}{(2.0-1.5)} * (\frac{1.75}{1.495}) * 1.05E{+}12 + \frac{(1.5-1.33)}{(1.5-1.0)} * (\frac{1.25}{1.495}) * 3.41E{+}13$$
$$= 1.009E{+}13$$

B3.7-2 DETERMINATION OF THE NEUTRON SOURCE SPECTRA

The neutron source in spent fuel is from either spontaneous fission of the actinides or from (α,n) reactions. For this fuel, the spontaneous fission source and (α, n) reactions are present. The spontaneous neutron source is due primarily to six nuclides: Cm-242, Cm-244, Cm-246, Pu-238, Pu-240, and Pu-242.

From Reference 2, the following fission source is tabulated below:

Table B3.7-3 (α,n) and Spontaneous Fission Source for Mark IV Fuel

Component of Source	Source Strength (neutrons/sec/MCO)	%
(α,n)	3.578E+06	33%
Spontaneous Fission	7.317E+06	67%
Total	1.090E+07	

Table B3.7-4 Spontaneous Fission Specrta

Upper Energy (MeV)	Fraction
0.00	0.00000
0.10	0.01194
0.20	0.01972
0.30	0.02424
0.40	0.02726
0.50	0.02934
0.60	0.03076
0.70	0.03167
0.80	0.03218
0.90	0.03238
1.00	0.03232
1.20	0.06368
1.40	0.06140
1.60	0.05832
1.80	0.05475
2.00	0.05090
2.20	0.04695
2.40	0.04301
2.60	0.03917
2.80	0.03549
3.00	0.03202
3.20	0.02876
3.40	0.02574
3.60	0.02297
3.80	0.02043
4.00	0.01812
4.20	0.01603
4.40	0.01415
4.60	0.01246
4.80	0.01095
5.00	0.00960
5.50	0.01907
6.00	0.01354
6.50	0.00953
7.00	0.00665
7.50	0.00461
8.00	0.00318
9.00	0.00366
10.00	0.00169
11.00	0.00076
12.00	0.00034
13.00	0.00015
14.00	0.00007
15.00	0.00003
Total	0.99999

Table B3.7-5 (α,n) Fission Spectra

Upper Energy (MeV)	Fraction
0.00	0.00000
0.10	0.01059
0.20	0.01184
0.30	0.01153
0.40	0.01371
0.50	0.01869
0.60	0.02103
0.70	0.02305
0.80	0.02523
0.90	0.02414
1.00	0.01994
1.10	0.02087
1.20	0.02259
1.30	0.02539
1.40	0.02741
1.50	0.02804
1.60	0.02944
1.70	0.03193
1.80	0.03551
1.90	0.03692
2.00	0.03879
2.10	0.03894
2.20	0.04065
2.30	0.04128
2.40	0.03956
2.50	0.03785
2.60	0.03645
2.70	0.03474
2.80	0.03209
2.90	0.03115
3.00	0.02928
3.10	0.02586
3.20	0.02430
3.30	0.02087
3.40	0.01698
3.50	0.01433
3.60	0.01231
3.70	0.00997
3.80	0.00857
3.90	0.00748
4.00	0.00607
4.10	0.00545
4.20	0.00358
4.30	0.00280
4.40	0.00171
4.50	0.00109
	1.00000

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FOR SPONTANEOUS FISSION SPECTRA

For Group 1, 6.434 - 20.0 *MeV*:

$$= \left(\frac{(6.434-6.0)}{(6.5-6.0)} * \left(\frac{6.25}{11.22}\right) * 0.00953\right) + 0.00665 + 0.00461 + 0.00318$$
$$+ 0.00366 + 0.00169 + 0.00076 + 0.00034 + 0.00015 + 0.00007 + 0.00003$$
$$= 0.02184$$

For Group 2, 3.00 - 6.434:

$$= 0.02876 + 0.02574 + 0.02297 + 0.02043 + 0.01812 + 0.01063 + 0.01415 + 0.01246$$
$$+ 0.01095 + 0.00960 + 0.01907 + \left(\frac{6.434-6.00}{6.50-6.00} * 0.00953 * \frac{6.25}{4.717}\right) + 0.1354$$
$$= 0.22278$$

FOR (α, *n*) *SPECTRA*

For Group 2, 3.0 - 6.434 *Mev*:

$$= 0.02586 + 0.02430 + 0.02087 + 0.01698 + 0.01433 + 0.01231 + 0.00997$$
$$+ 0.00857 + 0.00748 + 0.00607 + 0.00545 + 0.00358 + 0.00280 + 0.00171 + 0.000109$$
$$= 0.16137$$

For Group 3, 1.85 - 3.0 *MeV*:

$$= 0.02928 + 0.03115 + 0.03209 + 0.03474 + 0.03645 + 0.03785 + 0.03956 + 0.04128$$
$$+ 0.04065 + 0.03894 + 0.03879$$
$$+ \frac{1.90-1.85}{1.90-1.80} * 0.03692 * \frac{1.85}{2.425}$$
$$= 0.41486$$

B3.7-3 SAS1 INPUT FILES

Axial Model, Top

```
=SAS1
K-BASIN FUEL 5/96 - NEUTRON WHC-ST-TP-SARP-017,  GAMMA ECN 191402
27N-18COUPLE INFHOMMEDIUM
'  FUEL MODELED, 6.34 MTU PER MCO - SS304 BASKET - ZIRC CLAD
URANIUM      1   DEN=6.28   1.0  293  92235  1.0  92238  99.0  END
ZIRCALLOY    1   DEN=0.441  END
SS304        1   DEN=0.338  END
SS304        2   1.0        END
END COMP
END
LAST
TOP MODEL 12"  SHIELD PLUG ONLY
DISC   REFLECTED
1   130.0  40   -1   0   0  10.8    2.87E9
1   186.29  40  -1   0   0   10.8    2.878E9
2   216.77  31   0
 END ZONE
0.01463  0.20251  0.28869  0.13389  0.14380  0.14175  0.07145 26Z
0.00000  0.00024  0.00348  0.00833  0.01236  0.31211  0.64458
0.01829   4Z
0.01463  0.20251  0.28869  0.13389  0.14380  0.14175  0.07145 26Z
0.00000  0.00024  0.00348  0.00833  0.01236  0.31211  0.64458
0.01829   4Z
NDETEC=4 DY=103.06  DZ=103.06
READ XSDOSE
51.53
 0.0  2.0   0.0  100.   0.0  200.   0.0  300.
END

=SAS1
K-BASIN FUEL 5/96 - NEUTRON WHC-ST-TP-SARP-017,  GAMMA ECN 191402
27N-18COUPLE INFHOMMEDIUM
'  FUEL MODELED, 6.34 MTU PER MCO - SS304 BASKET - ZIRC CLAD
URANIUM      1   DEN=6.28   1.0  293  92235  1.0  92238  99.0  END
ZIRCALLOY    1   DEN=0.441  END
SS304        1   DEN=0.338  END
SS304        2   1.0        END
```

```
END COMP
END
LAST
TOP MODEL 12in MCO SHIELD PLUG AND 3in TN-WHC LID
DISC   REFLECTED
1   130.0  40   -1   0   0  10.8     2.87E9
1   186.29  40  -1   0   0   10.8    2.878E9
2   216.77  31   0
2   224.39  8    0
 END ZONE
0.01463  0.20251  0.28869  0.13389  0.14380  0.14175  0.07145 26Z
0.00000  0.00024  0.00348  0.00833  0.01236  0.31211  0.64458
0.01829   4Z
0.01463  0.20251  0.28869  0.13389  0.14380  0.14175  0.07145 26Z
0.00000  0.00024  0.00348  0.00833  0.01236  0.31211  0.64458
0.01829   4Z
NDETEC=4 DY=103.06  DZ=103.06
READ XSDOSE
51.53
 0.0  2.0   0.0  100.    0.0  200.   0.0  300.
END
```

Axial Model, Bottom

```
=SAS1
K-BASIN FUEL 5/96 - NEUTRON WHC-ST-TP-SARP-017,  GAMMA ECN 191402
27N-18COUPLE INFHOMMEDIUM
'  FUEL MODELED, 6.34 MTU PER MCO - SS304 BASKET - ZIRC CLAD
URANIUM      1   DEN=6.28   1.0  293  92235  1.0  92238  99.0  END
ZIRCALLOY   1   DEN=0.441  END
SS304        1   DEN=0.338  END
SS304        2   1.0      END
END COMP
END
LAST
BOTTOM MODEL TN-WHC 6.125in THICK AND MCO 1.76in THICK
DISC   REFLECTED
1   130.0  40   -1   0   0  10.8     2.87E9
1   186.29  40  -1   0   0   10.8    2.878E9
2   190.76  4   0
```

```
2   206.32  17  0
 END ZONE
0.01463  0.20251  0.28869  0.13389  0.14380  0.14175  0.07145 26Z
0.00000  0.00024  0.00348  0.00833  0.01236  0.31211  0.64458
0.01829   4Z
0.01463  0.20251  0.28869  0.13389  0.14380  0.14175  0.07145 26Z
0.00000  0.00024  0.00348  0.00833  0.01236  0.31211  0.64458
0.01829   4Z
NDETEC=4 DY=103.06  DZ=103.06
READ XSDOSE
51.53
 0.0  2.0   0.0  100.    0.0  200.   0.0  300.
END
```

Radial Model

```
=SAS1
K-BASIN FUEL 5/96 - NEUTRON WHC-ST-TP-SARP-017,  GAMMA ECN 191402
27N-18COUPLE INFHOMMEDIUM
' FUEL MODELED, 6.34 MTU PER MCO - SS304 BASKET - ZIRC CLAD
URANIUM     1  DEN=6.28   1.0  293  92235  1.0  92238  99.0  END
ZIRCALLOY   1  DEN=0.441  END
SS304       1  DEN=0.338  END
SS304       2  1.0      END
END COMP
END
LAST
RADIAL MODEL TN-WHC  7.25in THICK AND MCO 0.5in THICK
CYLINDRICAL
1   29.37  30  -1   0  0   10.8  2.87E9
2   30.64  2  0
0   32.00  1  0
2   50.42   20   0
 END ZONE
0.01463  0.20251  0.28869  0.13389  0.14380  0.14175  0.07145 26Z
0.00000  0.00024  0.00348  0.00833  0.01236  0.31211  0.64458
0.01829   4Z
NDETEC=4 DY=103.06  DZ=103.06
READ XSDOSE
372.57
52.00  186.29    152.00  186.29     252.00  186.29  367.64 186.29
```

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END

SAS4 INPUT FILES

Radial Gamma

```
=sas4
Westinghouse Hanford Cask  3-D Shielding  Analysis  7/96
27N-18couple  infhommedium
' Fuel modeled, 6.34 MTU per MCO - SS304 basket - Zr clad
uranium   1  den=6.28  1.0  293  92235  1.0  92238  99.0  end
zircalloy  1  den=0.441  end
ss304      1  den=0.338  end
ss304    2  1.0  end
end comp
idr=0  ity=2  izm=4  frd=29.37  end
29.37  30.64  32.00  50.42  end
1  2  0  2  end
xend
tim=20.0  nst=500  nod=3  sfa=2.898+15  fr2=0.7  fr3=0.7  fr4=0.7
igo=0  mfu=1  nit=800  end
soe 34z  0.00024  0.00348  0.00833  0.01286  0.31211  0.64458
0.01829  4z  end
det  52.0  0.  194.16   81.0  0.  194.16  81.0 0. 206.0  end
gend
TN-WHC Cask Radial Gamma Dose Rate around drain port with cover(HOLE)
fue  186.29  186.30  end
fend
cav  0  32.00  190.77  end
ins  2  30.64  190.76  end
inn  2  37.95  190.80  end
rs1  2  48.51  190.20  end
our  2  50.42  206.33  end
as1  2  37.95  198.12  end
cend
end
```

Radial Neutron

```
=sas4
```

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```
Westinghouse Hanford Cask  3-D Shielding  Analysis  7/96
27N-18couple  infhommedium
' Fuel modeled, 6.34 MTU per MCO - SS304 basket - Zr clad
uranium   1  den=6.28  1.0  293  92235  1.0  92238  99.0  end
zircalloy  1  den=0.441  end
ss304      1  den=0.338  end
ss304    2  1.0  end
end comp
idr=0  ity=1  izm=4  frd=29.37  end
29.37  30.64  32.00  50.42  end
1  2  0  2  end
xend
tim=30.0  nst=100  nod=3  sfa=1.09+7  fr2=0.7  fr3=0.7  fr4=0.7
igo=0  mfu=1  nit=100  end
soe 0.01463  0.20251  0.28869  0.13389  0.14380  0.14175  0.07145
20z  end
det  52.0  0.  194.16   81.0  0.  194.16  81.0 0. 206.0  end
gend
TN-WHC Cask Radial Neutron Dose Rate around drain port with cover(HOLE)
fue  186.29  186.30  end
fend
cav  0  32.00  190.77  end
ins  2  30.64  190.76  end
inn  2  37.95  190.80  end
rs1  2  48.51  190.20  end
our  2  50.42  206.33  end
as1  2  37.95  198.12  end
cend
end
```

B4.0 STRUCTURAL EVALUATION

B4.1 INTRODUCTION

This Section, including its appendices, presents the structural evaluation of the cask. This evaluation demonstrates that the cask structural design satisfies the Hanford Specification[1].

B4.2 STRUCTURAL EVALUATION OF PACKAGE

B4.2.1 Structural Design and Features

The structural integrity of the cask under normal conditions of transport and hypothetical accident conditions specified in Hanford Specification is shown to meet the design criteria described in Sections B4.3 and B4.4. The cask is a transport packaging which consists of two major structural components: the shell or cask body assembly and the lid assembly. These components are described in Section A2.0 and are shown on drawings provided in Section A9.1, Appendix.

The shell or cask body cylinder assembly is an open ended (at the top) cylindrical unit with an integral closed bottom end. This assembly consists of a 7.31 inch thick ASME SA336 Type F304 stainless steel shell welded to a massive stainless steel bottom closure. The cask bottom is 6.13 in. thick.

The lid assembly is a 3.50 in. thick plate made of ASME SA336 Type F304 stainless steel. The lid is grooved to retain the closure seal. Two trunnions with brackets and gussets, welded to the lid, are used to lift the cask during handling. The lid, lid seal, vent and drain covers, their seals and bolts complete the packaging containment boundary. The lid assembly is bolted to the shell or body cylinder assembly with twelve (12) 1.5" high strength closure bolts.

The wall thickness of the outer shell, bottom plate and the lid enable the packaging to withstand the hypothetical puncture accident. The shell and lid are designed to be both strong and ductile in order to be capable of withstanding the punch loading.

Appendix B4.5A provides the impact analysis of the cask. Appendix B4.5B describes the lid bolt analysis. Appendix B4.5C presents the structural analysis of the cask body. Appendix B4.5D presents the stress analysis of the cask lifting attachment.

B4.2.2 Mechanical Properties of Materials

The mechanical properties of structural materials used in the cask is shown on Table B4.2-1 and

the effects of temperature on these properties are also shown on Table B4.2-1. The materials are identified and procured by reference to ASME and corresponding ASTM specifications. The yield and ultimate strengths of the structural steels shown on Table B4.2-1 are the minimum values specified in the material specifications. The ASME design stress intensity values (S_m) for Class 1 components are used to establish allowable stresses for the elastic analyses performed for the cask. Values of S_m are provided on Table B4.2-1. Stress intensity limits for the various stress categories are discussed in Sections B4.3 and B4.4.

Table B4.2-1 Temperature Dependent Material Properties

Component	Material	Temp. °F	Ultimate S_u(ksi)	Yield S_y(ksi)	Allow. S_m(ksi)	E (E^6 psi)	α^* (E^{-6})
Cask Body and Lid	SA-336 Type F304	70	70	30	20	28.3	8.55
		200	66.2	25	20	27.6	8.79
		300	61.5	22.5	20	27.0	9.0
		400	60.0	20.7	18.7	26.5	9.19
Lid Bolt	SA-479 XM19 Hot Rolled	70	135	105		28.3	8.87
		200				27.6	9.02
		300				27.0	9.10
		400				26.5	9.14

* Mean Coefficient of Thermal Expansion (in/in-°F) From 70°F to the Indicated Temperature.

B4.2.3 Chemical and Galvanic Reaction

The materials of fabrication are summarized in section B4.2.2. All structural components are the same or similar alloys of stainless steel and therefore are not subject to chemical or galvanic interaction.

B4.2.4 Size of Package and Cavity

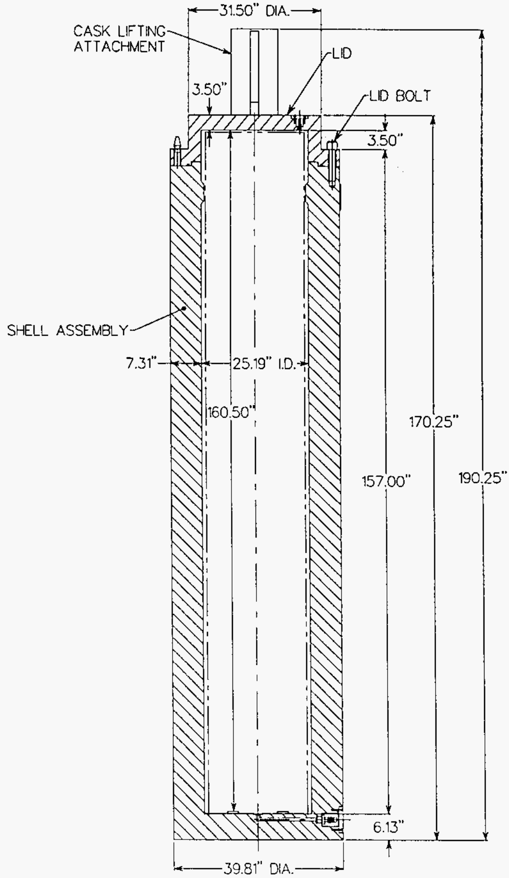
The basic structure of the cask is a right circular cylinder. The cask is 170.25 inches long and 39.81 inches in diameter except at the lid end where the diameter is 31.50 inches. The cask cavity has a length of 160.50 inches. The general arrangement of the cask is depicted in Figure B4.2-1. Component terminology used in this DAR is also identified on Figure B4.2-1. The closure lid end is referred to as the top with the packaging in the vertical orientation. Detailed design drawings for the cask are provided in Appendix A9.1. Table B4.2-2 summarizes the materials of construction used in the cask.

The basic components of the cask are the cask body, closure lid, and lid bolts. The cask body consists of the cylindrical shell assembly and bottom plate. The closure lid is attached to the cask body with twelve 1.5 inch diameter bolts. Two lifting trunnions with brackets and gussets are welded to the lid and are a 180° apart. Two penetrations into the containment are provided to support cask operations. One is located in the lid and the other is located in the cask bottom. The maximum gross weight of the loaded cask is 57,910 pounds including a payload of 18,950 pounds. The cask is transported in the vertical orientation with the lid end facing the up-direction. During transport, the cask is supported on the trailer by a tiedown system.

Table B4.2-2 Material of Construction

Component	Material
Shell Assembly	SA-336, Type F304
Lid	SA-336, Type F304
Lid Bolt	SA-479 XM19 Hot Rolled
Trunnion	SA-182, GR. F304
Brackets and Gussets	Type 304 SS
Vent & Drain Covers	SA-240 Type 304
Bolts for Vent & Drain Covers	SA-193-B8

Figure B4.2-1 General Arrangement of TN-WHC CASK



B4.2.5 Weights and Center of Gravity

The calculated gross weight of the cask in the transport configuration (including dry payload of 18,950 lbs) is 57,910 pounds. Approximate weights of major individual components or subassemblies are tabulated below:

Weight of Lid:	1,890 lbs
Weight of Shell:	34,300 lbs
Weight of Bottom:	2,270 lbs
Weight of Lifting Attachment:	500 lbs
Weight of Dry MCO:	18,950 lbs
Gross Package Weight (Dry):	57,910 lbs

The center of gravity of the unloaded cask is located on the cylindrical axis at 82.29 inches from the outer bottom surface.

The center of gravity for a loaded cask (dry) is located on the cylindrical axis at approximately 83.6 inches from the outer bottom surface.

B4.2.6 Tamper - Indicating Feature

The tamper indicating feature is not required.

B4.2.7 Positive Closure

Positive containment closure is accomplished entirely by the bolted design. Twelve bolts are used to close the cask closure lid. Four bolts are used to close the drain port cover and the vent port cover. This extensive bolting configuration prevents unintentional opening of the containment system.

B4.2.8 Cask Lifting Attachments and Tiedown System

The detailed stress calculations of the cask lifting attachment and tiedown system are presented in Appendix B4.5D and B7.3, respectively.

B4.2.9 Brittle Fracture

Brittle fracture of the cask body components is precluded by the choice of austenitic stainless steel for fabrication of the cask.

B4.3 NORMAL TRANSPORT CONDITIONS

This section describes the response of the cask to the loading conditions specified by the Hanford Specification. The design criteria established for the cask for the normal conditions of transport are described in Section 4.3.2. These criteria are selected to ensure that the package performance standards specified by the Hanford Specification is satisfied. Under normal conditions of transport there will be no loss or dispersal of radioactive contents, no significant increase in external radiation levels, and no substantial reduction in the effectiveness of the packaging.

Detailed structural analyses of various cask components subjected to individual loads are provided in the Appendices to this section. The limiting results from these analyses are used in this Section to quantify cask performance in response to the normal condition of transport load combinations selected for typical transport cask design. Table B4.3-1 provides an overview of the performance evaluations reported in each load combination subsection. Each subsection provides the limiting structural analysis result for the affected cask component(s) in comparison to the established design criteria. This comparison permits the minimum margin of safety for a given component subjected to a given loading condition to be readily identified. In all cases, the acceptability of the cask design with respect to established criteria and consequently with respect to the Hanford Specification standards is demonstrated.

The impact analysis results for the cask structure can be taken directly from the analysis in Appendix B4.5A. The structural analysis of the cask body is presented in Appendix B4.5C and covers a wide range of individual loading conditions. The stress results from the various individual loads must be combined in order to represent the stress condition in the cask body under the specified condition evaluated in this section. An explanation of the results reporting format and stress combination technique used to apply the results from Appendix B4.5C is provided here.

Reporting Method for Cask Body Stresses

Appendix B4.5C provides the detailed description of the structural analyses of the cask body. That appendix describes the detailed ANSYS[3] model used to analyze various applied loads. Table B4.3-2 identifies the individual loads (IL) analyzed which are applicable to normal conditions of transport. Some of these individual loads are axisymmetric (e.g. pressure) and others are asymmetric (e.g. free drop).

Figure B4.3-1 shows the selected locations on the cask body where stress results for these analyses are reported. Detailed stresses are actually available at as many locations as there are nodes in the finite element model. However, for practical considerations, the reporting of stress results is limited to those locations shown on Figure B4.3-1. These locations were selected to be representative of the stress distribution in the cask body with special attention given to areas subject to high stresses. The maximum stress may occur at a different location for each individual load.

The stress results for the individual load case tables reported in Appendix B4.5C are the maximum stresses for each individual load case. Two or more individual load cases must be combined to determine the total stresses at the standard stress reporting locations for the various load combinations. This is accomplished using the ANSYS postprocessor which algebraicly adds the stress components at each of the standard locations.

Several other items should be noted. In the cask, thermal stresses occur due to the effects of differential thermal expansion. When evaluating stresses, these thermal stresses are conservatively treated as primary stresses and the combined stresses due to primary loads (like pressure) and differential expansion (such as heating from 70°F to hot thermal conditions) are evaluated as primary stresses. In addition, some individual load cases in Appendix B4.5C were performed for the corresponding unit load (1G) condition (like the end drop and side drop) and are factored for the normal condition.

For the axisymmetric cases, the stress is constant around the circumference of the cask at each stress reporting location. For asymmetric analyses with significant differences in stress magnitudes on the extreme opposite sides of the cask (usually top and bottom for a horizontal cask) the stresses at locations on both sides are reported in separate tables.

Table B4.3-3 provides a matrix of the individual loads and how they are combined to determine the cask body stresses for the specified normal conditions of transport. The thermal stresses due to the hot and cold conditions are actually secondary stresses that could be evaluated using higher allowables than for primary stresses. They are conservatively added to the primary stresses and the combined stresses are evaluated using primary stress allowables. An "x" in Table B4.3-3 indicates that the stress results for the individual load case are used directly. A quantitative number (F) indicates the load factor applied to the individual stresses.

For the increased external pressure load combination, it is conservatively assumed that the cask cavity is at 0 psia. Since the specified load combination condition is 20 psia., the net differential pressure acting on the cask body is 20 psi.

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Table B4.3-1 Normal Conditions of Transport, TN-WHC Cask Performance Evaluation Overview

Loading Conditions	DAR Section	Scope of Evaluation
Thermal - Hot	B4.3.4.2	Cask Body Stresses due to Different Thermal Expansion - Hot
Thermal - Cold	B4.3.4.2	Cask Body Stresses due to Different Thermal Expansion - Cold
Maximum Pressure	B4.3.4.2	Cask Body Stresses due to Maximum Internal pressure
Increased External Pressure	B4.3.4.3.1	Cask Body Stresses (External Pressure = 20 psi)
Reduced External Pressure	B4.3.4.3.2	Cask Body Stresses (Internal Pressure = 161.2 psi)
Vibration	B4.3.4.3.3	Cask Body Stresses for Vibration Normally Incident to Transport
Water Spray	B4.3.4.3.4	Negligible
Free Drop	B4.3.4.3.5	Cask Body Stresses for Bottom End and Lid End Drops
	B4.3.4.3.5	Cask Body Stresses for Side Drop
	B4.3.4.3.5	Cask Body Stresses for C.G. Over Lid End Corner Drop
Penetration	B4.3.4.3.6	Negligible
Fatigue Analysis	B4.3.4.3.7	Fatigue Analysis Under Normal Transport Condition
Lid Bolt Analysis	B4.3.4.3.8	Lid Bolt Stresses - Lid End Corner Impact
Conclusions	B4.3.4.3.9	Summary of the Results

Table B4.3-2 Normal Conditions of Transport, Individual Load Cases for Cask Body Analysis

Load Case	Individual load Description	Stress Results Table
IL-1	Bolt Preload	B4.5C-3
IL-2	Thermal Stress at Hot Environment	B4.5C-11
IL-3	Thermal Stress at Cold Environment	B4.5C-12
IL-4	Internal Pressure	B4.5C-4
IL-5	External Pressure	B4.5C-5
IL-6	1G Down Cask Supported by Tie-Down System	B4.5C-7
IL-7	Vibration Load Cask Supported by Tie-Down System	B4.5C-6
IL-8	One Foot End Drop on Bottom End (1G)	B4.5C-7
IL-9	One Foot End Drop on Lid End (1G)	B4.5C-8
IL-10	One Foot Side Drop (1G)	B4.5C-9
IL-11	One Foot C.G. Over Lid End Corner Drop (1G)	B4.5C-10

Table B4.3-3 Summary of Load Combinations for Normal Conditions of Transport

Load Combinations	Applicable Individual Load											Stress Result Table No.
	IL-1	IL-2	IL-3	IL-4	IL-5	IL-6	IL-7	IL-8	IL-9	IL-10	IL-11	
Hot Environment	x	x		x		x						B4.3-5
Cold Environment	x		x		x	x						B4.3-6
Transport Vibrations	x	x		x			x					B4.3-7
	x		x		x		x					B4.3-8
1 Foot Bottom End Drop (25G)	x	x		x				x F=25				B4.3-9
	x		x		x			x F=25				B4.3-10
1 Foot Lid End Drop (25G)	x	x		x					x F=25			B4.3-11
	x		x		x				x F=25			B4.3-12
1 Foot Side Drop (24G)	x	x		x						x F=24		B4.3-13 B4.3 -14
	x		x		x					x F=24		B4.3-15 B4.3-16
1 Foot Lid Corner Drop (18G)	x	x		x							x F=18	B4.3-17 B4-3-18
	x		x		x						x F=18	B4.3-19 B4.3 -20

B4.3.1 Conditions To Be Evaluated

The cask will be designed to withstand each of the normal transport conditions specified in Hanford Specification as listed below:

B4.3.1.1 Environmental Conditions

The design temperature limits for the individual components, parts, and materials of the package will be determined by analyses. The analyses will be based upon the conditions listed below. The operational temperatures will be shown to not exceed the design limits.

a) Maximum heat generation rate of worst-case source (for normal conditions) plus maximum solar heat load plus maximum air temperature of 115 °F.

b) Minimum air temperature of -27 °F and zero heat generation rate.

B4.3.1.2 Reduced External Pressure

An external pressure of 3.5 psi absolute.

B4.3.1.3 Increased External Pressure

An external pressure of 20 psi absolute.

B4.3.1.4 Internal Pressure

An internal working pressure of 161.2 psi will be used for stress calculations.

B4.3.1.5 Vibration

The casks will be evaluated to confirm containment integrity when exposed to normal vibration due to the transportation from the 100 K West and East basins to the CSB in the 200 East Area by the transport vehicle. The cask is heavy and rigid and attached directly to the trailer bed. Trailer bed shock and vibration levels are applied directly to the package. The shock and vibration design limits by truck/trailer are those stated in Hanford Specification.

B4.3.1.6 Water Spray

The cask will be evaluated to confirm containment integrity through a water spray that simulates exposure to rainfall of approximately 2 in. (5 cm) per hour for at least one hour.

B4.3.1.7 Free Drop

The package will be evaluated to demonstrate containment after to a 1-ft (0.3-m) free drop onto a horizontal, yielding surface. During the free drop, the MCO will not be exposed to greater than 100*g*'s.

B4.3.1.8 Penetration

Impact of the hemispherical end of a vertical steel cylinder of 1.25 in. (3.2 cm) diameter and 13 lb (6.00 kg) mass, dropped from a height of 40.00 in (1.00 m) onto the exposed surface of the package which is expected to be most vulnerable to puncture. The long axis of the cylinder must be perpendicular to the package surface.

B4.3.2 Acceptance Criteria

The packaging consists of two major components:

- Cask Body Cylinder Assembly
- Lid Assembly

The structural design criteria for these components are described below.

<u>Containment Boundary</u>

The containment boundary consists of the cask body cylindrical shell , bottom plate and closure flange out to the seal seating surface and the lid. The lid bolts and seals are also part of the containment boundary as is the drain and vent cover plates, bolts and seals. The containment boundary is designed to the maximum practical extent as an ASME Class I component in accordance with the rules of the ASME[(4)] Boiler and Pressure Vessel Code, Section III, Subsection NB (1992 Edition). The Subsection NB guidelines for materials, design, fabrication and examination are applied to the above components as required by the Specification.

The acceptability of the containment boundary under the applied loads is based on the following criteria:

- ASME Code Design Stress Intensities
- Fatigue Failure to be Precluded
- Brittle Fracture to be Precluded
- Buckling to be Prevented

The values for material properties, design stress intensities (S_m) and design fatigue curves for Class 1 components given in Part D of Section II of the ASME B&PV Code will be used for the containment boundary materials. Allowable stress levels for containment components are outlined in Table B4.3-4 of this Section.

The design properties of other materials will be based on industry-recognized specifications, or standards, or on appropriate test data.

Bolting

In the special case of bolting, the average bolt stress is limited to 2/3 S_y and the maximum combined stress is limited to 0.9 S_y for normal condition of transport.

Brittle Fracture

The containment vessel is entirely austenitic stainless steel (Type 304) which is ductile even at low temperature. Thus, brittle fracture is precluded.

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Table B4.3-4 Containment Structure/Fastener Allowable Stress

STRESS CATEGORY	CONTAINMENT STRUCTURE ALLOWABLE STRESS	
	Normal Conditions	Accident Conditions
Primary Membrane General P_m Local P_L	 S_m $1.5\ S_m$	Lesser of : $2.4\ S_m$ or $0.7\ S_u$ (1) $3.6\ S_m$ or S_u (1)
Primary Membrane + Bending (P_m or P_L) + P_b	$1.5\ S_m$	Lesser of : $3.6\ S_m$ or S_u (1)
Range of Primary + Secondary (P_m or P_L) + P_b +Q	$3.0\ S_m$	$2 \times S_a$ for 10 Cycles (Code Sect. III, App. I)
Bearing Stress	S_y	S_y for Seal Surface S_u Elsewhere
Pure Shear Stress	$0.6\ S_m$	$0.42\ S_u$
Fatigue	Cumulative Fatigue Usage Factor ≤ 1	Not Applicable

STRESS CATEGORY	CONTAINMENT FASTENER ALLOWABLE STRESS	
	Normal Conditions	Accident Conditions
Average Tensile Stress	$2/3\ S_y$	Lesser of: $0.7\ S_u$ or S_y
Average Shear Stress	$0.4\ S_y$	Lesser of: $0.42\ S_u$ or $0.6\ S_y$
Maximum Combined Stress	$0.9\ S_y$	S_u

(1) When evaluating the results from the nonlinear elastic plastic analysis for the accident conditions, the general primary membrane stress intensity, P_m, shall not exceed $0.7\ S_u$ and the maximum primary stress intensity at any location (P_L or $P_L + P_b$) shall not exceed 0.9 S_u. These limits are in accordance with Appendix F of Section III of the Code.

B4.3.3 Structural Model

The cask body consists of the cylindrical shell, the bottom, the lid and the lid bolts. The elements used to model the bolts are ANSYS STIF3, beam elements. The cylindrical shell, the bottom end closure and the lid are modeled using either ANSYS STIF25 axisymmetric solid elements or ANSYS STIF42 axisymmetric solid elements. The loading applied to this type of elements may be either axisymmetric for some cases and asymmetric for other cases. The model geometry is based on Drawings H-1-81535, sheets 1 to 5. The contact surface at the lid and cylindrical shell is modeled using separate nodes in the interfacing components. These nodes are coupled or left uncoupled for specific constraint conditions as discussed below. All the analyses were performed using the model shown in Figures B4.5C-1 and B4.5C-2. The mechanical properties for the materials in this model are the linear values described in Section B4.2.2.

B4.3.4 Initial Conditions

B4.3.4.1 Environmental Heat Loading

Section B5.0 describes the thermal analyses performed for the cask subjected to hot environment conditions. These thermal analysis results are used to support various aspects of the structural evaluations as described in the following .

Maximum Temperature

Stress allowables for packaging components are a function of component temperature. Stress allowables are based on actual maximum calculated temperatures or conservatively selected higher temperatures. Section B5.0 summarizes significant temperatures calculated for the cask subjected to hot environment conditions. These temperatures are used to establish the allowables for every normal accident (except the thermal accident which has higher temperatures) load combination evaluated in this DAR.

Maximum Pressure

For purposes of the structural analysis of containment, a value of 150 psig is used for MNOP. The structural analysis performed assuming the same outward pressure different across the cask wall as during the reduced external pressure case, (150 + 14.7 - 3.5) 161.2 psi.

B4.3.4.2 Maximum Thermal and Pressure Stresses

Maximum Thermal Stress - Hot Environment

The thermal analysis of the cask is performed as described in Section B5.0. The temperature distribution from that analysis is used to perform an ANSYS structural analysis of the cask body thermal stresses.

Cask body stresses for the hot environment normal condition of transport are obtained by a combination of individual loads as summarized in Table B4.3-3. For this condition, it is assumed that the cask is in its normal transport configuration, mounted vertically on the trailer, and support by the tie-down system. Lid bolt preload effects and the dead weight loading are included.

Table B4.3-5 lists the total nodal stress intensity at each of the standard stress reporting locations. It may be noted that these stress intensities are the peak nodal stress intensities, the membrane and membrane plus bending stress intensities at the same locations are less than the peak nodal stress intensities. The maximum stress intensity calculated for this load combination is 1440 psi which occurs at node number 94. This stress intensity is well below the allowable membrane stress intensity of 20,000 psi, and membrane plus bending stress intensity of 30,000 psi (at 150^0F temperature).

Maximum Thermal Stress - Cold Environment

Containment vessel thermal stresses do occur in the cold environment due to the differential thermal expansion. The thermal stresses are determined in load case IL-3 with results tabulated in Table B4.5C-12. The cask cavity pressure at the cold environment condition is conservatively assumed to be 0 psia. This results in a net external pressure loading of 20 psi, load case IL-5 with results in Table B4.5C-5. Again, lid bolt preload and gravity load are included for cold environment load combinations.

Brittle fracture of the cask body components is precluded by the choice of austenitic stainless steel for fabrication of the cask.

Table B4.3-6 lists the total nodal stress intensity at each of the standard stress reporting locations. It may be noted that these stress intensities are the peak nodal stress intensities, the membrane and membrane plus bending stress intensities at the same locations are less than the peak nodal stress intensities. The maximum stress intensity calculated for this load combination is 369 psi which occurs at node number 34. This stress intensity is well below the allowable membrane stress intensity of 20,000 psi, and membrane plus bending stress intensity of 30,000 psi.

Maximum Pressure Stresses

For purposes of the structural analysis of containment, a value of 161.2 psi is used. This pressure loading is analyzed using the ANSYS model of the cask body as described in Appendix B4.5C and the results are reported in Table B4.5C-4 of that Appendix. This load case and corresponding results are designated as individual load IL-4. IL-4 is used to support various load combination evaluations as listed in Table B4.3-3.

B4.3.4.3 Structural Evaluations and Conclusions

B4.3.4.3.1 Increased external pressure

Cask body stresses for the increased external pressure, 20 psia, normal condition of transport are obtained by a combination of individual loads as summarized in Table B4.3-3 (same as cold environment). The conservatively assumed minimum cask cavity pressure of 0 psia results in a net external pressure loading of 20 psi.

This load case is combined with stresses due to bolt preload, gravity and cold thermal stresses. Table B4.3-6 lists the total nodal stress intensity at each of the standard stress reporting locations. It may be noted that these stress intensities are the peak nodal stress intensities, the membrane and membrane plus bending stress intensities at the same locations are less than the peak nodal stress intensities. The maximum stress intensity calculated for this load combination is 369 psi which occurs at node number 34. This stress intensity is well below the allowable membrane stress intensity of 20,000 psi, and membrane plus bending stress intensity of 30,000 psi.

B4.3.4.3.2 Reduced External Pressure

Cask body stresses for the 3.5 psia ambient normal condition of transport are obtained by a combination of individual loads as summarized in Table B4.3-3 (same as hot environment). The conservatively assumed MNOP of 150 psig results in a net internal pressure loading of (150+14.7-3.5) 161.2 psi. The lid bolt preload and gravity load are included. The thermal stress for the hot thermal condition are included in the load combination.

Table B4.3-5 lists the total nodal stress intensity at each of the standard stress reporting locations. It may be noted that these stress intensities are the peak nodal stress intensities, the membrane and membrane plus bending stress intensities at the same locations are less than the peak nodal stress intensities. The maximum stress intensity calculated for this load combination is 1440 psi which occurs at node number 94. This stress intensity is well below the allowable membrane stress intensity of 20,000 psi, and membrane plus bending stress intensity of 30,000 psi.

B4.3.4.3.3 Vibration

The input loading conditions used to evaluate the cask for transport vibration are obtained from truck bed accelerations in ANSI N14.23[5]. The peak inertia values used are 0.30 G, 0.30 G, and 0.60 G for the longitudinal, lateral and vertical directions, respectively. The stress due to the transport vibration load case are presented in Table B4.5C-6.

The combined stress results for this load case are provided in Tables B4.3-7 and B4.3-8. The highest nodal stress intensity is 1415 psi which occurs at node number 94. This stress intensity is well below the allowable membrane stress intensity of 20,000 psi, and membrane plus bending stress intensity of 30,000 psi.

B4.3.4.3.4 Water Spray

All exterior surfaces of the cask are metal and therefore not subject to soaking or structural degradation from water absorption. The water spray condition is therefore of no consequence to the cask.

B4.3.4.3.5 Free Drop

Four drop orientations are considered credible for the normal condition of transport one-foot free drop. The structural response of the cask body is evaluated for a one-foot end drop on the bottom end, lid end, one-foot corner drop on lid end and a one-foot side drop. The nodal stress intensities calculated from the finite element model analysis (Appendix B4.5C) for the above loading conditions are reported in Tables B4.5C-7, 8, 9, and 10.

The load combinations performed to evaluate these drop events are indicated in Table B4.3-3. In all case, bolt preload effects are included. For the hot environment condition, the thermal stress load case for that temperature, the 161.2 psi pressure load case and the impact load case factored for the normal condition G level are combined. For the cold temperature evaluation, the cold thermal stress case, the 20 psi external pressure case, and the impact load case factored for the normal condition G level are combined.

Table B4.3-9 lists the total nodal stress intensity at each of the standard stress reporting locations for the bottom end drop under hot environment conditions. The maximum stress intensity calculated for this load combination is 2436 psi which occurs at node number 214. This stress intensity is well below the allowable membrane stress intensity of 20,000 psi, and membrane plus bending stress intensity of 30,000 psi.

Table B4.3-10 lists the total nodal stress intensity at each of the standard stress reporting locations for the bottom end drop under cold environment conditions. The maximum stress intensity calculated for this load combination is 1228 psi which occurs at node number 214. This stress intensity is well below the allowable membrane stress intensity of 20,000 psi, and membrane plus bending stress intensity of 30,000 psi.

Table B4.3-11 lists the total nodal stress intensity at each of the standard stress reporting locations for the lid end drop under hot environment conditions. The maximum stress intensity calculated for this load combination is 3361 psi which occurs at node number 45. This stress intensity is well below the allowable membrane stress intensity of 20,000 psi, and membrane plus bending stress intensity of 30,000 psi.

Table B4.3-12 lists the total nodal stress intensity at each of the standard stress reporting locations for the lid end drop under cold environment conditions. The maximum stress intensity calculated for this load combination is 3958 psi which occurs at node number 51. This stress intensity is well below the allowable membrane stress intensity of 20,000 psi, and membrane plus bending stress intensity of 30,000 psi.

Table B4.3-13 lists the total nodal stress intensity at each of the standard stress reporting locations for the side drop under hot environment conditions (contact side). The maximum stress intensity calculated for this load combination is 3408 psi which occurs at node number 157. This stress intensity is well below the allowable membrane stress intensity of 20,000 psi, and membrane plus bending stress intensity of 30,000 psi.

Table B4.3-14 lists the total nodal stress intensity at each of the standard stress reporting locations for the side drop under hot environment conditions (opposite contact side). The maximum stress intensity calculated for this load combination is 1691 psi which occurs at node number 94. This stress intensity is well below the allowable membrane stress intensity of 20,000 psi, and membrane plus bending stress intensity of 30,000 psi.

Table B4.3-15 lists the total nodal stress intensity at each of the standard stress reporting locations for the side drop under cold environment conditions (contact side). The maximum stress intensity calculated for this load combination is 3025 psi which occurs at node number 427. This stress intensity is well below the allowable membrane stress intensity of 20,000 psi, and membrane plus bending stress intensity of 30,000 psi.

Table B4.3-16 lists the total nodal stress intensity at each of the standard stress reporting locations for the side drop under cold environment conditions (opposite contact side). The maximum stress intensity calculated for this load combination is 1551 psi which occurs at node number 157. This stress intensity is well below the allowable membrane stress intensity of 20,000 psi, and membrane plus bending stress intensity of 30,000 psi.

Table B4.3-17 lists the total nodal stress intensity at each of the standard stress reporting locations for the lid end corner drop under hot environment conditions (contact side). The maximum stress intensity calculated for this load combination is 12,252 psi which occurs at node number 51. This stress intensity is well below the allowable membrane stress intensity of 20,000 psi, and membrane plus bending stress intensity of 30,000 psi.

Table B4.3-18 lists the total nodal stress intensity at each of the standard stress reporting locations for the lid end corner drop under hot environment conditions (opposite contact side). The maximum stress intensity calculated for this load combination is 10,111 psi which occurs at node number 74. This stress intensity is well below the allowable membrane stress intensity of 20,000 psi, and membrane plus bending stress intensity of 30,000 psi.

Table B4.3-19 lists the total nodal stress intensity at each of the standard stress reporting locations for the lid end corner drop under cold environment conditions (contact side). The maximum stress intensity calculated for this load combination is 13,796 psi which occurs at node number 51. This stress intensity is well below the allowable membrane stress intensity of 20,000 psi, and membrane plus bending stress intensity of 30,000 psi.

Table B4.3-20 lists the total nodal stress intensity at each of the standard stress reporting locations for the lid end corner drop under hot environment conditions (opposite contact side). The maximum stress intensity calculated for this load combination is 11,263 psi which occurs at node number 74. This stress intensity is well below the allowable membrane stress intensity of 20,000 psi, and membrane plus bending stress intensity of 30,000 psi.

B4.3.4.3.6 Penetration

Due to lack of sensitive external protuberances, the one meter (40 in.) drop of a 13 pound hemispherical-headed, 1-1/4 inch diameter, steel cylinder is of negligible consequence to the cask.

B4.3.4.3.7 Fatigue Analysis

The purpose of the fatigue analysis is to show quantitatively that the containment vessel stresses are within acceptable limits under normal transport conditions. The highest cyclical loading is the vibration loading. The highest nodal stress intensity under vibration loading in the containment boundary is ±138 psi (Table B4.5C-6, node number 133).

If we apply a stress concentration factor of 4 for the structural discontinuities, the total peak stress intensity range is ±552. As shown in Figure I-9.2.2 of the ASME Code Section III, Appendix 1, austenitic steel can withstand an alternating stress of 23,700 psi for 10^{11} cycles.

Therefore the containment vessel alternating stress of 552 psi is well below the range where fatigue failure can occur.

A separate fatigue analysis of the lid bolts is presented in Appendix B4.5B.

B4.3.4.3.8 Lid Bolt Analysis

The lid bolts are analyzed for normal condition loadings in Appendix B4.5B. The analysis is based on NUREG/CR-6007[(6)]. The bolts are analyzed for the following normal conditions: operating preload, internal pressure, external pressure, temperature changes, impact loads and vibration loads.

The worst combined loading is due to a one foot end drop and 161.2 psi internal pressure. This results in a maximum stress intensity of 67,330 psi, which is below the allowable stress of 90,900 psi (0.9 S_y) at 150^{0}F temperature. The fatigue analysis of the lid bolt is presented in Appendix B4.5B. The analysis shows that based on 400 round trip shipments of the cask, the total usage factor is less than one.

B4.3.4.3.9 Conclusion

From the analyses presented in Section B4.3, it can be shown that the normal loads will not result in any structural damage of the cask and the containment function of the MCO will be maintained.

Figure B4.3-1 Standard Stress Reporting Locations

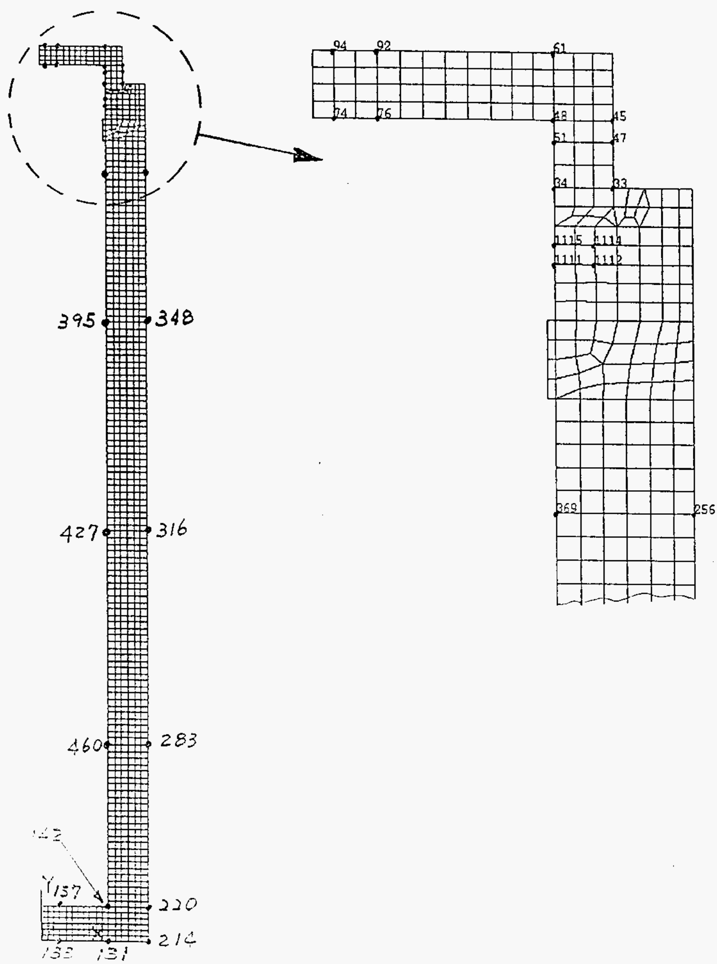

Table B4.3-5 Cask Body Stresses Under Hot Environment
(Bolt Preload, Hot Thermal,161.2 psi Internal Pressure,1G Gravity)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	676
	131	840
	214	1300
	157	1077
	142	489
	220	849
Cask Cylinder	460	445
	427	422
	395	550
	369	904
	283	715
	316	712
	348	813
	256	1004
Cask Flange	1111	212
	1112	503
	1115	309
	1114	724
Lid	34	596
	33	650
	51	1296
	47	401
	74	975
	76	722
	48	911
	45	449
	94	1440
	92	1288
	61	1264

* See Figure B4.3-1 for node locations.

Table B4.3-6 Cask Body Stresses Under Cold Environment
(Bolt Preload, Cold Thermal, 20 psi External Pressure, 1G Gravity)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	30
	131	67
	214	49
	157	66
	142	87
	220	33
Cask Cylinder	460	70
	427	66
	395	67
	369	51
	283	51
	316	39
	348	28
	256	14
Cask Flange	1111	53
	1112	51
	1115	29
	1114	241
Lid	34	369
	33	328
	51	367
	47	162
	74	237
	76	220
	48	206
	45	148
	94	245
	92	228
	61	120

* See Figure B4.3-1 for node locations.

Table B4.3-7 Cask Body Stresses Under Hot Environment Vibrations
(Bolt Preload, Hot Thermal, 161.2 psi Internal Pressure, Vibrations)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	678
	131	853
	214	1279
	157	1206
	142	483
	220	863
Cask Cylinder	460	433
	427	418
	395	550
	369	894
	283	713
	316	709
	348	826
	256	1008
Cask Flange	1111	211
	1112	503
	1115	304
	1114	722
Lid	34	590
	33	651
	51	1303
	47	399
	74	980
	76	726
	48	913
	45	451
	94	1415
	92	1292
	61	1265

* See Figure B4.3-1 for node locations.

Table B4.3-8 Cask Body Stresses Under Cold Environment Vibrations
(Bolt Preload, Cold Thermal, 20 psi External Pressure, Vibrations)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	165
	131	30
	214	8
	157	136
	142	104
	220	15
Cask Cylinder	460	68
	427	68
	395	58
	369	51
	283	47
	316	44
	348	15
	256	15
Cask Flange	1111	59
	1112	46
	1115	36
	1114	237
Lid	34	365
	33	328
	51	361
	47	160
	74	232
	76	216
	48	200
	45	145
	94	240
	92	224
	61	119

* See Figure B4.3-1 for node locations.

Table B4.3-9 Cask Body Stresses Under Hot Environment 1 Foot Bottom End Drop
(Bolt Preload, Hot Thermal, 161.2 psi Internal Pressure, 1 Foot Drop 25G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	1627
	131	1847
	214	2436
	157	202
	142	888
	220	1837
Cask Cylinder	460	1342
	427	1035
	395	887
	369	1059
	283	1038
	316	747
	348	813
	256	848
Cask Flange	1111	253
	1112	524
	1115	366
	1114	714
Lid	34	706
	33	599
	51	1060
	47	412
	74	765
	76	542
	48	836
	45	379
	94	1147
	92	1044
	61	1132

* See Figure B4.3-1 for node locations.

Table B4.3-10 Cask Body Stresses Under Cold Environment 1 Foot Bottom End Drop
(Bolt Preload, Cold Thermal, 20 psi External Pressure, 1 Foot Drop 25G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	923
	131	1157
	214	1228
	157	1025
	142	1199
	220	1148
Cask Cylinder	460	968
	427	672
	395	364
	369	295
	283	949
	316	652
	348	365
	256	168
Cask Flange	1111	66
	1112	133
	1115	97
	1114	366
Lid	34	474
	33	347
	51	616
	47	205
	74	447
	76	412
	48	362
	45	221
	94	507
	92	472
	61	252

* See Figure B4.3-1 for node locations.

Table B4.3-11 Cask Body Stresses Under Hot Environment 1 Foot Lid End Drop
(Bolt Preload, Hot Thermal, 161.2 psi Internal Pressure, 1 Foot Drop 25G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	462
	131	749
	214	1238
	157	972
	142	366
	220	871
Cask Cylinder	460	723
	427	1010
	395	1432
	369	2070
	283	715
	316	722
	348	1009
	256	959
Cask Flange	1111	2696
	1112	2016
	1115	2820
	1114	2380
Lid	34	2533
	33	2846
	51	2529
	47	3238
	74	165
	76	261
	48	2951
	45	3361
	94	2259
	92	2120
	61	2377

* See Figure B4.3-1 for node locations.

Table B4.3-12 Cask Body Stresses Under Cold Environment 1 Foot Lid End Drop
(Bolt Preload, Cold Thermal, 20 psi External Pressure, 1 Foot Drop 25G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	244
	131	122
	214	36
	157	173
	142	217
	220	23
Cask Cylinder	460	349
	427	647
	395	928
	369	1326
	283	331
	316	627
	348	920
	256	1136
Cask Flange	1111	2606
	1112	1834
	1115	2857
	1114	3256
Lid	34	2445
	33	3023
	51	3958
	47	3056
	74	1048
	76	1035
	48	2997
	45	2810
	94	606
	92	615
	61	2390

* See Figure B4.3-1 for node locations.

Table B4.3-13 Cask Body Stresses Under Hot Environment 1 Foot Side Drop (contact side)

(Bolt Preload, Hot Thermal, 161.2 psi Internal Pressure, 1 Foot Drop 24G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	2357
	131	1810
	214	1318
	157	3408
	142	1999
	220	782
Cask Cylinder	460	2882
	427	2977
	395	2780
	369	2116
	283	939
	316	1023
	348	898
	256	1129
Cask Flange	1111	1907
	1112	830
	1115	2217
	1114	729
Lid	34	1565
	33	872
	51	917
	47	176
	74	1312
	76	946
	48	702
	45	59
	94	2139
	92	1631
	61	1251

* See Figure B4.3-1 for node locations.

Table B4.3-14 Cask Body Stresses Under Hot Environment 1 Foot Side Drop (opp. contact side)

(Bolt Preload, Hot Thermal, 161.2 psi Internal Pressure, 1 Foot Drop 24G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	1403
	131	538
	214	851
	157	1591
	142	560
	220	535
Cask Cylinder	460	1126
	427	1219
	395	1020
	369	842
	283	727
	316	1100
	348	931
	256	896
Cask Flange	1111	500
	1112	519
	1115	742
	1114	635
Lid	34	637
	33	522
	51	1116
	47	343
	74	961
	76	967
	48	666
	45	378
	94	1691
	92	1473
	61	1270

* See Figure B4.3-1 for node locations.

Table B4.3-15 Cask Body Stresses Under Cold Environment 1 Foot Side Drop (contact side)

(Bolt Preload, Cold Thermal, 20 psi External Pressure, 1 Foot Drop 24G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	2345
	131	946
	214	701
	157	3050
	142	2303
	220	806
Cask Cylinder	460	2898
	427	3025
	395	3001
	369	2558
	283	1681
	316	1761
	348	1738
	256	1504
Cask Flange	1111	1948
	1112	814
	1115	1950
	1114	1163
Lid	34	1435
	33	955
	51	1632
	47	490
	74	339
	76	333
	48	1368
	45	615
	94	507
	92	229
	61	582

* See Figure B4.3-1 for node locations.

Table B4.3-16 Cask Body Stresses Under Cold Environment 1 Foot Side Drop (opp. contact side)

(Bolt Preload, Cold Thermal, 20 psi External Pressure, 1 Foot Drop 24G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	1151
	131	336
	214	425
	157	1551
	142	81
	220	315
Cask Cylinder	460	1142
	427	1265
	395	1240
	369	921
	283	831
	316	1221
	348	1001
	256	593
Cask Flange	1111	503
	1112	247
	1115	471
	1114	570
Lid	34	396
	33	463
	51	566
	47	129
	74	618
	76	477
	48	503
	45	195
	94	1413
	92	655
	61	188

* See Figure B4.3-1 for node locations.

Table B4.3-17 Cask Body Stresses Under Hot Environment 1 Foot Corner Drop (contact side)

(Bolt Preload, Hot Thermal, 161.2 psi Internal Pressure, 1 Foot Drop on lid side 18G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	1218
	131	571
	214	1073
	157	1350
	142	659
	220	755
Cask Cylinder	460	498
	427	717
	395	1282
	369	2390
	283	764
	316	790
	348	952
	256	1302
Cask Flange	1111	3912
	1112	2796
	1115	4161
	1114	4203
Lid	34	4892
	33	4534
	51	12252
	47	2353
	74	10462
	76	8496
	48	8284
	45	986
	94	5307
	92	7955
	61	4721

* See Figure B4.3-1 for node locations.

Table B4.3-18 Cask Body Stresses Under Hot Environment 1 Foot Corner Drop (opp. contact side)

(Bolt Preload, Hot Thermal, 161.2 psi Internal Pressure, 1 Foot Drop on lid side 18G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	1065
	131	978
	214	1423
	157	1998
	142	408
	220	983
Cask Cylinder	460	765
	427	951
	395	1045
	369	1148
	283	709
	316	762
	348	789
	256	687
Cask Flange	1111	928
	1112	996
	1115	1249
	1114	1065
Lid	34	1693
	33	1189
	51	1548
	47	961
	74	10111
	76	3770
	48	1659
	45	813
	94	7337
	92	3207
	61	1666

* See Figure B4.3-1 for node locations.

Table B4.3-19 Cask Body Stresses Under Cold Environment 1 Foot Corner Drop (contact side)

(Bolt Preload, Cold Thermal, 20 psi External Pressure, 1 Foot Drop on lid side 18G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	1062
	131	299
	214	200
	157	1283
	142	261
	220	99
Cask Cylinder	460	124
	427	354
	395	802
	369	1875
	283	22
	316	255
	348	830
	256	1490
Cask Flange	1111	3829
	1112	2645
	1115	4199
	1114	5087
Lid	34	4840
	33	4546
	51	13796
	47	2285
	74	10652
	76	4268
	48	9060
	45	1131
	94	6148
	92	9351
	61	6096

* See Figure B4.3-1 for node locations.

Table B4.3-20 Cask Body Stresses Under Cold Environment 1 Foot Corner Drop (opp. contact side)

(Bolt Preload, Cold Thermal, 20 psi External Pressure, 1 Foot Drop on lid side 18G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	1050
	131	166
	214	151
	157	1278
	142	466
	220	138
Cask Cylinder	460	391
	427	587
	395	542
	369	477
	283	486
	316	664
	348	486
	256	370
Cask Flange	1111	860
	1112	757
	1115	1011
	1114	1126
Lid	34	1467
	33	1163
	51	2704
	47	953
	74	11263
	76	4363
	48	2496
	45	1003
	94	8841
	92	3884
	61	2462

* See Figure B4.3-1 for node locations.

B4.4 ACCIDENT CONDITIONS

This section describes the response of the cask to the accident loading conditions specified by the Hanford Specification. The design criteria established for the TN-WHC for the hypothetical accident conditions are described in Section B4.4.2. These criteria are selected to ensure that the package performance standards specified by the Hanford Specification[1] are satisfied.

The presentation of the hypothetical accident condition analyses and results is accomplished in the same manner as that used for the normal condition of transport. The detailed analyses of the various packaging components under different loading conditions are presented in the Appendices to this Section. The limiting results for the specified hypothetical accident loading conditions are taken from the Appendices and summarized here with a comparison made to the established design criteria.

Table B4.4-1 provides an overview of the performance evaluations presented in this section. Stress analysis results for the cask body and lid bolts are taken directly from the corresponding analysis appendix.

Reporting Method for Cask body Vessel Stresses

The structural analysis of the cask body was performed using an ANSYS finite element model. Stress results are reported at selected representative locations as described in Section B4.3. Because of the asymmetric characteristic of most of the hypothetical accident loads, stress results are generally reported on two opposite sides of the cask body.

Appendix B4.5C provides the detailed description of the structural analyses of the cask body. That appendix describes the detailed ANSYS model used to analyze various applied loads. Table B4.4-2 identifies the individual loads (IL) analyzed using the ANSYS model which are applicable to the hypothetical accident conditions. Some of these individual loads are axisymmetric (e.g. pressure) and others are asymmetric (e.g. side impact).

Figure B4.3-1 shows the selected locations on the cask body where stress results for these analyses are reported. Detailed stresses are actually available at as many locations as there are nodes in the finite element model. However, for practical considerations, the reporting of stress results is limited to those locations shown on Figure B4.3-1. These locations were selected to be representative of the stress distribution in the cask body with special attention given to areas subject to high stresses. The maximum stress may occur at a different location for each individual load.

The stress results for the individual load case tables reported in Appendix B4.5C are limited to the maximum stress components. Two or more individual load cases must be combined to determine the total stresses at the standard stress reporting locations for the various load combinations. This is accomplished using the ANSYS postprocessor which algebraicly adds the stress components at each of the standard locations. The membrane stress intensity is then found from the membrane stress components and the inner and outer surface membrane plus bending stress intensities are determined from the membrane ± bending stress components.

Several other items also described in Section B4.3 should be noted. For the axisymmetric cases such as the end drop on the lid and bottom, the stress is constant around the circumference of the cask at each stress reporting location. For asymmetric analyses with significant differences in stress magnitudes on the extreme opposite sides of the cask, the stress at locations on both sides of the cask are reported in separate tables.

Table B4.4-3 provides a matrix of the individual loads and how they are combined to determine the cask body stresses for the hypothetical accident conditions. The thermal stresses due to the hot and cold conditions are actually secondary stresses that could be evaluated using higher allowables than for primary stresses. They are conservatively added to the primary stresses and the combined stresses are evaluated using the primary stress allowables. An x in Table B4.4-3 indicates that the stress results for the individual load case are used directly. A quantitative number (F) indicates the load factor applied to the individual stresses.

For the minimum internal pressure load combination, it is conservatively assumed that the cask cavity is at 0 psia. The net differential pressure acting on the cask body is then 20 psi (external pressure).

Table B4.4-1 Accident Conditions of Transport, TN-WHC Performance Evaluation Overview

Loading Conditions	DAR Section	Scope of Evaluation
Thermal Accident	B4.4.4.2	Cask Body Stresses due to Different Thermal Expansion
Maximum Pressure	B4.4.4.2	Cask Body Stresses due to Maximum Internal pressure
Impact	B4.4.4.3.1	Cask Body Stresses for Bottom End and Lid End Drops
	B4.4.4.3.2	Cask Body Stresses for Side Drop
	B4.4.4.3.3	Cask Body Stresses for C.G. Over Lid End Corner Drop
Lid Bolt Analysis	B4.4.4.3.4	Lid Bolt Stresses - Lid End Corner Drop
Puncture	B4.4.4.3.5	Cask Body Evaluation for 40 inch Drop onto the Puncture Bar
Conclusions	B4.4.4.3.6	Summary of the Results

Table B4.4-2 Accident Conditions of Transport, Individual Load Cases for Cask Body Analysis

Load Case	Individual load Description	Stress Results Table*
IL-1	Bolt Preload	B4.5C-3
IL-2	Thermal Stress at Hot Environment	B4.5C-11
IL-3	Thermal Stress at Cold Environment	B4.5C-12
IL-4	Internal Pressure	B4.5C-4
IL-5	External Pressure	B4.5C-5
IL-8	End Drop on Bottom End (1G)	B4.5C-7
IL-9	End Drop on Lid End (1G)	B4.5C-8
IL-10	Side Drop (1G)	B4.5C-9
IL-11	C.G. Over Lid End Corner Drop (1G)	B4.5C-10

* These tables are presented in Appendix B4.5C

Table B4.4-3 Summary of Load Combinations for Accident Conditions of Transport

Load Combinations	Applicable Individual Load									Stress Result Table No.
	IL-1	IL-2	IL-3	IL-4	IL-5	IL-8	IL-9	IL-10	IL-11	
30 Foot Bottom End Drop (30G)	x	x		x		x F=30				B4.4-4
	x		x		x	x F=30				B4.4-5
30 Foot Lid End Drop (30G)	x	x		x			x F=30			B4.4-6
	x		x		x		x F=30			B4.4-7
30 Foot Side Drop (40G)	x	x		x				x F=40		B4.4-8 B4.4-9
	x		x		x			x F=40		B4.4-10 B4.4-11
30 Foot Lid Corner Drop (20G)	x	x		x					x F=20	B4.4-12 B4.4 -13
	x		x		x				x F=20	B4.4-14 B4.4 -15

B4.4.1 Conditions To Be Evaluated

The cask is designed to withstand each of the accident transport conditions specified in Hanford Specification[1] as listed below:

B4.4.1.1 Impact

The response of the cask is evaluated for a free drop from a height of 30 feet onto an yielding surface at various orientations. The inertial loading applied to the cask components is determined Appendix B4.5A. The 30 foot drop is measured from the impact surface to the bottom of the impact limiter; the C.G. of the cask is much higher than 30 feet.

Cask body stresses are reported for the standard drop orientations of lid end and bottom end drops, side drop, center-of-gravity over lid end corner drop.

B4.4.1.2 Puncture

The worst case credible puncture incident is equivalent to a free drop of the cask through a distance of 40 in (1 m) in a position for which the maximum damage is expected, onto the upper end of solid, vertical, cylindrical, mild steel bar mounted on an essentially unyielding, horizontal surface. The bar must be 6 in (15 cm) in diameter, with the top horizontal and its edge rounded to a radius of not more than 1/4 in (6 mm) and of a length as to cause maximum damage to the package, but not less than 8 in (20 cm) long.

B4.4.1.3 Thermal

An ANSYS transient thermal analysis for the 30 minute thermal accident is reported in Section B5.0. The initial condition is steady state at 115^0 F ambient with maximum decay heating. The initial steady state condition is followed by 0.5 hour severe thermal transient which is then followed by a cool-down period. The temperature through the cross section of the package at the time where individual temperatures peak (0.5 hours)are summarized below:

Cask inner surface temperature = 727^0F
Cask outer surface temperature = 1068^0F
Lid bolt temperature = 1068^0F

B4.4.2 Acceptance Criteria

Containment Boundary

The cask shall be designed so that during accident conditions the cask maintains confinement of the MCO, as demonstrated by analysis. Elastic-plastic analysis may be performed to demonstrate maintenance of confinement after the accident conditions. ASME B&PV Code Section III, Service Level D allowables will be used for acceptance. After any accident condition, as a minimum, the containment function of the MCO shall be maintained. Allowable stress levels for containment components are outlined in Table B4.3-4 of Section 4.3.

Bolting

In the special case of bolting, the maximum combined stress is limited to S_u for accident condition of transport.

Brittle Fracture

The containment vessel is entirely austenitic stainless steel (Type 304) which is ductile even at low temperature. Thus, brittle fracture is precluded.

B4.4.3 Structural Model

The cask body consists of the cylindrical shell, the bottom, the lid and the lid bolts. The elements used to model the bolts are ANSYS STIF3, beam elements. The cylindrical shell, the bottom end closure and the lid are modeled using either ANSYS STIF25 axisymmetric solid elements or ANSYS STIF42 axisymmetric solid elements (Puncture Analysis). The loading applied to this type of elements may be either axisymmetric for some cases and asymmetric for other cases. The model geometry is based on Drawings H-1-81535, sheets 1,2,3, 4, and 5 provided in Section A9.1. The contact surface at the lid and cylindrical shell is modeled using separate nodes in the interfacing components. These nodes are coupled or left uncoupled for specific constraint conditions as discussed in Appendix B4.5C. All the analyses were performed using the model shown in Figures B4.5C-1 and B4.5C-2. The mechanical properties for the materials in this model are the linear values described in Section B4.2.2.

B4.4.4 Initial Conditions

B4.4.4.1 Environmental Heat Loading

Section B5.0 describes the thermal analyses performed for the cask subjected to thermal accident conditions. These thermal analysis results are used to support various aspects of the structural evaluations as described in the following .

Maximum Temperature

Stress allowables for packaging components are a function of component temperature. Stress allowables are based on actual maximum calculated temperatures or conservatively selected higher temperatures. Section B5.0 summarizes significant temperatures calculated for the cask subjected to thermal conditions. These temperatures are used to calculate the cask body thermal stress.

Maximum Pressure

For purpose of the structural analysis of containment, a value of 150 psi is used for MNOP. The structural analysis is performed assuming the same outward pressure differences across the cask wall as during the reduced external pressure case, (150 + 14.7 - 3.5) 161.2 psi.

B4.4.4.2 Maximum Thermal and Pressure Stresses

Maximum Thermal Stress

For the accident load combinations, the normal thermal stresses as described in Section B4.3.4.2 are used for the accident load combinations. The thermal expansion bolt stresses due to the thermal accident condition (fire condition) are presented in Appendix B4.5B.

Maximum Pressure Stresses

For purposes of the structural analysis of containment, a value of 161.2 psi as described above is used. This pressure loading is analyzed using the ANSYS model of the cask body as described in Appendix B4.5C and the results are reported in Table B4.5C-4.

B4.4.4.3 Structural Evaluations and Conclusions

B4.4.4.3.1 Bottom End and Lid End Drops

The impact analysis of the cask shows that the maximum expected inertia loading from the 30-foot end drop is 25 G's for the 90° orientation.

The structural analysis of the cask body for this loading condition was performed using an inertial loading of 30 G (90° bottom end drop and lid end drop). As shown in Table B4.5C-7 of Appendix B4.5C, the maximum stresses due to the bottom end drop is 1,440 psi and 4,350 psi for the lid end drop.

The load combinations performed to evaluate these drop events are indicated in Table B4.4-3. In all case, bolt preload effects are included. For the hot environment condition, the thermal stress load case for that temperature, the 161.2 psi pressure load case and the impact load case factored for the accident condition G level are combined. For the cold temperature evaluation, the cold thermal stress case, the 20 psi external pressure case, and the impact load case factored for the accident condition G level are combined.

Table B4.4-4 lists the total nodal stress intensity at each of the standard stress reporting locations for the bottom end drop under hot environment conditions. The maximum stress intensity calculated for this load combination is 2,674 psi which occurs at node number 214. This stress intensity is well below the allowable membrane stress intensity of 47,670 psi, and membrane plus bending stress intensity of 68,1000 psi (at 150^{0}F temperature).

Table B4.4-5 lists the total nodal stress intensity at each of the standard stress reporting locations for the bottom end drop under cold environment conditions. The maximum stress intensity calculated for this load combination is 1,434 psi which occurs at node number 214. This stress intensity is well below the allowable membrane stress intensity of 47,670 psi, and membrane plus bending stress intensity of 68,1000 psi (at 150^{0}F temperature).

Table B4.4-6 lists the total nodal stress intensity at each of the standard stress reporting locations for the lid end drop under hot environment conditions. The maximum stress intensity calculated for this load combination is 3,950 psi which occurs at node number 45. This stress intensity is well below the allowable membrane stress intensity of 47,670 psi, and membrane plus bending stress intensity of 68,1000 psi (at 150^{0}F temperature).

Table B4.4-7 lists the total nodal stress intensity at each of the standard stress reporting locations for the lid end drop under cold environment conditions. The maximum stress intensity calculated for this load combination is 4,681 psi which occurs at node number 51. This stress intensity is well below the allowable membrane stress intensity of 47,670 psi, and membrane plus bending stress intensity of 68,1000 psi (at 150^{0}F temperature).

B4.4.4.3.2 Side Drop

The analysis of the 30-foot side drop provided a inertial loading of 37 G for side drop and 39 G for slap down (Appendix 4.5A). The structural analysis of the cask body for this loading condition was performed using an inertial loading of 40 G to envelop the worst side drop and slap down conditions. As shown in Table B4.5C-9 of Appendix B4.5C, the maximum stresses due to the side drop is 5,152 psi. This maximum stress value in the containment is much less than the allowables for general membrane stress intensity of 47,670 psi.

Table B4.4-8 lists the total nodal stress intensity at each of the standard stress reporting locations for the side drop under hot environment conditions (contact side). The maximum stress intensity calculated for this load combination is 5,085 psi which occurs at node number 157. This stress intensity is well below the allowable membrane stress intensity of 47.670 psi, and membrane plus bending stress intensity of 68,1000 psi (at 150^{0}F temperature).

Table B4.4-9 lists the total nodal stress intensity at each of the standard stress reporting locations for the side drop under hot environment conditions (opposite contact side). The maximum stress intensity calculated for this load combination is 2,598 psi which occurs at node number 157. This stress intensity is well below the allowable membrane stress intensity of 47,670 psi, and membrane plus bending stress intensity of 68,1000 psi (at 150^{0}F temperature).

Table B4.4-10 lists the total nodal stress intensity at each of the standard stress reporting locations for the side drop under cold environment conditions (contact side). The maximum stress intensity calculated for this load combination is 5,086 psi which occurs at node number 427. This stress intensity is well below the allowable membrane stress intensity of 47,670 psi, and membrane plus bending stress intensity of 68,1000 psi (at 150^{0}F temperature).

Table B4.4-11 lists the total nodal stress intensity at each of the standard stress reporting locations for the side drop under cold environment conditions (opposite contact side). The maximum stress intensity calculated for this load combination is 2,586 psi which occurs at node number 157. This stress intensity is well below the allowable membrane stress intensity of 47,670 psi, and membrane plus bending stress intensity of 68,1000 psi (at 150^{0}F temperature).

B4.4.4.3.3 C.G. Over Corner Drop

The response of the cask to the 30-foot corner drop was analyzed for impact on the top or lid end corner which is the more critical cask orientation (than the bottom corner) because it is the closure end. The analysis was performed using the ANSYS model as described in Appendix B4.5C. The center-of-gravity over corner drop occurs at a drop angle of approximately 80°. That is, the longitudinal axis of the cask is at an angle of 80° from the impact surface. The analysis (Appendix B4.5A) of the 80° drop orientation resulted in maximum inertia loading of 19.7 G (axial) along the cask longitudinal axis and 3.5 g transverse to the longitudinal axis at the cask CG. The maximum stress result for the 30 foot lid end corner drop is 14,964 psi.

Table B4.4-12 lists the total nodal stress intensity at each of the standard stress reporting locations for the lid end corner drop under hot environment conditions (contact side). The maximum stress intensity calculated for this load combination is 13,747 psi which occurs at node number 51. This stress intensity is well below the allowable membrane stress intensity of 47,670 psi, and membrane plus bending stress intensity of 68,1000 psi (at 150^{0}F temperature).

Table B4.4-13 lists the total nodal stress intensity at each of the standard stress reporting locations for the lid end corner drop under hot environment conditions (opposite contact side). The maximum stress intensity calculated for this load combination is 11,338 psi which occurs at node number 74. This stress intensity is well below the allowable membrane stress intensity of 47,670 psi, and membrane plus bending stress intensity of 68,1000 psi (at 150^{0}F temperature).

Table B4.4-14 lists the total nodal stress intensity at each of the standard stress reporting locations for the lid end corner drop under cold environment conditions (contact side). The maximum stress intensity calculated for this load combination is 15,293 psi which occurs at node number 51. This stress intensity is well below the allowable membrane stress intensity of 47,670 psi, and membrane plus bending stress intensity of 68,1000 psi (at 150^{0}F temperature).

Table B4.4-15 lists the total nodal stress intensity at each of the standard stress reporting locations for the lid end corner drop under hot environment conditions (opposite contact side). The maximum stress intensity calculated for this load combination is 12,490 psi which occurs at node number 74. This stress intensity is well below the allowable membrane stress intensity of 47,670 psi, and membrane plus bending stress intensity of 68,1000 psi (at 150^0F temperature).

B4.4.4.3.4 Lid Bolts

The lid bolts were analyzed in accordance with NUREG/CR-6007, Stress Analysis of Closure Bolts for Shipping Casks[6]. This analysis is presented in Appendix B4.5B. The governing hypothetical accident load is the combination of maximum internal pressure and a near perpendicular, oblique 30-foot drop in which the lid end strikes the target first and the cask contents impact on the inner side of the lid. This drop orientation is the most severe because, based on the impact analysis (Appendix B4.5A), this drop orientation results in the highest axial inertia forces that result in the highest lid bolt tensile stresses. The results in Appendix B4.5B show that the maximum stress intensity due to tension plus shear plus bending is 72,900 psi which is less than the allowable maximum stress intensity of 133,000 psi (at 150^0F).

The fire accident results in a maximum bolt and lid temperature of 1068^0F (1091^0F is conservatively used for calculation). The thermal stress at the bolt due to this differential thermal expansion is 20,154 psi. The maximum combined stress including stresses due to preload and shears 49,386 psi. This stress is less than the bolt yield stress of 82,500 psi. The MCO will therefore be secure inside the cask during the fire accident.

B4.4.4.3.5 Puncture

<u>Puncture Force</u>

The most severe damage to the cask resulting from the puncture drop will occur on the outer center of the lid. The analysis is based on the Nelms[7] equation. The Nelms puncture relation is given as:

$$t = (W/S_u)^{0.71}$$

Where:

t = lid thickness = 3.5"
W = package weight = 57,910 lbs
S_u = ultimate tensile strength of the lid = 70,000 psi

The package weight that can result in puncture is:

$$W = S_u\, t^{1.41} = 70{,}000\ (3.5)^{1.41} = 409{,}482 \text{ lbs}$$

The actual package weight is 57,910 lbs, Therefore, the factor of safety for puncture resistance on the energy basis is:

F.S. = 409,482/57,910 = 7.07

When the package contacts the puncture bar, the force applied to the package is:

F_I = impact force = $\sigma_s A_p$
σ_s = dynamic flow pressure of stainless steel = 45,000 psi (reference 8)
A_p = area of the puncture bar = $\pi/4\ (6)^2 = 28.27\ in^2$
$F_I = 45{,}000 \times 28.27 = 1.272 \times 10^6$ lbs

This force produces a cask deceleration:

G = cask deceleration = $F_I/W = 1.272 \times 10^6/57{,}910 = 22$

This deceleration is smaller to that which will occur during impact on end after the 30 foot free drop (25G). Therefore, global stresses that result from the inertial force will be smaller. The bending stress at the center of the lid will be calculated using the above finite element model.

Lid Stresses

The lid stresses are computed using the 2-D model as described in Appendix B4.5C-4. The loading distribution and boundary conditions are shown on Figures B4.5C-21 and B4.5C-22. The 22 G inertia load due to 40" drop is applied as body acceleration. The content's inertia load is applied as equivalent pressure on the lid as follows:

Contents weight = 19,120 lbs

$P = 19{,}120 \times 22\ /\pi\ (12.595)^2 = 844.05$ psi

Elastic Analysis:

ANSYS computer Code is used for the analysis. A stress run was made using the above noted loads and boundary conditions. STIF 42 (Axisymmetric) finite element was used in the analysis.

The stresses are linearized at critical sections. The maximum membrane and maximum membrane plus bending stress intensities are as follows:

Location (Node number) (Figure B4.5C-23)	P_m (psi)	$P_m + P_b$ (psi)
84	12,560	83,280
94	10,880	85,010
93	5,275	70,560
92	30,780	57,550
91	25,430	59,960

The maximum membrane stress intensity calculated for this load is 30,780 psi at node number 92. This stress is below the allowable membrane stress intensity of 47,670 psi. The maximum membrane plus bending stress intensity is 85,010 psi at node number 94. This stress exceeds the allowable membrane plus bending stress intensity of 68,100 psi. Therefore, an elastic - plastic analysis was performed to recalculate the stresses.

Plastic Analysis:

A plastic analysis was performed (using the same finite element model, boundary conditions, and loads). The stress - strain properties used for the stainless steel is given in Figure B4.5C-24. The total load (22 G inertia and 844.05 psi) was divided in eight load steps for proper converged solution.

The maximum membrane and maximum membrane plus bending stress intensities are as follows:

Location (Node number) (Figure B4.5C-23)	P_m (psi)	$P_m + P_b$ (psi)
84	2,934	45,030
94	3,326	46,620
93	6,889	42,140
92	25,470	36,060
91	26,350	40,780

The maximum membrane stress intensity calculated for this load is 26,350 psi at node number 91. This stress is below the allowable membrane stress intensity of 47,670 psi ($0.7S_u$). The maximum membrane plus bending stress intensity is 46,620 psi at node number 94. This stress is below the allowable membrane plus bending stress intensity of 61,290 psi ($0.9S_u$). The analysis shows the stresses are within the ASME Code allowables.

B4.4.4.3.6 Conclusions

From the analyses presented in Section B4.4 above, it can be shown that the accident load conditions will not result in any significant structural damage of the TN-WHC cask.

The maximum combined stresses due to the 30 foot drop event are also presented in Tables B4.4-4 to B4.4-15. In nearly all of the load cases, the maximum stresses are less than the membrane allowable stress with a large margin of safety.

The lid bolt stresses do not exceed the ultimate strength during the hypothetical 30 ft drop accidents as shown in Appendix B4.5B.

During the 40 inch drop onto a 6.0 inch diameter puncture bar, the packaging may deform locally above the punch. It has been shown by analysis that the package will not be punctured and that the MCO will be confined.

The cask body material is a stainless steel. The thermal stresses due to the differential thermal expansion are insignificant. Thermal stress of the lid bolt due to the differential thermal expansion under the thermal accident conditions is less than the yield stress.

From the analyses presented in Section 4.4, it can be shown that the accident loads will not result in any significant structural damage of the cask. The cask maintains the confinement function of the MCO.

Table B4.4-4 Cask Body Stresses Under Hot Environment 30 Foot Bottom End Drop
(Bolt Preload, Hot Thermal, 161.2 psi Internal Pressure, 30 Foot Drop 30G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	1826
	131	2067
	214	2674
	157	199
	142	1121
	220	2067
Cask Cylinder	460	1529
	427	1163
	395	957
	369	1091
	283	1225
	316	874
	348	813
	256	817
Cask Flange	1111	265
	1112	536
	1115	384
	1114	712
Lid	34	729
	33	588
	51	1012
	47	414
	74	722
	76	505
	48	821
	45	365
	94	1093
	92	993
	61	1105

* See Figure B4.3-1 For Node Locations.

Table B4.4-5 Cask Body Stresses Under Cold Environment 30 Foot Bottom End Drop
(Bolt Preload, Cold Thermal, 20 psi External Pressure, 30 Foot Drop 30G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	1121
	131	1384
	214	1474
	157	1225
	142	1434
	220	1380
Cask Cylinder	460	1155
	427	800
	395	454
	369	237
	283	1137
	316	780
	348	435
	256	200
Cask Flange	1111	87
	1112	151
	1115	118
	1114	392
Lid	34	496
	33	352
	51	669
	47	215
	74	491
	76	451
	48	396
	45	237
	94	562
	92	523
	61	280

* See Figure B4.3-1 For Node Locations.

Table B4.4-6 Cask Body Stresses Under Hot Environment 30 Foot Lid End Drop
(Bolt Preload, Hot Thermal, 161.2 psi Internal Pressure, 30 Foot Drop 30G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	427
	131	733
	214	1233
	157	944
	142	333
	220	875
Cask Cylinder	460	786
	427	1133
	395	1161
	369	2305
	283	715
	316	844
	348	1189
	256	1178
Cask Flange	1111	3223
	1112	2369
	1115	3393
	1114	2981
Lid	34	2950
	33	3384
	51	3235
	47	3877
	74	33
	76	420
	48	3499
	45	3950
	94	2427
	92	2285
	61	2747

* See Figure B4.3-1 For Node Locations.

Table B4.4-7 Cask Body Stresses Under Cold Environment 30 Foot Lid End Drop Condition

(Bolt Preload, Cold Thermal, 20 psi External Pressure, 30 Foot Drop 30G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	279
	131	139
	214	41
	157	203
	142	251
	220	27
Cask Cylinder	460	412
	427	769
	395	1108
	369	1592
	283	395
	316	750
	348	1101
	256	1364
Cask Flange	1111	3135
	1112	2194
	1115	3430
	1114	3861
Lid	34	2861
	33	3579
	51	4681
	47	3699
	74	1212
	76	1200
	48	3569
	45	3400
	94	773
	92	778
	61	2855

* See Figure B4.3-1 For Node Locations.

Table B4.4-8 Cask Body Stresses Under Hot Environment 30 Foot Side Drop (contact side)

(Bolt Preload, Hot Thermal, 161.2 psi Internal Pressure, 30 Foot Drop 40G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	3921
	131	2464
	214	1373
	157	5085
	142	3503
	220	1201
Cask Cylinder	460	4858
	427	5038
	395	4825
	369	3742
	283	2042
	316	2180
	348	2038
	256	1751
Cask Flange	1111	3213
	1112	1339
	1115	3525
	1114	1198
Lid	34	2523
	33	1535
	51	1431
	47	367
	74	1553
	76	1092
	48	1315
	45	367
	94	2628
	92	1854
	1361	136

* See Figure B4.3-1 For Node Locations.

Table B4.4-9 Cask Body Stresses Under Hot Environment 30 Foot Side Drop (opp. contact side)

(Bolt Preload, Hot Thermal, 161.2 psi Internal Pressure, 30 Foot Drop 40G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	1922
	131	341
	214	577
	157	2598
	142	578
	220	326
Cask Cylinder	460	1932
	427	2108
	395	1891
	369	1209
	283	1260
	316	1905
	348	1538
	256	971
Cask Flange	1111	819
	1112	555
	1115	1056
	1114	578
Lid	34	722
	33	548
	51	1001
	47	327
	74	973
	76	1127
	48	533
	45	335
	94	2372
	92	1592
	61	1269

* See Figure B4.3-1 For Node Locations.

Table B4.4-10 Cask Body Stresses Under Cold Environment 30 Foot Side Drop (contact side)

(Bolt Preload, Cold Thermal, 20 psi External Pressure, 30 Foot Drop 40G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	3909
	131	1600
	214	1169
	157	508
	142	3813
	220	1335
Cask Cylinder	460	4874
	427	5086
	395	5045
	369	4297
	283	2784
	316	2918
	348	2879
	256	2498
Cask Flange	1111	3261
	1112	1352
	1115	3261
	1114	1792
Lid	34	2389
	33	2389
	51	2521
	47	769
	74	553
	76	526
	48	2196
	45	940
	94	990
	92	405
	61	927

* See Figure B4.3-1 For Node Locations.

Table B4.4-11 Cask Body Stresses Under Cold Environment 30 Foot Side Drop (opp. contact side)

(Bolt Preload, Cold Thermal, 20 psi External Pressure, 30 Foot Drop 40G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	1917
	131	536
	214	702
	157	2586
	142	102
	220	523
Cask Cylinder	460	1948
	427	2156
	395	2112
	369	1569
	283	1376
	316	2026
	348	1659
	256	980
Cask Flange	1111	851
	1112	406
	1115	796
	1114	797
Lid	34	561
	33	607
	51	735
	47	207
	74	891
	76	782
	48	758
	45	245
	94	2355
	92	1025
	61	270

* See Figure B4.3-1 For Node Locations.

Table B4.4-12 Cask Body Stresses Under Hot Environ. 30 Foot Corner Drop (contact side)

(Bolt Preload, Hot Thermal, 161.2 psi Internal Pressure, 30 Foot Drop on lid side Corner 20G)

Location		Nodal Stress Intensity (psi)
Cask Bottom		
Cask Cylinder		
Cask Flange		
Lid		

* See Figure B4.3-1 For Node Locations.

Table B4.4-13 Cask Body Stresses Under Hot Environ. 30 Foot Corner Drop (opp. contact side)

(Bolt Preload, Hot Thermal, 161.2 psi Internal Pressure, 30 Foot Drop on lid side corner 20G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	1181
	131	994
	214	1441
	157	2097
	142	419
	220	998
Cask Cylinder	460	805
	427	1012
	395	1102
	369	1175
	283	708
	316	835
	348	786
	256	673
Cask Flange	1111	1026
	1112	1061
	1115	1363
	1114	1166
Lid	34	1817
	33	1299
	51	1806
	47	1051
	74	11338
	76	4228
	48	1897
	45	912
	94	8290
	92	3588
	61	1932

* See Figure B4.3-1 For Node Locations.

Table B4.4-14 Cask Body Stresses Under Cold Environ. 30 Foot Corner Drop (contact side)

(Bolt Preload, Cold Thermal, 20 psi External Pressure, 30 Foot Drop on lid side corner 20G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	1180
	131	328
	214	222
	157	1426
	142	293
	220	110
Cask Cylinder	460	134
	427	390
	395	895
	369	2084
	283	27
	316	285
	348	924
	256	1657
Cask Flange	1111	4259
	1112	2935
	1115	4667
	1114	5626
Lid	34	5337
	33	5048
	51	15293
	47	2539
	74	11831
	76	10274
	48	10046
	45	1247
	94	6816
	92	10367
	61	6760

* See Figure B4.3-1 For Node Locations.

Table B4.4-15 Cask Body Stresses Under Cold Environ. 30 Foot Corner Drop (opp. contact side)

(Bolt Preload, Cold Thermal, 20 psi External Pressure, 30 Foot Drop on lid side corner 20G)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	1167
	131	187
	214	168
	157	1420
	142	512
	220	154
Cask Cylinder	460	431
	427	649
	395	598
	369	531
	283	538
	316	736
	348	539
	256	411
Cask Flange	1111	961
	1112	838
	1115	1126
	1114	1237
Lid	34	1592
	33	1291
	51	2968
	47	1048
	74	12490
	76	4828
	48	2760
	45	1103
	94	9799
	92	4296
	61	2728

* See Figure B4.3-1 For Node Locations.

References For Section B4.0

1. Performance Specification For TN-WHC Cask And Transportation System, WHC-S-0396, Rev. 1, September 1995.

2. Design Criteria for the TN-WHC Cask System, E-14427, Rev. 0.

3. ANSYS Engineering Analysis System, User's Manual Volumes 1&2, Rev. 4.4A.

4. ASME Boiler and Pressure Vessel Code, Section II, III, V & IV, American Society of Mechanical Engineers, NY, 1992.

5. Design Basis for Resistance to Shock and Vibration of Radioactive Material Packages in Truck Transport, ANSI N14.23, American National Standards Institute, May 1980.

6. Stress Analysis of Closure Bolts for Shipping Casks, NUREG/CR-6007,

7 A Guide for Design, Fabrication, and Analyzing of Shipping Casks for Nuclear Application, Cask Designer Guide, p.18, Nelms Equation.

8. Charles R. Adams, A Comparison of Analytical Techniques for Analyzing a Nuclear-Spent-Fuel Shipping Cask Subjected to An end-On Impact, NUREG/CR-1018.

B4.5 APPENDICES

APPENDIX B4.5A G LOAD CALCULATION

APPENDIX B4.5B LID BOLT ANALYSIS

APPENDIX B4.5C STRUCTURAL EVALUATION OF CASK BODY

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APPENDIX B4.5A

G LOAD CALCULATION

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APPENDIX B4.5A

G LOAD CALCULATION

B4.5A-1 INTRODUCTION

This Appendix evaluates the effects of a hypothetical drop of the cask on the concrete storage pad. The following cases are evaluated:

- 30.0 ft. end drop onto the concrete slab.
- 30.0 ft. side drop onto the concrete slab.
- 30.0 ft. C.G. over corner drop onto the concrete slab.
- 30.0 ft. shallow angle impact (slap down) onto the concrete slab.

The impact analysis is based on methodology of EPRI NP-4830[1] and NP-7551[2]. This appendix considers the mass and geometry of the cask but assumes it to be rigid compared to the concrete storage pad. The storage pad properties and the cask geometry are used to determine the pad hardness parameter. The report provides graphs that show the force on the cask as a function of storage pad hardness. Scale model drop testing at Sandia National Laboratories and full scale cask drop testing in England have recently been performed in an attempt to "benchmark" the EPRI methodology. The preliminary results of the tests (end drops) show excellent correlation with the predicted results.

B4.5A-2 GENERAL APPROACH

The EPRI reports give Force (applied to the cask) vs. Deformation (of the target) curves for different magnitudes of target hardness. The target hardness is defined as a set of parameters times the area of the impact surface. This impact area usually depends of the deformation. The following procedure is used to determine the maximum deceleration of the cask and deformation of the target:

1. A small target deformation is taken.
2. The geometry of the cask relative to the target is used to compute the impact area for the given deformation.
3. The target hardness is then computed for this target area.
4. The data in the EPRI report is used to determine the force associated with the deformation.

5. The energy absorbed in the increments in deformation is evaluated as the area under the force vs. deformation curve for the increment in deformation.

6. The deformation is increased and step 2-5 repeated.

7. This process is continued until the absorbed energy equals to weight times drop height. This is the final solution for the force and deformation.

B4.5A-3 CASK AND CONCRETE PAD/SOIL DESCRIPTION

The geometry of the cask is shown on drawing H-1-81535 sheet 1 of 5. The technical data used for cask and concrete slab/soil are :

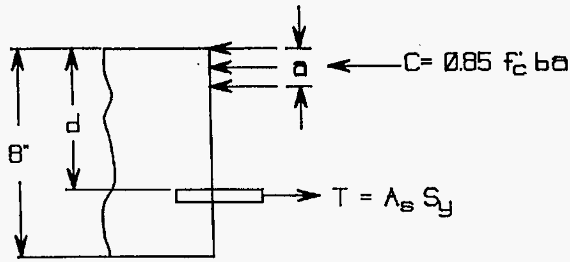
W = Weight of cask = 60,000 lbs
E_c = Concrete elastic modules = 3.6E6 psi
σ_u = Ultimate concrete strength = 4,000 psi
υ_s = Poisson's ratio of concrete = 0.17
h_c = Concrete pad thickness = 8 inches
S_y = Rebar yield strength = 60,000 psi
E_s = Sub-soil modulus = 28,000 psi
υ_s= Poisson's ratio of soil = 0.49

The concrete slab contains 7/8 inch diameter rebar (#7) on 12 inch spacing top and bottom, two-way, with 2" coverage. The design criteria of the rebar are listed in the Table B4.5A-1. The ultimate moment capacity of the slab is required for the analysis. This is evaluate using standard method (reference 3, pages 85-86) and is calculated in table B4.5A-2.

Table B4.5A-1
Mechanical Properties of Rebar

Rebar Size	#7 (7/8")
Spacing	12"
Rebar Dia.	0.875"
Area	0.6 in^2
Yield Strength - S_y	60,000 psi
Modulus of Elasticity - E	29×10^6 psi

Table B4.5A-2
M_u Calculation - 8" Concrete Slab With 7/8" Diameter Rebar



Size of Rebar = 7/8"
A_S = Cross Section Area of rebar = 0.6 in^2
S_y = Rebar Yield Strength = 60,000 psi
f'_c = Ultimate Concrete Strength = 4,000 psi
d = Average Depth of Steel = 8" - 2" -7/8" = 5.125"

By $\sum F = 0$ $C = T$

$A_s S_y = 0.85 f'_c b a$

$a = A_S S_y / 0.85 f'_c b = 0.6 \times 60{,}000/0.85 \times 4000 \times 12 = 0.8824"$

$\sum M = 0$

$M_u = A_S S_y (d - a/2) = 0.6 \times 60{,}000 (5.125-0.8824/2) = 168{,}618$ lbs/in

B4.5A-4 END DROP

The results of the EPRI reports are presented in term of a target hardness number (S). In general this is given by:

$$S = \frac{M_u \ \sigma_u \ A}{W^2 \ \delta_e}$$

Where

M_u = Ultimate moment capacity 1foot section of slab = 168,624 #/in.
σ_u = Ultimate concrete strength = 4,000 psi
A = Area of impact surface.
W = Weight of cask = 60,000 lbs.
δ_e = Deflection of cask under weight of cask (1G).

For the end drop, the area A= Area of the cask

$$A = \pi R^2 = \pi (40.57/2)^2 = 1292.7 \text{ in}^2$$

The deflection (δ_e) is given as:

$$\delta_e = \frac{W}{2 Rk} (1- e^{-\beta R} \cos \beta R)$$

Where

$$k = \frac{\pi E_s}{1 - \upsilon_s^2} = \frac{\pi (28,000)}{1 - 0.49^2} = 115,758 \text{ psi/in}$$

$$D_c = \frac{E_c h^3}{12 (1-\upsilon_c^2)} = \frac{3.6 (10)^6 (8)^3}{12 (1-0.17^2)} = 158,171,146 \text{ in-lbs}$$

$$\beta = \left(\frac{E_s}{4 \ D_c}\right)^{1/4} = \left(\frac{28000}{4 \times 158,171,146}\right)^{1/4} = 0.0816$$

$$\delta_e = \frac{W}{2\ Rk}\left(1 - e^{-\beta R}\cos\beta R\right) = \frac{60000}{2\times 20.285\times 115758}\left(1 - e^{-.0816\times 20.285}\cos 0.0816\times 20.285\right)$$

$$= 0.013''$$

Then

$$S = \frac{M_u\ \sigma_u\ A}{W^2\ \delta_e} = \frac{168618\times 4000\times 1292.7}{60000^2\times 0.013} = 18{,}656$$

The force-deformation curve is obtained by interpolating the data shown on Figure 14 of EPRI report (reference 1) and is shown on figure B4.5A-1. The peak force is 25G (times weight) and the displacement at the end of elastic phase is 0.39".

We now use energy method to compute final deformation:

Let x = final deformation. Then energy absorbed by the target equals area under force vs. displacement curve to x

$$E_{ab} = W\ F\ (\ 0.39/2 + (\ x - 0.39\ ))$$

$$W = 60{,}000 \text{ lbs}$$

$$F = 25$$

The potential energy of the drop is

$$E_{drop} = W\ (H + x) \qquad H = \text{drop height}$$

<u>For 1 foot (12") drop</u>

$$W\ (12 + x) = W\ (25)\ (0.39/2 + x - 0.39)$$

$$x = 0.7031''$$

The total energy is

$$E_{drop} = W\ (H + x) = 60000\ (12 + 0.7031) = 762{,}186 \text{ in-lbs}$$

$$E_{ab} = W\ F\ (\ 0.39/2 + x - 0.39\ ) = 60000\ (25)\ (0.39/2 + 0.7031 - 0.39) = 762{,}150 \text{ in-lbs}$$

For 30 foot (360") drop

$$W\ (360 + x) = W\ (25)\ (0.39/2 + x - 0.39)$$

$$x = 15.203"$$

The total energy is

$$E_{drop} = W\ (H + x) = 60000\ (360 + 15.203) = 22{,}512{,}180 \text{ in-lbs}$$

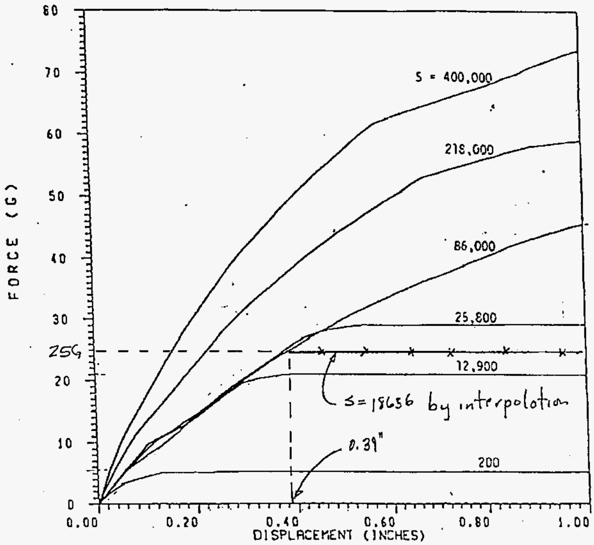
$$E_{ab} = W\ F\ (\ 0.39/2 + x - 0.39\ ) = 60000\ (25)\ (0.39/2 + 15.203 - 0.39) = 22{,}512{,}000 \text{ in-lbs}$$

The results of end drop:

1foot Drop Peak Acceleration = 25 G
Target Displacement = 0.7031"

30 foot Drop Peak Acceleration = 25 G
Target Displacement = 15.2"

Figure B4.5A-1
Force vs. Displacement Curves



B4.5A-5 Side Drop

The side drop analysis is conducted in the same manner as for the end drop except that the expression for δ_e varies and the target impact area changes as the depth of the penetration increase. δ_e is given as:

$$\delta_e = \frac{W\,\beta}{2\,k}$$

Where

$$\beta = \left(\frac{E_s}{4\ E_c\,I_c}\right)^{1/4}$$

$$I_c = 1/12\ L\ h^3 = 1/12\ (168.5)\ (8)^3 = 7189\ in^4$$

$$\beta = \left(\frac{28{,}000}{4 \times 3.6 \times 10^6 \times 7189}\right)^{1/4} = 0.0228$$

$$k = E_s = 28{,}000\ psi$$

$$\delta_e = \frac{W\,\beta}{2\,k} = 60000 \times 0.0228/(2 \times 28000) = 0.0244''$$

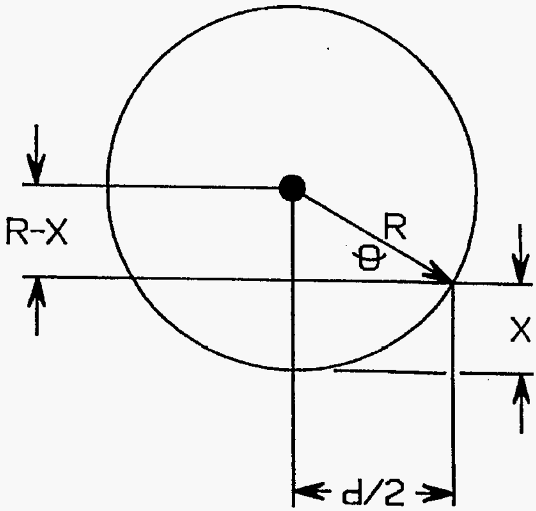
Then

$$S = \frac{M_u \sigma_u\ A}{W^2\ \beta} = \frac{(168618)\ (4{,}000)\ A}{(60{,}000)^2\ (0.0244)}$$

$$= 7.678\ A$$

The impact area $A = L \times d$, where d depends on the deformation x and is shown on Table B4.5A-3.

Table B4.5A-3
Side Drop Area Calculation



$\text{SIN } \theta = (R\text{-}X)/R \qquad \theta = \text{SIN}^{-1} (R\text{-}X)/R$

$R^2 = (R\text{-}X)^2 + (d/2)^2$

$d/2 = (2RX - X^2)^{1/2} \qquad d = 2(2RX - X^2)^{1/2}$

$A = L \times d = 2L \ (2RX - X^2)^{1/2}$

$S = 7.678 \ A = 7.678 \ (2) \ (L) \ (2RX - X^2)^{1/2} = 15.356 \ (L) \ (2RX - X^2)^{1/2}$

From Table B4.5A-3, $S = 15.356 (L)(2Rx - x^2)^{1/2}$. Since the elastic portion of the force vs. deflection curves are shown to be unimportant, only the perfectly plastic part is used for the side drop analysis.
The following data is obtained from Figures 14 and 16 of the EPRI report (reference 1).

S - Hardness	F - Force	Remark
12,900	21G	Figure 14
25,800	29G	Figure 14
86,000	48.5G	Figure 16

These are plotted in the Figure B4.5A-2. A spread sheet solution is carried out to increment x, and calculate absorbed energy with solution selected at the point where absorbed energy equals W(H + x).
The following steps are carried out in calculation of absorbed energy:

1. Select deformation x
2. Calculate S, $S = 15.356 (L)(2Rx - x^2)^{1/2}$.
3. Calculate F, $F= [\![18 + S(48.7-18)/80000]\!] W$
4. Calculate energy increment ΔE, $\Delta E = (x_i - x_{i-1})(F_i + F_{i-1})/2$
5. Add ΔE to the previous energy to obtain current total energy
6. Increment x until total energy equals W(H + x)

The spread sheet results are given on Table B4.5A-4.

<u>For 1 foot (12") drop</u>

Let x = 1"

Potential Energy = W (H + 1) = 60000 (12 +1) = 780,000 in-lbs

$E_{\text{absorbed by the target}}$ = 1,037,026 in-lbs (from Table A-4) $\rangle$ 780,000 in-lbs

G = F/W = 1,454,766/60,000 = 24 G's

<u>For 30 foot (360") drop</u>

Let x = 12.5"

Potential Energy = W (H +12.5) = 60000 (360 + 12.5) = 22,320,000 in-lbs

$E_{\text{absorbed by the target}}$ = 23,284,539 in-lbs (from Table A-4) $\rangle$ 22,320,000 in-lbs

G = F/W = 2,195,973/60,000 = 36.6 G's

Figure B4.5A-2
Force vs. Target Hardness Curve

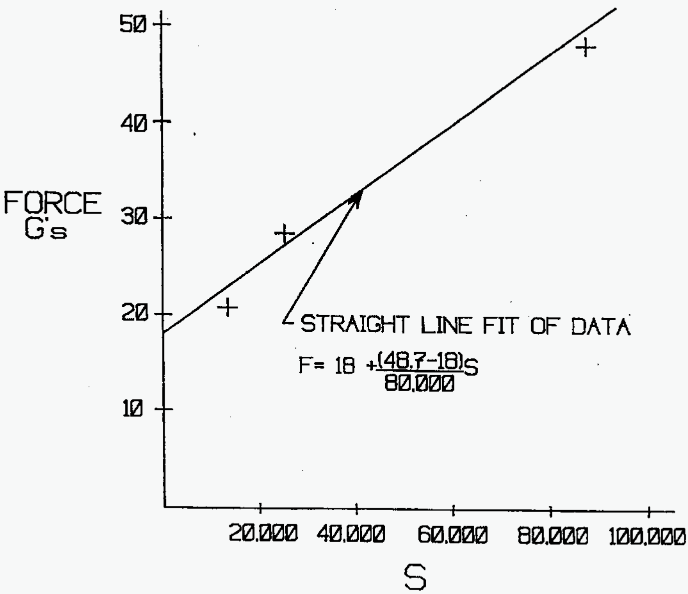


Table B4.5A-4
Calculation of Absorbed Energy for Side Drop

x (inches)	d (inches)	S	Force (lbs)	Energy Incr (in-lbs)	Total Energy (in-lbs)
0	0.00	0	0		0
0.5	8.95	11,582	1,346,669	336,667	336,667
1	12.58	16,277	1,454,766	700,359	1,037,026
1.5	15.31	19,808	1,536,084	747,713	1,784,739
2	17.57	22,726	1,603,260	784,836	2,569,575
2.5	19.51	25,243	1,661,218	816,119	3,385,694
3	21.23	27,470	1,712,498	843,429	4,229,123
3.5	22.78	29,473	1,758,614	867,778	5,096,901
4	24.19	31,295	1,800,560	889,794	5,986,695
4.5	25.48	32,965	1,839,027	909,897	6,896,591
5	26.67	34,507	1,874,520	928,387	7,824,978
5.5	27.78	35,936	1,907,422	945,485	8,770,463
6	28.80	37,265	1,938,031	961,363	9,731,826
6.5	29.76	38,505	1,966,585	976,154	10,707,980
7	30.66	39,665	1,993,277	989,965	11,697,946
7.5	31.50	40,750	2,018,265	1,002,885	12,700,831
8	32.28	41,767	2,041,682	1,014,987	13,715,818
8.5	33.02	42,721	2,063,641	1,026,331	14,742,148
9	33.71	43,615	2,084,237	1,036,969	15,779,118
9.5	34.36	44,454	2,103,552	1,046,947	16,826,065
10	34.97	45,240	2,121,659	1,056,303	17,882,368
10.5	35.54	45,977	2,138,617	1,065,069	18,947,437
11	36.07	46,666	2,154,483	1,073,275	20,020,712
11.5	36.57	47,310	2,169,304	1,080,947	21,101,659
12	37.03	47,910	2,183,122	1,088,106	22,189,765
12.5	37.46	48,468	2,195,973	1,094,774	23,284,539
13	37.86	48,986	2,207,892	1,100,966	24,385,505
13.5	38.23	49,464	2,218,908	1,106,700	25,492,206
14	38.57	49,904	2,229,046	1,111,989	26,604,194
14.5	38.89	50,307	2,238,330	1,116,844	27,721,038
15	39.17	50,674	2,246,779	1,121,277	28,842,315
15.5	39.43	51,006	2,254,412	1,125,298	29,967,613
16	39.65	51,303	2,261,246	1,128,915	31,096,528
16.5	39.86	51,565	2,267,292	1,132,134	32,228,662
17	40.03	51,794	2,272,565	1,134,964	33,363,626

B4.5A-6 C.G. Over Corner Drop

The C. G. over corner drop is performed in a similar manner as the side drop: Calculation of δ_e and evaluation of the impact area as a function of the deformation into the target. Some geometry relations used to evaluate of the impact area as a function of the deformation into the target are shown in Figure B4.5A-3. Table B4.5A-5 tabulates the results of the area vs. the deformation of the target. The next quantity that is needed is the deflection, δ_e. This deflection will occur as a result of the cask resting on a small portion of the cask with the area increasing as δ increases. This is similar to the side drop condition and we use that as the basis for the evaluation. Figure B4.5A-4 illustrates this relations. From page B4.5A-8:

$$\delta_e = \frac{W \beta}{2 k}$$

Where

$$\beta = \left(\frac{E_s}{4 \; E_c \, I_c}\right)^{1/4}$$

$$I_c = 1/12 \; L \; h^3 = 1/12 \; (L) \; (8)^3 = 42.6 \; L$$

$$\beta = \left(\frac{28{,}000}{4 \times 3.6 \times 10^6 \times I_c}\right)^{1/4} = 0.21/(I_c)^{1/4}$$

$$k = E_s = 28{,}000 \text{ psi}$$

$$\delta_e = W \, \beta/2k = 60000 \times \beta/2 \times 28000 = 1.071 \; \beta$$

$$L = 2 \; [\![2 \, R \, \delta_e /\cos \Theta - \delta_e^2/\cos^2\Theta \;]\!]^{1/2} = 2 \; (173.376 \; \delta_e - \delta_e^2/0.0548)^{1/2}$$

This equation is solved iteratively

$L_{initial}$	β	δ_e	L_{final}
10	0.0462	0.0495	5.84
8	0.0489	0.0523	6.00
6.5	0.0515	0.055	6.16
6.2	0.0521	0.056	6.20(solution)

From the above table, the solution of $\delta_e = 0.056$, then

$S = M_u\ \sigma_u\ A/W^2\ \delta_e = 168618 \times 40000 \times A/60000^2 \times 0.056 = 3.346A$

The solution is obtained on spread sheet by the following steps and is shown on Table B4.5A-5:

1. Calculate S, S = 3.346A (reference Table B4.5A-5 for value of A)
2. Calculate F, $F= [\![18 + S(48.7-18)/80000]\!] W$
3. Calculate energy increment ΔE, $\Delta E = (x_i - x_{i-1})(F_i + F_{i-1})/2$
5. Add ΔE to the previous energy to obtain current total energy
6. Increment x until total energy equals W(H + x)

<u>For 1 foot (12") drop</u>

Let x = 1" (reference Table B4.5A-6)

Potential Energy = W (H + 1) = 60000 (12 +1) = 780,000 in-lbs

$E_{\text{absorbed by the target}}$ = 812,430 in-lbs $\rangle$ 780,000 in-lbs

G = F/W = 1,085,654/60,000 = 18.09 G's

<u>For 30 foot (360") drop</u>

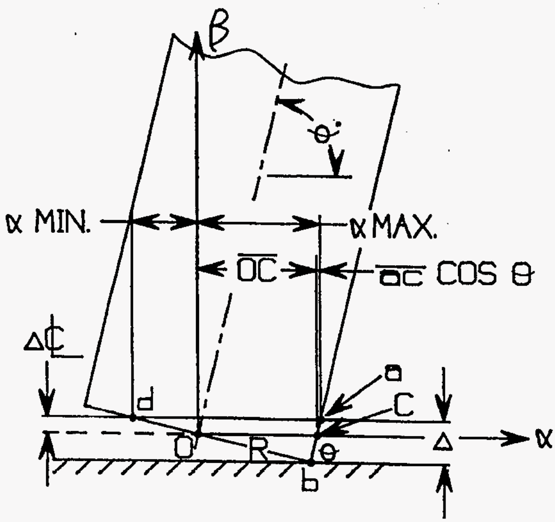
Let x = 20 " (reference Table B4.5A-6)

Potential Energy = W (H +20) = 60000 (360 + 20) = 22,800,000 in-lbs

$E_{\text{absorbed by the target}}$ = 22,865,514 in-lbs $\rangle$ 22,800,000 in-lbs

G = F/W = 1,180,536/60,000 = 19.7 G's

Figure B4.5A-3
Geometry of CG Over Corner Drop



$\sin\Theta = R/oc$ $\quad\quad\cos\Theta = bc/oc$ $\quad\quad\Theta = 76.46^0$

$bc = oc\cos\Theta = R(\cos\Theta/\sin\Theta)$

$ac = ab - bc = \Delta/\sin\Theta - R(\cos\Theta/\sin\Theta)$

$ad = ab/\cos\Theta = \Delta/\sin\Theta\cos\Theta$

$\Delta_{\text{℄}} = \Delta - bc\sin\Theta = \Delta - R\cos\Theta$

$\alpha_{max} = oc + ac\cos\Theta = R/\sin\Theta + ac\cos\Theta = R/\sin\Theta + \Delta_{\text{℄}}(\cos\Theta/\sin\Theta)$

$\alpha_{min} = ad - \alpha_{max} = \Delta/\sin\Theta\cos\Theta - R/\sin\Theta - \Delta_{\text{℄}}(\cos\Theta/\sin\Theta)$

$= \Delta_{\text{℄}}(1/\sin\Theta\cos\Theta - \cos\Theta/\sin\Theta)$

Figure B4.5A-3
Geometry of CG Over Corner Drop-Continue

The area of the impact surface is obtained by first writing equation for intersection curves between cylinder and plane surface. We set up the following coordinate systems with origin at bottom center of cask.
By transforming coordinates:

$$\alpha = X\sin\theta + Z\cos\theta \qquad X = \alpha\sin\theta - \beta\cos\theta$$
$$\beta = -X\cos\theta + Z\sin\theta \qquad Z = \alpha\cos\theta + \beta\sin\theta$$

Equation of cylinder is $X^2 + Y^2 = R^2$ or by transforming coordinates:

$$\alpha^2\sin\theta^2 - 2\alpha\beta\sin\theta\cos\theta + \beta^2\cos\theta^2 + Y^2 = R^2$$

By setting the intersection of this surface with target surface, $\beta = \Delta_{\mathrm{c}}$

Then equation of intersection curve is:

$$\alpha^2\sin\theta^2 - 2\alpha\Delta_{\mathrm{c}}\sin\theta\cos\theta + \Delta_{\mathrm{c}}^2\cos\theta^2 + Y^2 = R^2$$

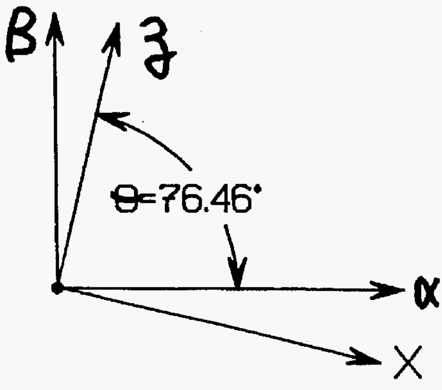


Figure B4.5A-3
Geometry of CG Over Corner Drop-Continue

The area as a function of the deformation is calculated by integrating the:

$$\alpha^2 SIN\theta^2 - 2\alpha\Delta_{\mathfrak{c}} \ SIN\theta \ COS\theta + \Delta_{\mathfrak{c}}^2 COS\theta^2 + Y^2 = R^2$$

$$\text{Area} \quad A = 2 \int_{\alpha_{min}}^{\alpha_{max}} Y d\alpha$$

Where Y is given as above equation

This is numerically integrated using 100 divisions and the trapezoidal rule. The results are tabulated in Table B4.5A-5.

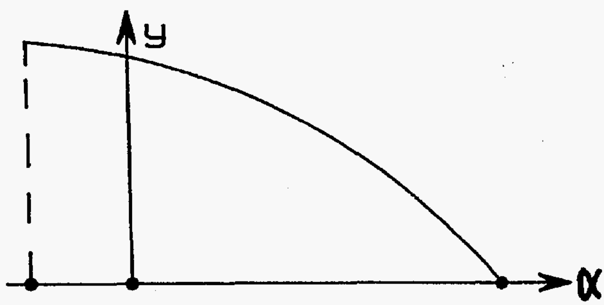


Figure B4.5A-4
CG Over Corner Drop - L Dimension Calculation

$(L/2)^2 = R^2 - (R - \delta_e/\text{COS}\theta)^2$ $\qquad$ $L = 2\,(2R\delta_e/\text{COS}\theta - \delta_e^2/\text{COS}^2\theta)^{1/2}$

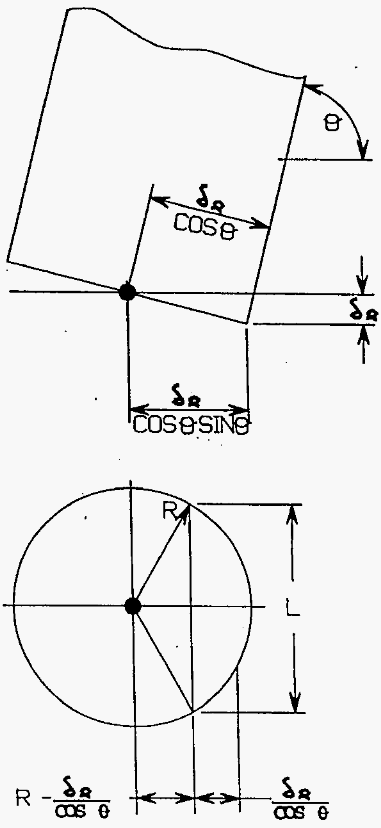


Table B4.5A-5
Area Calculation For CG Over Corner Drop

DELTA	DELTA CL	AMAX	AMIN	AREA
.500	-4.249	19.842	17.645	26.822
1.000	-3.749	19.962	15.569	74.604
1.500	-3.249	20.082	13.492	134.708
2.000	-2.749	20.203	11.416	203.698
2.500	-2.249	20.323	9.340	279.381
3.000	-1.749	20.444	7.263	360.141
3.500	-1.249	20.564	5.187	444.618
4.000	-.749	20.684	3.111	531.663
4.500	-.249	20.805	1.035	620.218
5.000	.251	20.925	-1.042	709.248
5.500	.751	21.046	-3.118	797.786
6.000	1.251	21.166	-5.194	884.820
6.500	1.751	21.287	-7.271	969.272
7.000	2.251	21.407	-9.347	1049.996
7.500	2.751	21.527	-11.423	1125.637
8.000	3.251	21.648	-13.499	1194.561
8.500	3.751	21.768	-15.576	1254.594
9.000	4.251	21.889	-17.652	1302.268
9.500	4.751	22.009	-19.728	1328.276
10.000	5.251	22.129	-21.805	1328.715
10.500	5.751	22.250	-23.881	1329.000
11.000	6.251	22.370	-25.957	1329.051
11.500	6.751	22.491	-28.033	1328.454
12.000	7.251	22.611	-30.110	1329.087
12.500	7.751	22.731	-32.186	1329.036
13.000	8.251	22.852	-34.262	1329.041
13.500	8.751	22.972	-36.339	1328.458
14.000	9.251	23.093	-38.415	1328.827
14.500	9.751	23.213	-40.491	1327.639
15.000	10.251	23.333	-42.568	1328.146
15.500	10.751	23.454	-44.644	1328.158
16.000	11.251	23.574	-46.720	1327.657
16.500	11.751	23.695	-48.796	1326.475
17.000	12.251	23.815	-50.873	1328.746
17.500	12.751	23.935	-52.949	1327.546
18.000	13.251	24.056	-55.025	1328.635
18.500	13.751	24.176	-57.102	1326.881
19.000	14.251	24.297	-59.178	1328.259
19.500	14.751	24.417	-61.254	1328.477
20.000	15.251	24.538	-63.330	1326.558

Table B4.5A-6
Calculation of Absorbed Energy for CG Over Corner Drop

x (inches)	Area (sq in)	S	Force (lbs)	Energy Incr (in-lbs)	Total Energy (in-lbs)
0.5	26.82	90	1,082,033	270,508	270,508
1	74.60	250	1,085,654	541,922	812,430
1.5	134.71	451	1,090,209	543,966	1,356,396
2	203.70	682	1,095,438	546,412	1,902,807
2.5	279.38	935	1,101,173	549,153	2,451,960
3	360.14	1,205	1,107,294	552,117	3,004,077
3.5	444.62	1,488	1,113,696	555,248	3,559,325
4	531.66	1,779	1,120,293	558,497	4,117,822
4.5	620.22	2,075	1,127,004	561,824	4,679,646
5	709.25	2,373	1,133,752	565,189	5,244,835
5.5	797.79	2,669	1,140,462	568,553	5,813,389
6	884.82	2,961	1,147,058	571,880	6,385,268
6.5	969.27	3,243	1,153,458	575,129	6,960,397
7	1,050.00	3,513	1,159,576	578,259	7,538,656
7.5	1,125.64	3,766	1,165,309	581,221	8,119,877
8	1,194.56	3,997	1,170,532	583,960	8,703,837
8.5	1,254.59	4,198	1,175,082	586,403	9,290,241
9	1,302.27	4,357	1,178,695	588,444	9,878,685
9.5	1,328.28	4,444	1,180,666	589,840	10,468,525
10	1,328.72	4,446	1,180,699	590,341	11,058,866
10.5	1,329.00	4,447	1,180,721	590,355	11,649,221
11	1,329.05	4,447	1,180,725	590,361	12,239,583
11.5	1,328.45	4,445	1,180,679	590,351	12,829,934
12	1,329.09	4,447	1,180,727	590,352	13,420,285
12.5	1,329.04	4,447	1,180,724	590,363	14,010,648
13	1,329.04	4,447	1,180,724	590,362	14,601,010
13.5	1,328.46	4,445	1,180,680	590,351	15,191,361
14	1,328.83	4,446	1,180,708	590,347	15,781,708
14.5	1,327.64	4,442	1,180,618	590,331	16,372,039
15	1,328.15	4,444	1,180,656	590,318	16,962,357
15.5	1,328.16	4,444	1,180,657	590,328	17,552,686
16	1,327.66	4,442	1,180,619	590,319	18,143,005
16.5	1,326.48	4,438	1,180,529	590,287	18,733,292
17	1,328.75	4,446	1,180,702	590,308	19,323,600
17.5	1,327.55	4,442	1,180,611	590,328	19,913,928
18	1,328.64	4,446	1,180,693	590,326	20,504,254
18.5	1,326.88	4,440	1,180,560	590,313	21,094,567
19	1,328.26	4,444	1,180,665	590,306	21,684,873
19.5	1,328.48	4,445	1,180,681	590,336	22,275,210
20	1,326.56	4,439	1,180,536	590,304	22,865,514

B4.5A-7 SHALLOW ANGLE IMPACT - SLAP DOWN

The energy balances used for the end, side, and corner drop cases cannot be applied to the slapdown cases since the kinetic energy in the cask is now divided between vertical velocity and rotational velocity. For the first three cases, there is a simple energy transfer between the kinetic energy (due to only vertical velocity) and the energy absorbed in the target. For the slapdown case, the additional possibitily of transferring energy to the cask rotational velocity requires that a time history analysis be performed. This is possible, but the numerical procedures required are complex and one questions whether the target model presented in the EPRI report contains adequate detail for such a use. Rather slapdown data for transport casks (rigid cask with limiters impacting on a rigid target) are used to develop reasonable upper bounds for the slapdown effect.

Larger deceleration forces than found for the side drop can occur when a cask with impact limiters strikes a rigid target with the cask oriented at a small angle to the horizontal. This could occur for the problem of interest here and is discussed in this section. Some of the results found for the transport casks with limiters are discussed and results are then applied to the present problem.

When the first end of the cask impacts the target (designated end 1 for the purposes of this discussion with the other end designated end 2), the kinetic energy of the cask results from the vertical velocity of the cask. After this impact this energy is partitioned into three parts: the vertical cask velocity, the rotational velocity of the cask, and the energy absorbed by the impact limiter at this end of the cask. The vertical CG velocity of the cask decreases and the rotational velocity of the cask increases. Both of these effects reduce the vertical velocity of end 1. However, the vertical velocity of end 2 is reduced by the decrease in cask CG velocity but increased by the increase in rotational velocity of the cask. The vertical velocity of end 2 therefore could be larger than the initial velocity of the cask, and in this case the impact force for the end 2 limiter would be larger than the force which occurs for the side drop (where the end 2 limiter impacts the target at the initial cask velocity). The magnitude of this effect and the drop angle causing the maximum slapdown effect is a function of the mass and geometric characteristics of the cask, and the stiffness characteristics of the impact limiter. A generic study of this problem for transport casks is report in reference 4 and the results of that study are presented in the Table B4.5A-7. The following definitions are given for the parameters in the table.

R_L = Cask Radius
σ_{III} = Crush Strength of Limiter
B = Length of Limiter Along Cask axis
L = Cask Length
W = Cask Weight
A = Length of Limiter Protruding Beyond End Cask
H = Drop Height

Table B4.5A-7
Energy Absorbed By Second Limiter During Slapdown

R_L/L	$\sigma_{III} R_L^2/W$	$(B-A)/R_L$	H / L	CRITICAL ANGLE (Degrees)	ENERGY RATIO (P)
0.25	25	0.25	1.75	7.8	0.704
	50			3.0	0.721
	75			2.0	0.725
	100			1.5	0.725
0.33	25	0.25	1.75	6.9	0.682
	50			4.1	0.695
	75			2.4	0.702
	100			1.3	0.719
0.50	25	0.25	1.75	9.0	0.598
	50			4.4	0.637
	75			2.5	0.650
	100			2.5	0.650
0.25	25	0.5	1.75	3.5	0.693
	75			1.0	0.701
	100			0.8	0.705
0.33	25	0.5	1.75	4.1	0.660
	75			1.0	0.684
	100			0.8	0.675
0.50	25	0.5	1.75	4.0	0.582
	75			1.3	0.603
	100			0.9	0.611
0.25	25	0.75	1.75	2.2	0.670
	50			1.0	0.678
	100			0.5	0.698
0.33	25	0.75	1.75	2.4	0.628
	75			1.4	0.634
	100			0.6	0.662
0.50	25	0.75	1.75	2.8	0.528
	75			0.9	0.549
	100			0.7	0.547
0.25	25	0.25	3.50	15.0	0.645
	75			7.4	0.686
	100			6.0	0.690
0.50	25	0.25	3.50	FIRST IMPACT MORE SEVERE	
	75			5.8	0.582
	100			3.7	0.598
0.25	25	0.75	3.50	4.6	0.638
	75			2.1	0.678
	100			1.0	0.656
0.50	25	0.75	3.50	FIRST IMPACT MORE SEVERE	
	75			FIRST IMPACT MORE SEVERE	
	100			1.3	0.502

Table B4.5A-7 gives the critical angle for which maximum slapdown effects occur, and the energy ratio (ratio of energy absorbed by the second limiter for slapdown as compared with the side drop case). As may be seen the critical angle varies from close to 0 to 15 degree, and the maximum energy ratio equals to 0.725. Note that the second limiter absorbs 50% of the energy for the side drop so that this maximum case indicates that the second limiter absorbs 0.725/0.5 = 1.45 more energy than it would for the side drop case (a 45% increase). It was also found that the critical angle resulting in these maximum energy ratio led to the cask response where the end 1 lifted off the impact surface just before end 2 impacts the target. It can also be seen from the results in the table that the energy ratio increases as:

$R_L/L \Rightarrow$ decreases

$\sigma_{III}\ R_L^2/W \Rightarrow$ increases

$(B-A)/R_L \Rightarrow$ decreases

$H/L \Rightarrow$ decreases

The problem of the cask impacts to the concrete is somewhat similar to the transport casks with the energy absorption characteristics of the limiter being replaced by the energy absorption characteristics of the slab/soil target. The following parameters needed for the use of the table may be calculated directly:

$R_L/L = 20.285/168.5 = 0.12$

$H/L = 360/168.5 = 2.14$

$A = 0$

The length of the equivalent impact limiter (B) actually can be extend along the entire cask (as in the side drop). Since the slap down effect increases as this length decreases, the value of B is taken as equal to the width of the impact surface (d defined in Table B4.5A-3). This is taken equal to 37.5" (the side drop value of d at maximum values from the Table B4.5A-4). The same results are used to obtain an effective crush strength by dividing the total force of the side drop (2,195,973 lbs) by the total impact area (2×37.5×37.5). Therefore:

$\sigma_{III} = 2{,}195{,}973/\ (2\times37.5\times37.5) = 781$ psi

$\sigma_{III}\ R_L^2/W = 781\times\ 20.285^2/60{,}000 = 5.4$

$(B-A)/R_L = (37.5-0)/20.285 = 1.85$

The following conservative values (see above discussion of variation of energy ratio as a function of the parameters) are selected:

$\sigma_{III}\ R_L^2/W = 25$

$(B-A)/R_L = 0.75$

$H/L = 1.75$

The results in the Table A-6 then indicate the following results:

R_L/L	Energy Ratio
0.25	0.67
0.33	0.628
0.5	0.528

These data points fit very well with a straight line:

Energy Ratio = 0.815 - 0.575 R_L/L

Therefore the energy ratio for $R_L/L = 0.12$ is equal to o.746. This indicates that the energy absorbed by the second end during impact could be 0.746/0.5 = 1.49 times the energy absorbed by the side drop. If this were all taken up by an increase in force (rather than partially by an increase in impact area) the peak deceleration would increase from the 36.6 G for the side drop to 1.49 × 36.6 = 54.4 G.It should be noted that this deceleration would not be constant across the length of the cask but would decrease from end 2 to end 1.

This estimate is quite conservative for the following reasons:

The parameters selected above were selected to maximize the effect. In particular the length of the impact surface (B) will increase as the cask rotate so that the most of the cask length will be engaged when the second end hits the target. The above analysis conservatively sets B = 37.5 and as shown in the following table, the energy ratio decreases as B increases.

$(B-A)/R_L$	Energy Ratio
0.25	0.704
0.50	0.693
0.75	0.670

The side drop analysis shows that target hardness (S) is 7.678 times impact area. The largest impact area could be the length times diameter of the cask (168.5 × 40.57) = 6836 in^2. Therefore the maximum S = 52,487. The maximum possible deceleration is equal to:

$$G = [\![18 + S(48.7-18)/80000]\!] = [\![18 + 52487(48.7-18)/80000]\!] = 38.1\ G$$

It is recommended that the maximum deceleration for the slapdown case be taken as 39 G based on the maximum impact area.

B4.5A-8 REFERENCES

1. "The Effects of Target Hardness on the Structural Design of Concrete Storage Pads for Spent- Fuel Casks"EPRI NP-4830, October 1986.

2. "Structural Design of Concrete Storage Pads for Spent-fuel Cask"EPRI NP-7551, August 1991.

3. "Design of Concrete Structures" By A. Nelson, Mcgraw-Hill, Inc. Eleventh Edition.

4. "Impact Loading on Waste Fuel Shipping Casks"By C.A. Miller. Transactions of the 9th International Conference on Structural Mechanics in Reactor Technology, August 1987.

APPENDIX B4.5B

LID BOLT ANALYSIS

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APPENDIX B4.5B

LID BOLT ANALYSIS

B4.5B-1 INTRODUCTION

The TN-WHC lid closure arrangement is shown in Figure B4.5B-1. The 3.5 inch thick lid is bolted directly to the end of the containment vessel body by 12 high strength stainless steel 1.5 inch diameter bolts. Close fitting alignment pins ensure that the lid is centered in the vessel.

The lid bolt is shown in Figure B4.5B-2. Note that the material is ASME SA-479, Type XM-19 Hot Rolled, which has a minimum yield strength of 105,000 psi at room temperature. The lid closure flange and bolt arrangement is shown in Figure B4.5B-3. The bolts are designed to be preloaded at assembly to seat the seals against the 161.2 psi maximum design pressure and to withstand all normal and accident loadings without yielding. The lid bolt analysis performed below is in accordance with NUREG/CR-6007 stress analysis of Closure Bolts for Shipping Casks (Reference 1).

B4.5B-2 NORMAL CONDITION ANALYSIS

The loadings considered for normal conditions include operating preload, pressure loads, temperature, impact loads and the vibration loads.

The non-prying tensile bolt force due to the applied preload is given by the formula

$$F_a = Q/KD_b$$

where
- Q is the applied torque for preload, 3,565 in. lbs.
- K is the nut factor for empirical relation between the applied torque and the achieved preload, 0.1, this value is based on lubricating the bolts with Neolube having a coefficient of friction of 0.03.
- D_b is the minimum diameter of the closure bolt, 1.22 inch.

$$F_a = 3565/(0.1)(1.22) = 29{,}225 \text{ lbs}$$

The torsional bolt moment per bolt is

$$M_t = 0.5\ Q = 0.5\ (3565) = 1783 \text{ in-lbs}$$

The maximum residual tensile bolt force after preload is

$$F_{ar} = F_a = 29{,}225 \text{ lbs}$$

FIGURE B4.5B-1
TN-WHC LID CLOSURE

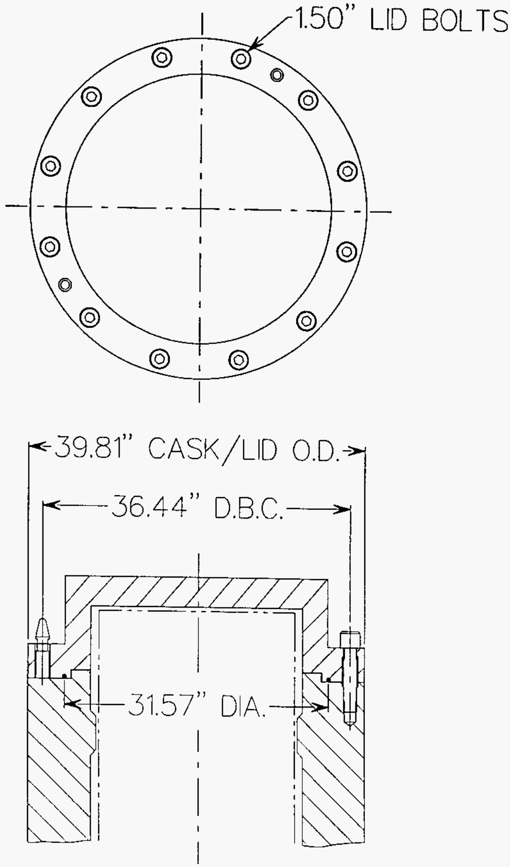


FIGURE B4.5B-2
TN-WHC LID BOLT

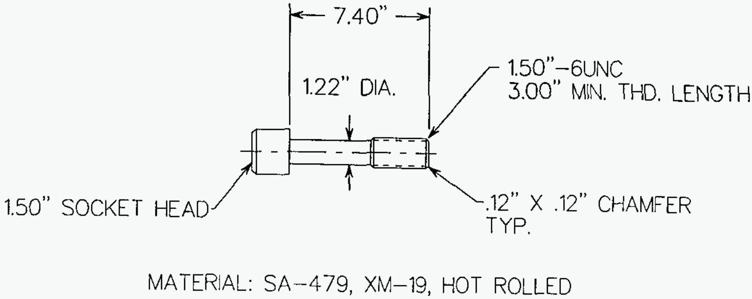
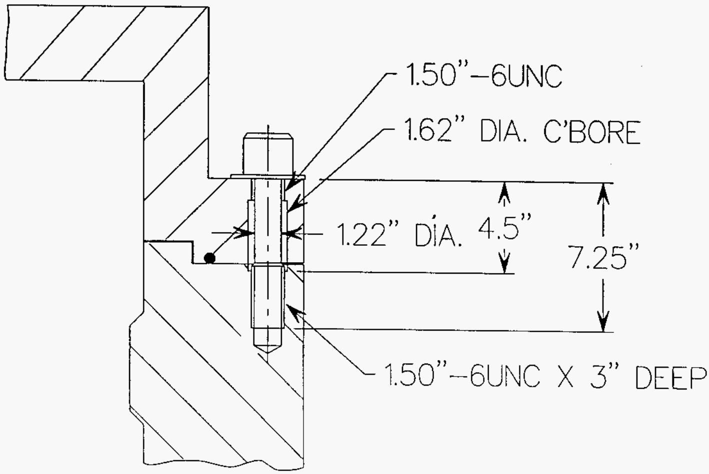


FIGURE B4.5B-3
TN-WHC FLANGE AND LID BOLT ARRANGEMENT



The maximum residual torsional bolt moment is

$$M_{tr} = 0.5Q = 1783 \text{ in-lbs.}$$

The gasket seating load is negligible since o-rings are used.
The loads caused by the pressure difference between the interior and the exterior of the closure components are calculated below. The non-prying tensile bolt force is

$$F_a = \pi (D_{lg})^2 (P_{li} - P_{lo}) /4 (N_b)$$

where D_{lg} is the closure lid diameter at the inner seal, 31.57 in.
P_{li} is the pressure inside the closure lid and
P_{lo} is the pressure outside the closure lid.
N_b is the number of bolts, 12

The maximum differential pressure for both normal and accident conditions is 161.2 psi.

$$F_a = \pi (31.57)^2 (161.2)/4 (12) = 10{,}515 \text{ lbs.}$$

The increased external pressure combined with no internal pressure results is a force of F_a = -1305 lbs.

The shear bolt force due to 161.2 psi differential pressure is

$$F_s = \pi (E_l) (t_l) (P_{li} - P_{lo})(D_{lb})^2/2 (N_b)(E_c)(t_c)(1-N_{ul})$$

where

E_l is Young's Modulus of the closure lid material, 28.3 x 10^6 psi
t_l is the lid thickness, 3.5 inches
$P_{li} - P_{lo}$ is the differential pressure on the cask wall, 161.2 psi
D_{lb} is the closure lid diameter at the bolt circle, 25.2 inches
E_c is the Young's Modulus of the cask wall material, 28.3x10^6 psi
t_c is the thickness of the cask wall, 7.3 inches
N_{ul} is Poisson's ratio of the closure lid material, 0.3.

$$F_s = \pi (28.3 \times 10^6)(3.5)(36.44)^2(161.2)/2(12)(28.3 \times 10^6)(7.31)(1-0.3)$$

$$= 19{,}167 \text{ lbs}$$

The fixed edge closure lid force (F_f) and Moment (M_f) for the calculation of prying tensile bolt force and bending bolt moment are given by the formulas below.

$$F_f = D_{lb}(P_{li} - P_{lo})/4 = 36.44\ (161.2)/4 = 1{,}469 \text{lbs}$$

$$M_f = D_{lb}^2(P_{li} - P_{lo})/32 = 36.44^2\ (161.2)/32 = 6{,}689 \text{ in-lbs}$$

The load caused by differential thermal expansion of the closure lid and bolt is calculated below.

$$F_a = 0.25\ \pi\ (D_b)^2(E_b)(\alpha_l T_l - \alpha_b T_b)$$

E_b is the Young's Modulus of the bolt material, 28.3×10^6 psi
α_l is the thermal expansion coefficient of the lid material, 8.55×10^{-6} in/in°F
T_l is the temperature change of the lid. The lid can get as hot as 150°F at an ambient temperature of 115°F with maximum insolation. The lid can get as cold as -27°F in the cold environment. Assuming the lid is bolted to the cask inside at a room temperature of 70°F, Tl is 130°F for the hot environment and -97°F for the cold environment.
α_b is the thermal expansion coefficient of the bolt material, 8.87×10^{-6} in/in°F
T_b is the temperature change of the bolt material. This is the same as Tl.
D_b is bolt diameter

$$F_a = 0.25\pi\ (1.22)^2\ (28.3\times10^6)(8.55\times10^6 - 8.87\times10^6)130$$

$$= -1377 \text{ lbs for the hot environment}$$

$$F_a = -1028 \text{ lbs for the cold environment}$$

There is no load caused by the thermal expansion difference between the closure lid and cask wall since they are made of the same material, and the temperature of the lid and flange are equal.

The worst loading on the bolts due to a 1 foot drop is during an lid end corner drop. The lip on the cask protects the closure lid during the side drop. The non prying tensile bolt force due to a one foot lid end corner drop is

$$F_a = 1.34\ (\sin xi)(D_{lf})(W_l + W_c)\ (ai)/N_b$$

where D_{lf} is the dynamic load factor, 1.2
W_l is the weight of the lid, 1890 lbs.
W_c is the maximum weight of the cargo, 19120 lbs.

ai is the maximum rigid body impact acceleration of the cask, 18 g's

xi angle of impact

F_a = 1.34 (sin 76^0)(1.2)(21010)(18)/12 = 49,170 lbs

The shear bolt force is not evaluated since bolts are protected in shear during impact by closure-flange shoulder.

The fixed edge closure lid force (F_f) and moment (M_f) is calculated below for the 1 ft lid end corner drop. F_f and M_f are 0 for the 1 ft side drop.

$$F_f = \frac{1.34\ D_{lf}\ (\sin xi) ai\ (W_l + W_c)}{\pi\ D_{lb}}$$

$$F_f = \frac{(1.34)(1.2)(\sin 76^0)(18)(21010)}{\pi(36.44)}$$

= 5,155 lbs.

$$M_f = \frac{1.34\ D_{lf}\ (\sin xi) ai\ (W_l + W_c)}{8\ \pi}$$

$$= \frac{(1.34)(1.2)(\sin 76^0)(18)(21010)}{8\pi}$$

= 23,477 lbs.

Vibration loads are insignificant on the bolts.

The load combinations are calculated using the methodology outlined in Table 4.9 of NUREG/CR-6007.

The sum of the tensile bolt forces for operating preload and temperature is

$$F_{a-pt} = 29225 + 1028 = 30{,}253 \text{ lbs.}$$

The sum of the tensile forces for the remainder of the loads is

$$F_{a-al} = 10515 + 49{,}170 = 59{,}685 \text{ lbs.}$$

This is based on the 1 foot impact and internal pressure. The combined non-prying tensile bolt force is the larger of the two forces calculated above, 59,685 lbs.

Combination of Prying Tensile Bolt Forces

The maximum combined prying fixed-edge force F_{f-c} is 1469 + 5155 = 6624 lbs and the maximum combined prying moment M_{f-c} is 6689 + 23477 = 30166 in-lbs.

The prying tensile bolt force for the combined load is zero because there is a gap between the flange and lid at the outer edge.

Combining the non-prying and prying tensile bolt force

$$F_{a-c} = 59{,}685 + 0 = 59{,}685 \text{ lbs.}$$

The maximum average tensile stress in a lid bolt is

$$S_{ba} = F_{a-c}/A_t$$

Where A_t is the tensile area of the bolt, 1.169 in^2

$$S_{ba} = 59{,}685/1.169 = 51{,}060 \text{ psi}$$

The allowable tensile stress is 2/3 of the yield strength at the operating temperature of 150°F, or 2/3 (101,000) or 67,330 psi.

The shear bolt force is not evaluated since the bolts and closure lid are protected during an impact by the lip of the cask flange. The bolts are not relied upon to resist transverse shear load. The bending bolt moment is calculated below.

$M_{bb} = [\pi D_{lb}/N_b]\ [K_b/(K_b+K_l)]\ M_f$

Where

$K_b = [N_b/L_b][E_b/D_{lb}][D_b^4/64]$

$= [12/4.65][28.3x10^6/36.44][1.22^4 /64]$

$= 0.0694 \times 10^6$

$K_l = E_l\,(t_l)^3/3\,[(1-N_{ul}^2) + (1- N_{ul})^2(D_{lb}/D_{lo})^2](D_{lb})$

$K_l = 8.405 \times 10^6$
$M_{f-c} = 30{,}166$ in-lbs.

$M_{bb} = [\pi(36.44)/12][.0694x10^6 /\ 8.405x10^6 + .0694x10^6][30{,}166]$

$= 2{,}358$ in-lbs.

The maximum bending stress caused by the bending bolt moment is

$S_{bb} = 10.186\ M_{bb}/(D_{ba})^3$

The minimum bolt diameter is equal to

$D_{ba} = 1.22$in.

$$S_{bb} = \frac{(10.186)(2358)}{(1.22)^3} = 13{,}230 \text{ psi}$$

The maximum shear stress caused by the torsional bolt moment, M_t is

$$S_{bt} = 5.093\ M_t/(D_{ba})^3 = 5.093\ (3565)/(1.22)^3 = 10{,}000 \text{ psi} \leq 0.4S_y = 40{,}400 \text{ psi}$$

The maximum stress intensity caused by tension plus shear plus bending plus torsion is

$$S_{bi} = [(S_{ba} + S_{bb})^2 + 4(S_{bt})^2]^{0.5} = [(51060 + 13230)^2 + 4(10000)^2]^{0.5} = 67{,}330 \text{ psi}$$

This is less than the allowable maximum stress intensity of $0.9S_y$ = 90,900 psi.

B4.5B-3 BOLT FATIGUE ANALYSIS

The purpose of the fatigue analysis is to show quantitatively that the fatigue damage to the bolts during normal transport conditions is acceptable. This is done by determining the fatigue usage factor for each normal transport event. From Reference 2, the shipment is to be completed in two calendar years and there are 200 shipping days per year and one shipment per shipping day. This shipping schedule translates into 400 round trip shipments. The total cumulative damage or fatigue usage for all events was conservatively determined by adding the usage factors for the individual events. The sum of the individual usage factors was checked to make certain that, for the 400 round trip shipments of the cask, the total usage factor is less than one. The following sequence of events was assumed for the fatigue evaluation.

1. Operating Preload
2. Pressure Fluctuations
3. Road Vibration
4. Test Pressure
5. Impact (1 Ft) End Drop
6. Handling Load

Number of Load/Stress Cycles for Each Loading

A. Test Pressure:

Proof Test: 1.5 x MNOP = 241.8 psi. This occurs once during the TN-WHC cask lifetime. (See Table B4.5B-1 for stress calculations).

B. Preload

The number of preload cycles is two times the number of trips, or 800. (See Table B4.5B-1 for stress calculations).

C. Road Vibrations

The bolt stresses are negligible for the road vibrations.

D. 1 Foot Drop:

Assume this occurs twice in two year operating life of the cask. The stress intensity of 52,370 psi (see Table B4.5B-1 for stress derivation) is a combination of the non prying and prying tensile stress due to the one foot end drop, with a zero preload.

E. Pressure and Temperature Fluctuations:

The full internal equilibrium temperature of 150°F is not reached during a typical trip. However, for conservatism we assume that the temperature increases from 70°F to -27°F during each trip (temperature increase from 70^0 F to 150^0 F does not develop tension in lid bolts). This results in a load due to differential thermal expansion coefficients, and also due to pressure change from 0 to 161.2 psig. The fatigue damage is based on 800 cycles and stress intensity range of 0 to 12,810 psi (See Table B4.5B-1 for stress calculations).

F. Handling Load

The number of handling load cycles is four times the number of trips, or 1600. The direct stress is calculated using 3G load (very conservative), 60000(3)/12(1.169)=12,840 psi. The bending stress is 4185 psi, and total combined stress is 17,025 psi.

Fatigue Evaluation - Usage Factor Calculations

Based on the stresses and cyclic histories described above, stress histograms are plotted in Figure B4.5B-4. In this histogram, a fatigue strength reduction factor (K) of 4.0 has been assumed in the evaluation. The stress range for each combination of events and the corresponding alternating stress are shown in Table B4.5B-2. The damage factors are computed using the fatigue curve shown in Table I-9.4 of ASME Section III Appendices. The cumulative fatigue damage factors in this case is 0.621 which is less than the limit of 1.0. Therefore, the TN-WHC cask lid bolts satisfy the fatigue requirements.

TABLE B4.5B-1
FORCES, MOMENTS AND STRESSES CALCULATED FOR FATIGUE EVALUATION

EVENT/ LOAD	F_a (LBS)	F_f (LBS)	M_f (IN-LB)	F_{ap} (LBS)	τ (PSI)	σ (PSI)
TEST PRESS.	15,773	2,204	10,034	0	----	18,062
PRE-LOAD	29,225	----	3,565	0	10,000	32,015
ONE FOOT DROP	49,170	5,155	23,477	0	----	52,370
PRESS. + TEMP.	11,543	1,469	6,689	----	----	12,810
HANDLING LOAD	15,000	----	9,540	----	----	17,025

FIGURE B4.5B-4
SCHEMATIC OF STRESS HISTOGRAM AT LID BOLTS (K = 4)

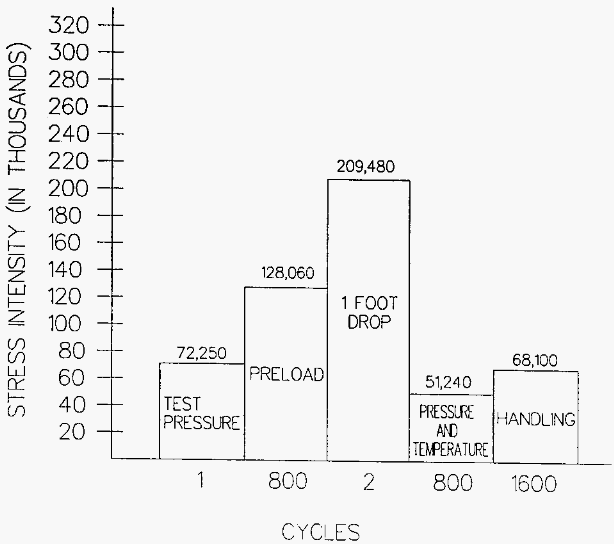


TABLE B4.5B-2
BOLT FATIGUE DAMAGE FACTORS

EVENT COMBINATIONS	STRESS RANGE (PSI)	S_a (PSI)	FATIGUE CURVE	CYCLES		DAMAGE FACTOR n/N
				n	N	
TEST PRESSURE	72250	36125	I-9.4	1	5000	0.0002
PRELOAD	128060	64030	I-9.4	800	2000	0.4000
ONE FOOT DROP	209480	104740	I-9.4	2	450	0.003
VIBRATION	328	164	I-9.4	7.2×10^8	∞	0
TEMPERATURE AND PRESSURE	51240	25620	I-9.4	800	20000	0.0400
HANDLING LOAD	68100	34050	I-9.4	1600	9000	0.178
TOTAL DAMAGE FACTOR						0.621

B4.5B-4 ACCIDENT CONDITION ANALYSIS

The hypothetical accident conditions considered for the bolt analysis are: impact and puncture.

The worst loading due to the 30 foot impact occurs at lid end corner drop. This results in a G loading of 20.

The nonprying tensile bolt force due to impact is:

$$F_a = 1.34\ (D_{lf})(\sin xi)(W_l + W_c)\ (ai)/N_b = 1.34(1.2)(\sin 76)(21010)(20)/12 = 54{,}633 \text{ lbs.}$$

There is no shear bolt force due to impact, since the load is taken by the lip of the cask flange. The fixed edge closure lid force (F_f) and moment (M_f) are

$$F_f = \frac{1.34(D_{lf})(\sin xi)ai(W_l+W_c)}{\pi D_{lb}}$$

$$= \frac{(1.34)(1.2)(\sin 76)(20)(21010)}{\pi(36.44)}$$

$$= 5{,}727 \text{ lbs.}$$

$$Mf = \frac{1.34(D_{lf})(\sin xi)\ ai\ (W_l+W_c)}{8\pi}$$

$$= \frac{(1.34)(1.2(\sin 76)(20)(21010)}{8\pi} = 26{,}085 \text{ in-lbs.}$$

The puncture accident results in an inward load on the bolts which relaxes the tensile force due to preload.

Therefore the worst accident condition for the bolts is the 30 foot lid end corner drop. This must be combined with preload, internal pressure and thermal expansion loads.

The sum of the tensile bolt forces for operating preload and temperature is 30,252 lbs. as in the normal load cases.

The sum of the non prying tensile forces from internal pressure and 30 foot drop accident is, f_{a-c} = 10515 + 54,630 = 65,148 lbs.

The combined non-prying tensile bolt force is the larger of the two forces calculated above, 65,148 lbs.

The maximum combined prying fixed edge force F_{f-c} is 5727 + 1469 = 7,196 lbs. The combined prying moment M_{f-c} is 26,085 + 6698 = 32,783 in. lbs.

The prying tensile bolt force for the combined load is zero.

Combining the non-prying and prying tensile bolt force

F_{a-c} = 65,148+ 0 = 65,148 lbs.

The maximum average tensile stress in a lid bolt is

S_{ba} = 65,148/1.169 = 55,730 psi

This is less than the smaller of 0.7 S_u or 0.9S_y which is 90,900 psi.

The average shear stress is due to torsion from preloading the bolts. The maximum shear stress is 10,000 psi. This is much less than the allowable stress 0.42 S_y or 42,420 psi.

The stress ratio for average tensile stress is 55730/909000 = 0.613. The stress ratio for average shear stress is 10000/42420 or 0.24.

The combined tensile and shear ratios must meet the following criterion:

$$R_t^2 + R_s^2 \leq 1$$

where R_t is the stress ratio for average tensile stress and R_s is the stress ratio for average shear stress ratio

$(.613)^2 + (.24)^2 = .43 \leq 1$

which is acceptable.

The maximum combined fixed edge moment due to pressure and 30 foot drop, $M_f = 6698 + 26085 = 32{,}783$ in-lbs.

Bolt bending moment, $M_{bb} = [2358/30166] \times 32783 = 2562$ in-lbs.

Bolt bending stress, $S_{bb} = 1.186 \times 2562/(1.22)^3 = 14{,}372$ psi

The maximum stress intensity due to tension, bending and shear is

$S_b = [(55730 + 14372)^2 + 4(10000)^2]^{0.5} = 72{,}900$ psi

This stress is less than the allowable S_u of 133,000 psi.

B4.5B-5 FIRE CONDITION

The fire accident results in a maximum bolt and lid temperature of 1068^{0}F (1091^{0}F is conservatively used for calculation). The thermal stress caused by differential thermal expansion of the closure lid and bolt is

Thermal Stress $= E_b (\Delta T)(\alpha_f - \alpha_b) = 23.5 \times 10^6 (1091 - 70)(10.24\text{-}9.40) \times 10^{-6} = 20{,}155$ psi

The preload axial tensile and shear stresses are combined to obtain the maximum stress intensity. The pressure load is not considered as the seal material will not be effective at this temperature.

$S_b = [(20155+25000)^2 + 4(10000)^2]^{0.5} = 49{,}386$ psi

This stress is below the bolt material tensile strength (S_u= 112,500 psi at 1100° F). The MCO will therefore be secure inside the cask during the fire accident.

Both the lid and lifting attachment welded to the lid are made in the same material (stainless steel), the thermal stresses due to the differential thermal expansion are insignificant.

B4.5B-6 CLOSURE FLANGE SHOULDER ANALYSIS

Transverse lid deceleration loads are resisted by the closure flange shoulder during all normal and accident conditions. The shoulder thickness at the base has a shear area equal to

$$\text{Shear Area} = \pi[(29.76)^2 - (25.5)^2]/4 = 184.9 \text{ in}^2$$

For conservatism, it is assumed that only a 120° arc of the shoulder is effective. Effective shear is:

$$\text{Effective Shear} = 120/360\ (184.9) = 61.6 \text{ in}^2$$

Normal Conditions Stresses

Maximum transverse deceleration loads during normal conditions occurs during the hypothetical one foot horizontal drop. Maximum deceleration is 24 g's. (Ref Appendix B4.5A)

Total Force = 24.0 x wt of lid = 24.0 (1890) = 45,360 lbs.

Average Shear Stress = 45360/61.6 = 737 psi

Allowable Average Shear = $0.4S_y$ = 0.4 (30000) = 12,000 psi

Factor of Safety = 12,000/737 = 16.3

Hypothetical Accident Conditions Stresses

The maximum transverse deceleration load during accident conditions is 40 g for the horizontal 30 foot drop. The average shear stress across the shoulder is

Average shear stress = (40/24)× 737 = 1,228 psi

Allowable average shear = $S_u/2$ = 75,000/2 = 37,500 psi

Factor of Safety = 37,500/1,228 = 30.5

B4.5B-7 CONCLUSIONS

The maximum average tensile stress in the lid bolts during normal conditions is 51,060 psi which is less than the allowable tensile stress of 2/3 yield, or 67,300 psi. The maximum stress intensity for the bolts during normal conditions is 67,330 psi which is much less than the allowable maximum stress intensity of 90,900 psi (0.9 S_y).

The fatigue analysis performed shows that for 400 round trip shipments, the bolts will not fail due to fatigue. The cumulative fatigue damage factor is 0.621 which is much less than the allowable limit of 1.0.

The maximum average tensile stress due to the accident conditions is 55,730 psi psi, which is less than the allowable stress of 90,900 psi. The maximum stress intensity for the bolts during accident conditions is 72,900 psi which is less than the allowable stress of 133,000 psi.

During fire accident condition, bolt and flange experiences a maximum temperature of 1068°F and the maximum bolt stress intensity is 49,386 psi which is below the bolt tensile strength of 112,500 psi. The lid bolts will keep the MCO secure in cask during a fire accident.

Lid shoulder stresses during both normal and accident conditions provide large margins of safety of resisting transverse lid deceleration loads.

B4.5B-8 REFERENCES

1. NUREG/CR-6007, Stress Analysis of Closure Bolts for Shipping Casks.

2. WHC-S-0396, Rev.1," Specification for TN-WHC cask and Transportation System".

APPENDIX B4.5C

STRUCTURAL EVALUATION OF CASK BODY

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APPENDIX B4.5C

STRUCTURAL EVALUATION OF CASK BODY

B4.5C-1 INTRODUCTION

This appendix presents the structural analyses of the cask body including the cylindrical shell assembly and bottom assembly, and the lid. The specific methods, models and assumptions used to analyze the cask body for the various individual loading conditions specified in the Hanford Specification[1]. Stress results are reported at selected locations for each load case. Maximum stresses from this appendix are evaluated in Sections B4.3 and B4.4 where the load combinations are performed and the results evaluated against the ASME Code and design criteria described in Sections B4.3 and B4.4.

The cask body structural analyses generally use static or quasistatic linear elastic methods so that combinations of loads can be examined by superimposing the results from individual loads. The stresses and deformations due to the applied loads are generally determined using the ANSYS[2] computer program.

The two analysis methods, described in this appendix and used to evaluate the cask body for the individual loading conditions, are:

- ANSYS Analysis - Axisymmetric and Asymmetric Loads
- Puncture Analysis

The method of combining stress results from individual load cases to evaluate the required load combinations is discussed in Section B4.3 for normal conditions of transport and Section B4.4 for hypothetical accident conditions.

B4.5C-2 ANSYS ANALYSIS

Model Description

The cask body consists of the cylindrical shell, the bottom, the lid and the lid bolts. The elements used to model the bolts are ANSYS STIF3, beam elements. The cylindrical shell, the bottom end closure and the lid are modeled using either ANSYS STIF25 axisymmetric harmonic solid elements or ANSYS STIF42 axisymmetric solid elements (Puncture Analysis). The loading applied to this type of elements may be either axisymmetric for some cases and asymmetric for other cases. The model geometry is based on Drawings H-1-81535, sheets 1,2,3,4,5 and are provided in Section A9.1. The contact surface at the lid and cylindrical shell is modeled using separate nodes in the interfacing components. These nodes are coupled or left uncoupled for specific constraint conditions as discussed below. The lifting attachment welded to the lid changes the usual cask drop analyses on the lid end drop and corner drop. A separate analysis was done to check this impact effects. Based on this calculation, the cask and lid closure structure remain intact but the welds at the trunnion brackets and gussets fail at lower G level. The bracket and gussets act like an impact limiter (reduced the G force at the cask body) during the drop events. It is conservative to neglect the brackets and gussets in the cask model for calculating the globe effect of the cask body. All the analyses were performed using the model shown in Figures B4.5C-1 and B4.5C-2. The mechanical properties for the materials in this model are the linear values described in Section B4.2.2.

Figure B4.5C-1
TN-WHC Cask Structural ANSYS Model
(2D AXISYMMETRIC)

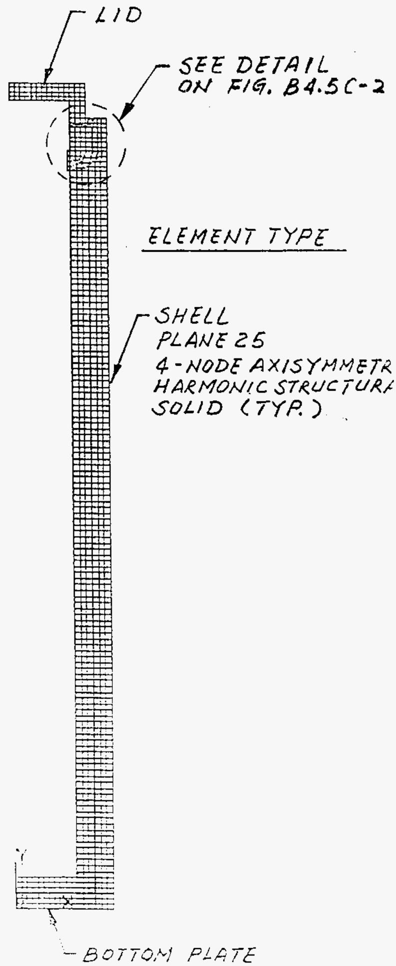
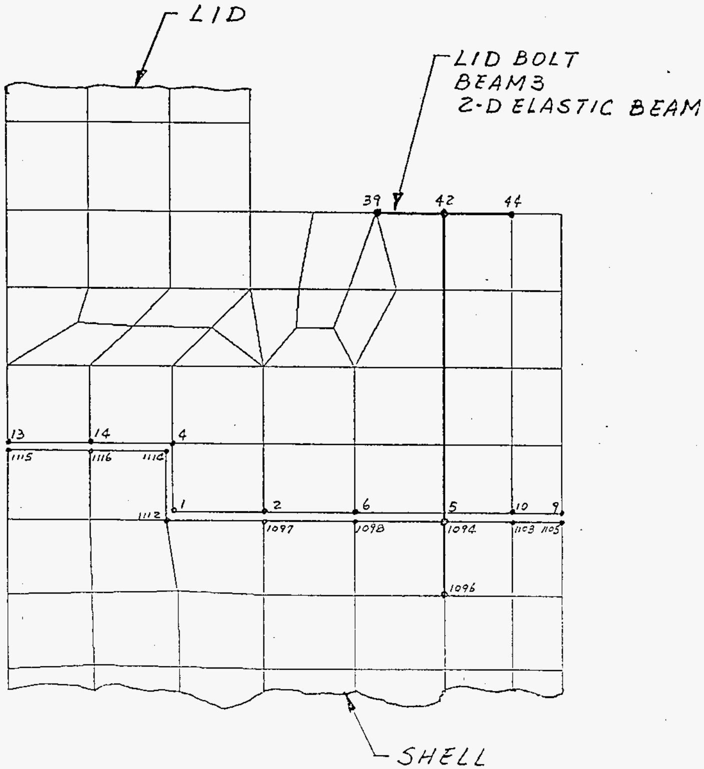


Figure B4.5C-2
TN-WHC Cask Structural ANSYS Model
(2D AXISYMMETRIC)



Finite Element Model Internal Constraints

The connections between various portions of the model were made using node coupling. The bolted connection between the lid and the cask body was modeled by coupling the interfacing nodes in the radial and axial directions.

Finite Element Model Boundary Conditions

For a static finite element structural analysis the structure must be restrained in such a way that there is no rigid body motion. For the drop analyses, the dynamic equilibrium problem is solved using D'Alembert's principle, i.e. the total inertia loading is balanced by the total reaction force. In an actual dynamic event, there are no physical locations in the structure that are stationary and, unless suitable boundary conditions are selected for analysis, rigid body motion may occur. To eliminate the rigid body motion problem, the cask model was carefully restrained in such a way that no appreciable forces were developed at the restraints. When only small reactions are developed at the restrained nodes the inertia loadings and reactions are well balanced. This is true for all loading conditions analyzed.

The boundary conditions used for the different loading conditions are shown on the following figures.

Figures B4.5C-3 and 4:	Boundary conditions for bolt preload, pressure and thermal
Figures B4.5C-5 and 6:	Boundary conditions for bottom end drop
Figures B4.5C-7 and 8:	Boundary conditions for lid end drop
Figures B4.5C-9 and 10:	Boundary conditions for side drop
Figures B4.5C-11 and 12:	Boundary conditions for corner drop

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Figure B4.5C-3
Boundary Conditions For Bolt Preload, Pressure, and Thermal

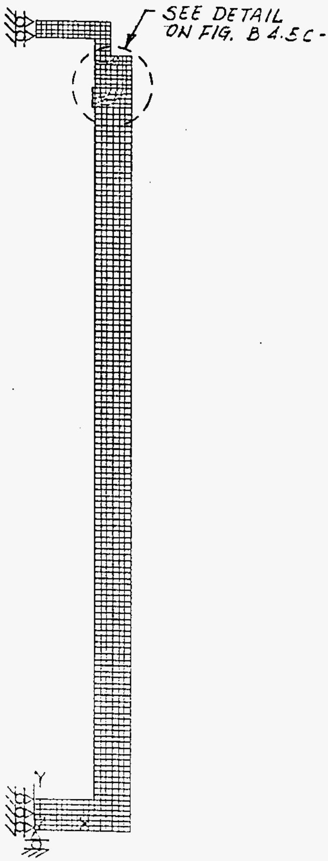
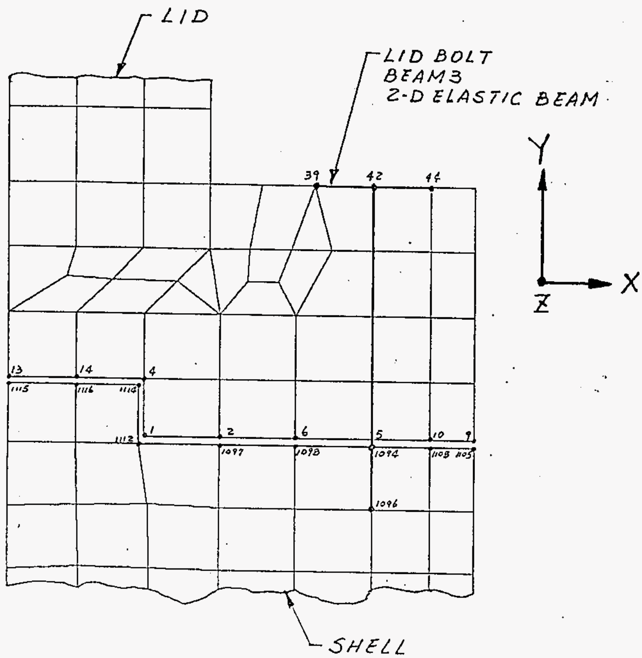


Figure B4.5C-4
Boundary Conditions For Bolt Preload, Pressure, and Thermal
(Lid and Lid Bolt)



NODES COUPLED IN X DIRECTION
(4,1114) (1,1112)

NODES COUPLED IN Y DIRECTION
(13,1115) (14,1116) (4,1114) (1,1112) (2,1097)
(6,1098) (5,1094) (10,1108) (9,1105)

NODES COUPLED IN Z DIRECTION
(1,1112) (2,1097) (6,1098) (5,1094)
(10,1108) (9,1105)

Figure B4.5C-5
Boundary Conditions For Bottom End Drop

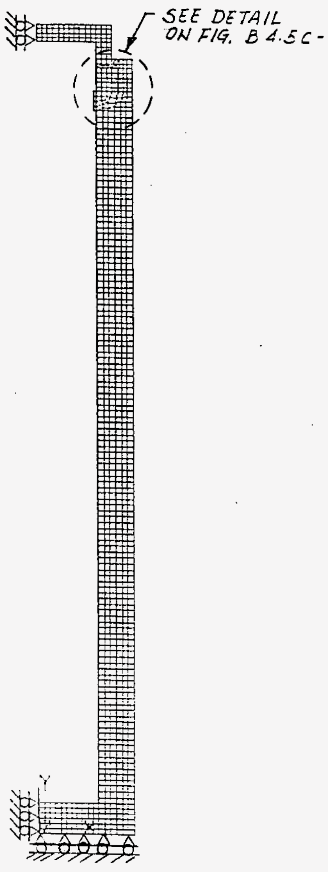
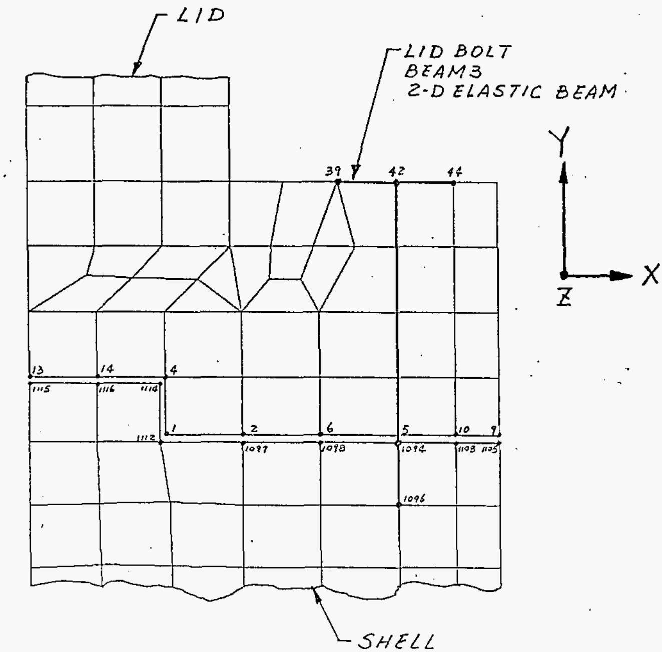


Figure B4.5C-6
Boundary Conditions For Bottom End Drop
(Lid and Lid Bolt)



NODES COUPLED IN X DIRECTION
(4,1114) (1,1112)

NODES COUPLED IN Y DIRECTION
(13,1115) (14,1116) (4,1114) (1,1112) (2,1097)
(6,1098) (5,1094) (10,1108) (9,1105)

NODES COUPLED IN Z DIRECTION
(1,1112) (2,1097) (6,1098) (5,1094)
(10,1108) (9,1105)

Figure B4.5C-7
Boundary Conditions For Lid End Drop

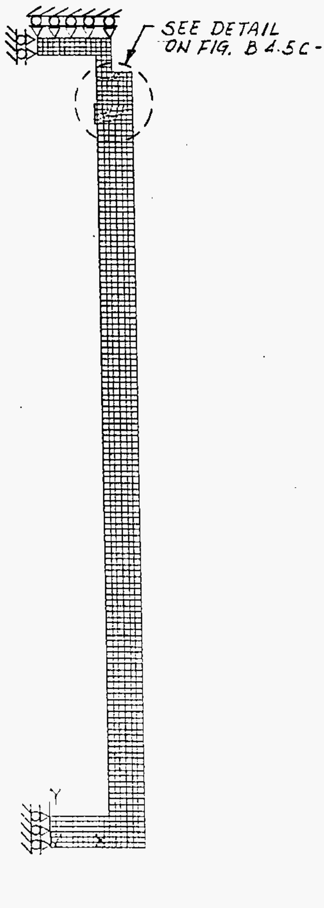
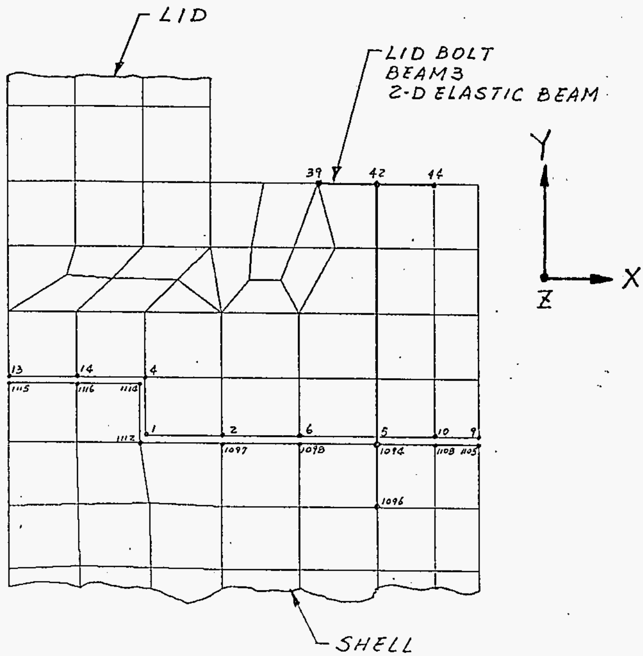


Figure B4.5C-8
Boundary Conditions For Lid End Drop
(Lid and Lid Bolt)



NODES COUPLED IN X DIRECTION
(4,1114) (1,1112)

NODES COUPLED IN Y DIRECTION
(13,1115) (14,1116) (4,1114) (1,1112) (2,1097)
(6,1098) (5,1094) (10,1108) (9,1105)

NODES COUPLED IN Z DIRECTION
(1,1112) (2,1097) (6,1098) (5,1094)
(10,1108) (9,1105)

Figure B4.5C-9
Boundary Conditions For Side Drop

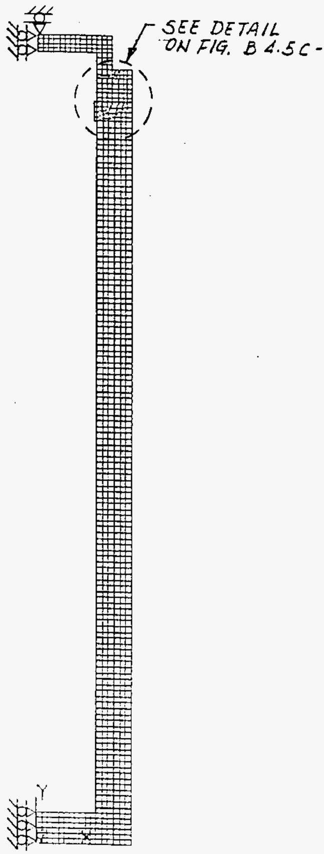
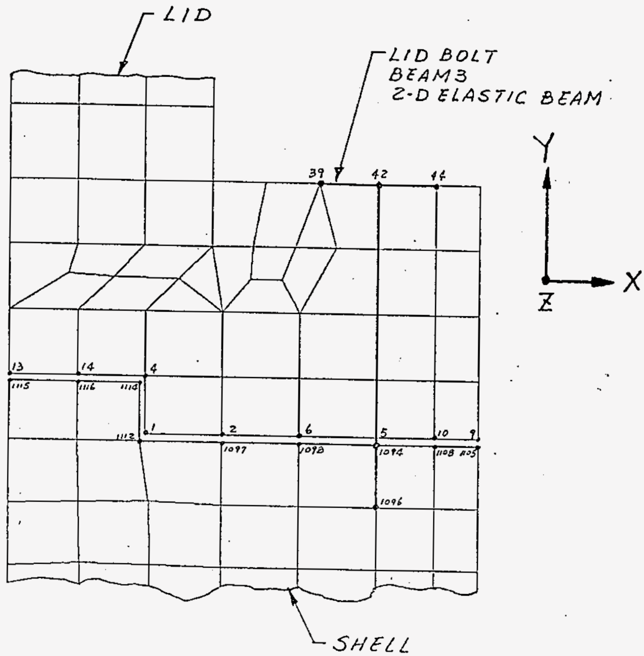


Figure B4.5C-10
Boundary Conditions For Side Drop
(Lid and Lid Bolt)



NODES COUPLED IN X DIRECTION
(4,1114) (1,1112)

NODES COUPLED IN Y DIRECTION
(13,1115) (14,1116) (4,1114) (1,1112) (2,1097)
(6,1098) (5,1094) (10,1108) (9,1105)

NODES COUPLED IN Z DIRECTION
(1,1112) (2,1097) (6,1098) (5,1094)
(10,1108) (9,1105)

Figure B4.5C-11
Boundary Conditions For Corner Drop

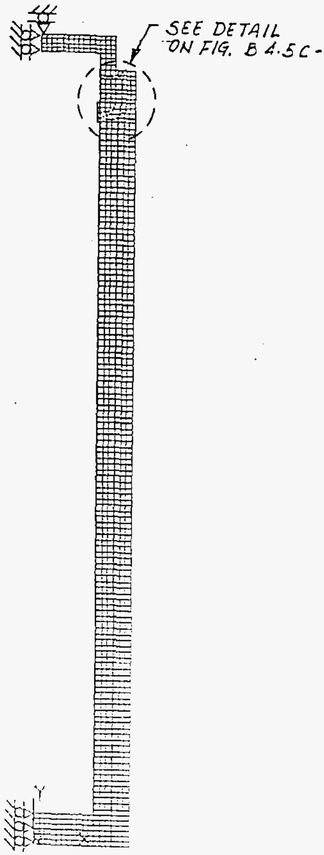
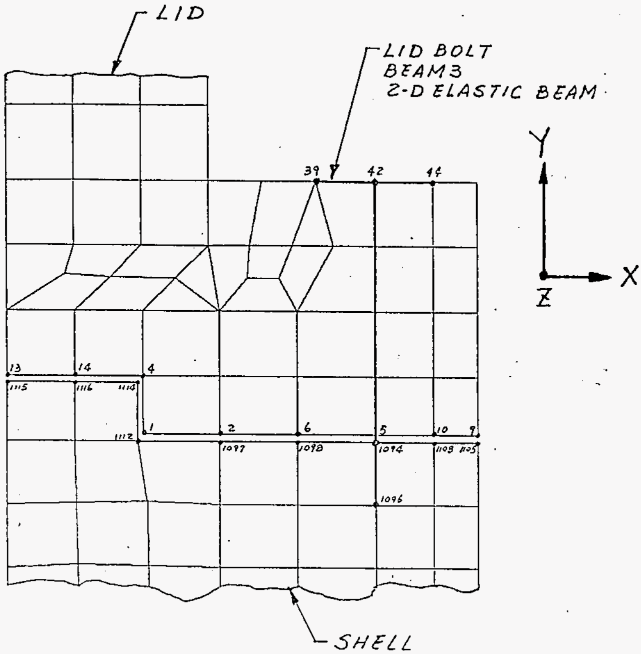


Figure B4.5C-12
Boundary Conditions For Corner Drop
(Lid and Lid Bolt)



NODES COUPLED IN X DIRECTION
(4,1114) (1,1112)

NODES COUPLED IN Y DIRECTION
(13,1115) (14,1116) (4,1114) (1,1112) (2,1097)
(6,1098) (5,1094) (10,1108) (9,1105)

NODES COUPLED IN Z DIRECTION
(1,1112) (2,1097) (6,1098) (5,1094)
(10,1108) (9,1105)

B4.5C-3 LOADINGS

The loading conditions analyzed simulate or represent various effects due to the normal conditions of transport and hypothetical accident conditions specified in the Hanford Specification.

B4.5C-3.1 Axisymmetric Loadings

The following individual axisymmetric load cases analyzed using this ANSYS model are described in this section.

(1) Bolt preload

(2) Internal pressure loading

(3) External pressure loading

(4) 1 foot and 30 foot end drops on bottom

(5) 1 foot and 30 foot end drops on lid

(6) Thermal stresses for hot environment at 115°F ambient temperature

(7) Thermal stresses for minimum air temperature of -27°F plus zero heat generation.

(8) Thermal accident condition

Since the individual load cases are linearly elastic, their results can be scaled and superimposed as required in order to perform the normal and hypothetical accident condition load combinations. The magnitudes of the loads used in each individual load case analysis are computed as described in the following paragraphs:

1. <u>Bolt Preload</u>

A lid seating load corresponding to 25,000 psi axial stress in the bolt is simulated by applying a prestrain of 0.000958 in/in in the bolt elements. The inputs for the ANSYS's finite element analysis are as follow:

Number of Bolts: 12
Diameter of Bolt: 1 1/2 in.
Bolt Circle Dia: 36.44 in.
Bolt Prestrain: 0.000958 in/in

2. Internal Pressure Loading

An internal pressure of 161.2 psi is applied to the cavity surface as shown in Figure B4.5C-13.

3. External Pressure Loading

An external pressure of 20 psi is applied to the outer surface of the cask body as shown in Figure B4.5C-14.

4. 1 Foot and 30 Foot End Drops on Bottom

The analysis described in Appendix B4.5A determined the inertial loads on the cask for 1 foot and 30 foot end drops onto an yielding surface. That analysis concluded that the maximum axial decelerations are 25 g and 30 g for 1 foot and 30 foot drops respectively. A quasistatic analysis of the cask body is performed with inertial forces balanced by the impact force for 1 G deceleration. Since the payload or cargo is not included in the model, its loading effect is simulated as distributed pressures applied on the cask at the appropriate locations. All nodes on the outside bottom surface of the cask are fixed in the axial directions. The system of forces on the cask body is presented on Figure B4.5C-15.

Following is the derivation of the inertia load (pressure) magnitudes for the ANSYS model run:

° Weight of Cask Body:	39,600 lb.(Actual wt.=38,960 lb)
° Weight of Cargo:	19,120 lb.(Actual wt.=18,950 lb.)
° Maximum Deceleration:	25 G for 1 foot drop and 30 G for 30 foot drop
° Pressure due to cargo inertia load	$P = 19{,}120/\pi\ (12.595)^2 = 38.366$ psi for 1 G

1 G was used for the analysis. The stresses for 25 G and 30 G are ratioed from the 1 G analysis results.

Figure B4.5C-13
Load Distribution - Internal Pressure

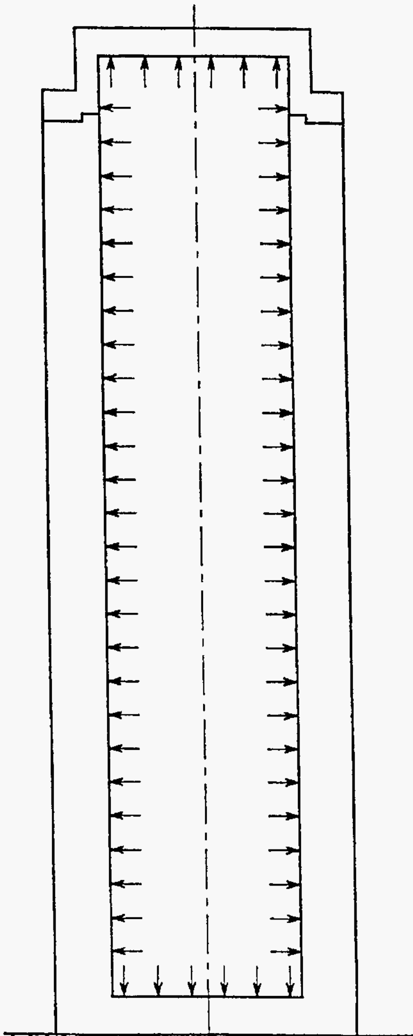


Figure B4.5C-14
Load Distribution - External Pressure

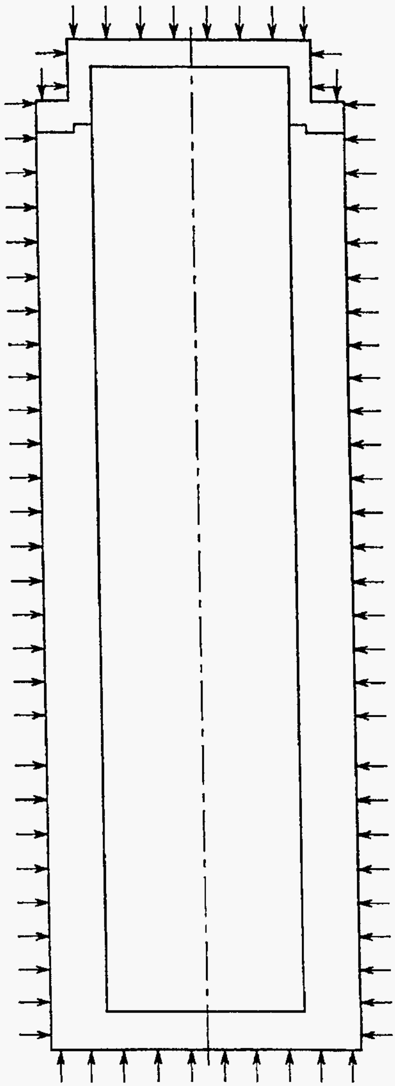
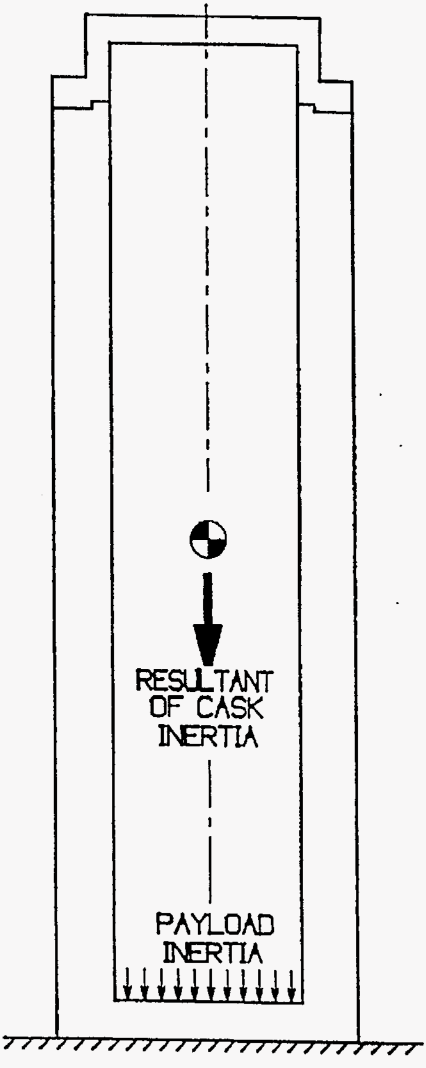


Figure B4.5C-15
Load Distribution - Bottom End Drop



5. 1 Foot and 30 Foot End Drops on Lid

An analysis similar to that for the 30 foot free drop on the bottom is performed for the 1 foot and 30 foot drops on the lid. The same inertial forces are used for the lid or top impact case as for the bottom impact case. The system of forces on the cask body is presented on Figure B4.5C-16 , and the derivation of the magnitudes follows:

° Weight of Cask Body:	39,600 lb.
° Weight of Cargo:	19,120 lb.
° Maximum Deceleration:	25 G for 1 foot drop and 30 G for 30 foot drop
° Pressure due to cargo inertia load	$P = 19{,}120/\pi\ (12.595)^2 = 38.366$ psi for 1 G

1 G was used for the analysis. The stresses for 25 G and 30 G are ratioed from the 1 G analysis results.

6. Thermal Stress for Hot Environment Condition at 115°F Ambient Temperature

The thermal analysis of the cask body is described in detail in Section B5.0 of this report. That analysis was performed to determine the temperature distribution in the cask body for the condition with maximum solar heating, maximum decay heat from MCO contents, and 115° F ambient air. The temperatures at the critical time-step (which resulted in the maximum temperature difference across the cask body thickness) are taken from that analysis and are used in this structural axisymmetric finite element model to calculate the cask body thermal stresses. It is assumed that there is a stress free state at 70° F for this case 7 below.

7. Thermal stresses for minimum air temperature of -27°F plus zero heat generation.

In this analysis, zero heat generation is assumed with -27° F ambient air temperature. Thus, the cask body will attain a uniform temperature of -27° F. For this temperature distribution, the cask body will mostly be stress free, except the flange region which will develop small stresses due to slightly unequal coefficients of expansion of cask lid and bolt materials.

8. Thermal Accident Condition

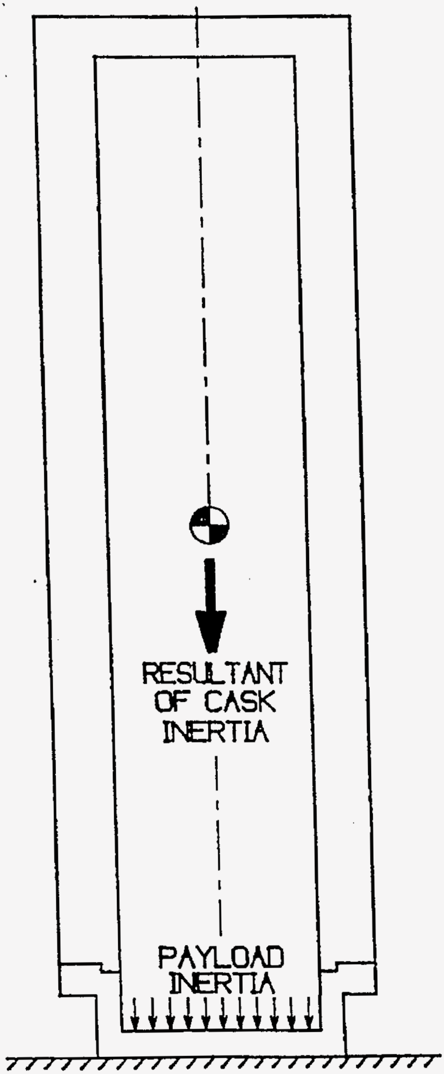
An ANSYS transient thermal analysis for the 30 minute thermal accident is reported in Section B5.0. The initial condition is steady state at 115° F ambient with maximum decay heating. The initial steady state condition is followed by a 0.5 hour severe thermal transient which is then followed by water quench. The temperatures through the cross section of the package at the time where individual temperatures peak (0.5 hrs.) are summarized below:

Cask, inner surface temperature = 727° F
Cask, outer surface temperature = 1068° F

Lid Bolt temperature = 1068° F

The thermal expansion bolt stresses are computed at the highest bolt and flange temperature (1068° F) in Appendix B4.5B of this report.

Figure B4.5C-16
Load Distribution - Lid End Drop



B4.5C-3.2 Asymmetric Loading

The asymmetric loadings of the axisymmetric cask body are applied to special ANSYS harmonic elements. Each load acting on the cask is expanded into a Fourier series and is input into ANSYS as a series of load steps. Each load step contains all of the terms from the applied loads having the same mode number. The number of terms in the Fourier series required to adequately represent a load varies with the type of load (whether it is a concentrated or a distributed load) and the degree of accuracy required. In the particular case where the applied loads are distributed over a large area (i.e., 180 degrees of the cask circumference), a few terms of the series are sufficient to represent the desired loading within a few percent.

The following individual asymmetric load cases analyzed (using the same two-dimensional ANSYS model previously discussed) are described in this section.

(1) 1 foot and 30 foot side drops with the cask axis parallel to the target.

(2) 1 foot and 30 foot C.G. over top corner (lid end) drops.

1. <u>1 Foot and 30 Foot Side Drops</u>

Figure B4.5C-17 shows the free body diagram for the 1 foot and 30 foot free drops on the side of the packaging with all of the forces acting on the cask. These forces are assumed to vary sinusoidally around the circumference, and are:

a. The payload is assumed to be a cosine function over 90^0 to 270^0 range. The fourier coefficients for this function are computed in Figure B4.5C-18 using ANSYS PREP 6 . It is seen from Figure B4.5C-18 that first 3 terms of Fourier series are sufficient to define the cosine function payload.

Total force (1 G) = 19,120 lbs

A cosine distribution is assumed with $90^0 \leq \theta \leq 270^0$

$$F = 19{,}120 = \int_{\pi/2}^{3\pi/2} P \cos\theta \; r \; d\theta \; L \cos\theta = P \; r \; L \;\; \pi/2$$

$P = 2F/rL\pi = 2(19{,}1200)/12.595(160.5)\pi = 6.0214$ psi

This peak pressure (P times fourier coefficients) is applied to the inside surface nodes.

b. The reaction pressures due to side drop impact are assumed to be a cosine function over 162^0 to 198^0 range. This range corresponds to normal condition side drop target deformation of 1". The first 15 terms are used to represent this function. The fourier coefficients are shown in Figure B4.5C-19. All loads are computed for 1 G deceleration.

F, total reaction force (1G) = cask mass + payload = 38,554 + 19,120 = 57,674 #
say 58,000 #

$$F = PrL \int_{162^0}^{198^0} \cos^2\theta \; d\theta = PrL \left[1/4 \sin 2\theta + \theta/2\right]_{162^0}^{198^0}$$

$$= PrL\ (0.6084)$$

$$P = 58{,}000/19.905 \times 163.25 \times 0.6084 = 29.34 \text{ psi}$$

c. The cask inertia load is developed by applying 1 G global deceleration. Stresses for 24 G (1 foot drop) and 40 G (30 foot drop) are ratioed from 1 G analysis results.

Figure B4.5C-17
Load Distribution - Side Drop

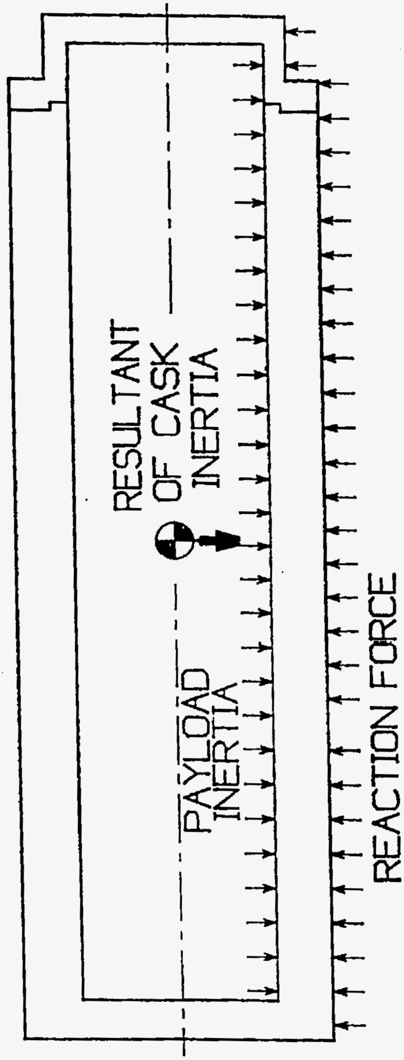
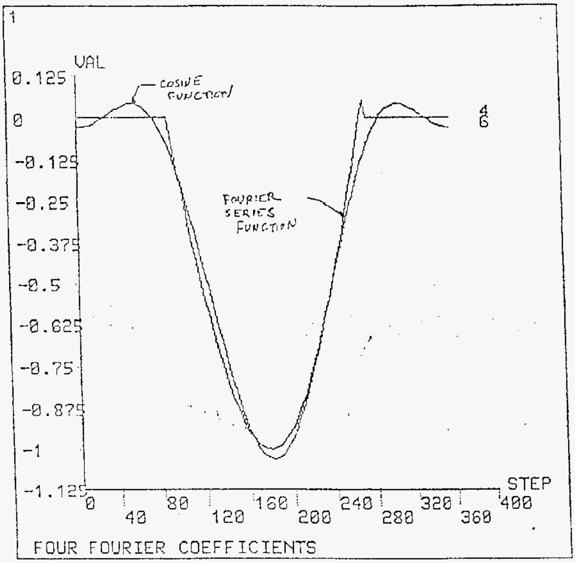


Figure B4.5C-18
Fourier Coefficients for the Function $90^0 \leq \Theta \leq 270^0$

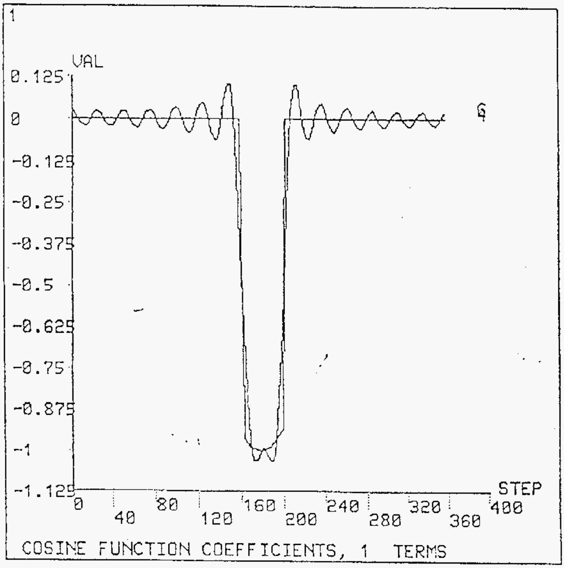


NUMBER OF FOURIER TERMS= 4

***** FOURIER COEFFICIENTS *****

TERM	MODE*ISYM	COEFFICIENT
1	0	-0.31780103E+00
2	1	0.49931477E+00
3	2	-0.21206110E+00
4	3	-0.15267271E-12

Figure B4.5C-19
Fourier Coefficients for the Function $162^0 \leq \Theta \leq 198^0$



***** FOURIER COEFFICIENTS *****

TERM	MODE*ISYM	COEFFICIENT
1	0	-0.10612053E+00
2	1	0.20825277E+00
3	2	-0.19655742E+00
4	3	0.17794199E+00
5	4	-0.15364810E+00
6	5	0.12527336E+00
7	6	-0.94645397E-01
8	7	0.63679383E-01
9	8	-0.34231121E-01
10	9	0.77582053E-02
11	10	0.13799300E-01
12	11	-0.30108963E-01
13	12	0.40499913E-01
14	13	-0.44976925E-01
15	14	0.43994560E-01

2. 1 Foot and 30 Foot C.G. Over Top Corner (Lid End) Drops

The crush footprint of the concrete slab was projected to the cask surface. The impact force was determined from the inertia loading reported in Appendix B4.5A. The impact angle for the C.G. over corner drop is approximately 79.83^0. Figure B4.5C-20 shows the free body diagram for the 1 foot and 30 foot free drops on the corner of the packaging showing all of the forces acting on the cask. These are:

(1) The crush footprint of the concrete slab was projected to the cask surface. The impact force was determined from the inertial loading reported in Appendix B4.5A. The crush force was converted into an equivalent element surface pressure (which varies sinusoidally in both the circumferential and axial directions) which was applied normal to the surfaces. All pressures are calculated for 1 G deceleration.

Normal Pressure

Crushing depth, L= 15.0"

$P_{normal} = 2F/r\ L\ \pi$

The total length of 15.0"(L) is divided two lengths:

7.0"(L_1) for 15.75" radius and 8.0" (L_2) for 19.905" radius

$P_{L1} = 31.969$ psi

$P_{L2} = 22.134$ psi

These pressures are assumed to be a cosine function over 90^0 to 270^0 range. The fourier coefficients for this function are computed in Figure B4.5C-18.

Axial Pressure

The axial load is distributed sinusoidally on the outer surface of the lid:

$F_{axial} = 37{,}400 \times 0.984 + 19.120 \times 0.984 = 55{,}616$ lbs

The computer analysis is based on the pressure varying sinusoidally at half of the outer surface of the lid.

$P_{axial} = 2 \times 55.616/\ \pi \times 15.75^2 = 142.73$ psi

(2) The resultant body inertia force (1 G deceleration) is shown acting at the cask C.G. in Figure B4.5C-20

(3) The cargo inertia loading was applied in two mutually perpendicular directions (one along the axis of the cask and the other perpendicular to it). The component along the axial direction was distributed uniformly over the inside surface of the lid. The other component was assumed to vary sinusoidally around the lower half of the inside surface of the inner shell. In this case, these pressures are not only varied sinusoidally around the circumference but also varied linearly with distance from the bottom inner surface (0) to top inner surface (max.).

For 1G acceleration at CG:

Axial G = $1.0 \times \sin 79.83^0 = 0.984$
Normal G = $1.0 \times \cos 79.83^0 = 0.177$

Axial Pressure

$P_{axial} = 19{,}120\ (0.984)/\pi \times 12.595^2 = 37.752$ psi

Normal Pressure

$P_{normal} = 2F/r\ L\ \pi$

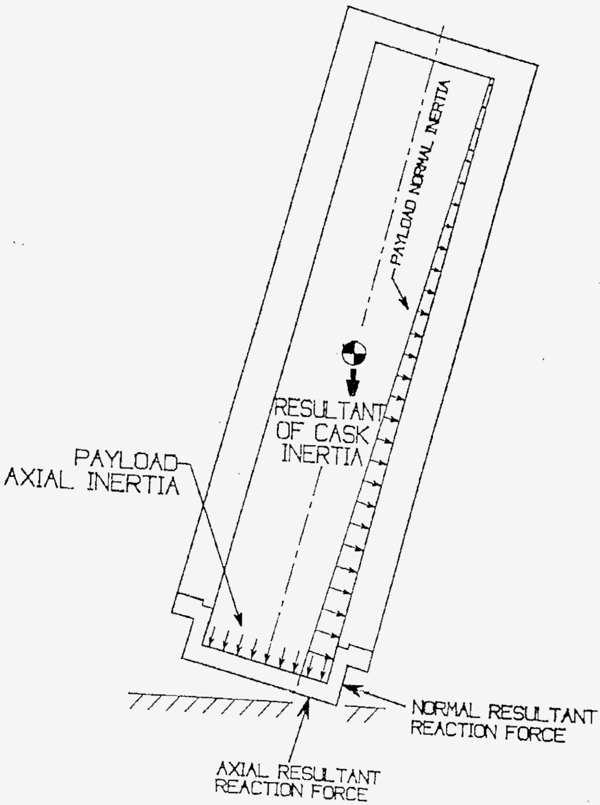
The normal acceleration component variation is assumed as triangular. This triangular G distribution is divided in four step conservative distribution as follow:

$P_1 = 0.089$ G = 0.536 psi
$P_2 = 0.177$ G = 1.065 psi
$P_3 = 0.2745$ G = 1.652 psi
$P_4 + 0.372$ G = 2.238 psi

These pressures are assumed to be a cosine function over 90^0 to 270^0 range.
The fourier coefficients for this function are computed in Figure B4.5C-18.

(4) Stresses for 18 G (1 foot drop) and 20 G (30 foot drop) are ratioed from 1 G analysis results.

Figure B4.5C-20
Load Distribution - Lid End Corner Drop



B4.5C-4 PUNCTURE ANALYSIS

Puncture Force

The most severe damage to the cask resulting from the puncture drop will occur on the outer center of the lid. The analysis is based on the Nelms[3] equation. The Nelms puncture relation is given as:

$$t = (W/S_u)^{0.71}$$

Where:

t = lid thickness = 3.5"

W = package weight = 57,800 lbs

S_u = ultimate tensile strength of the lid = 70,000 psi

The package weight that can result in puncture is:

$$W = S_u\, t^{1.41} = 70{,}000\ (3.5)^{1.41} = 409{,}482 \text{ lbs}$$

The actual package weight is 57,910 lbs, Therefore, the factor of safety for puncture resistance on the energy basis is:

$$F.S. = 409{,}482/57{,}910 = 7.07$$

When the package contacts the puncture bar, the force applied to the package is:

F_I = impact force = $\sigma_s\, A_p$

σ_s = dynamic flow pressure of stainless steel = 45,000 psi (reference 4)

A_p = area of the puncture bar = $\pi/4\ (6)^2 = 28.27\ in^2$

$F_I = 45{,}000 \times 28.27 = 1.272 \times 10^6$ lbs

This force produces a cask deceleration:

$$G = \text{cask deceleration} = F_I/W = 1.272 \times 10^6/57{,}910 = 22$$

This deceleration is smaller than that which will occur during impact on end after the 30 foot free drop (25G). Therefore, global stresses that result from the inertial force will be smaller. The bending stress at the center of the lid will be calculated using the above finite element model.

Lid Stresses

The lid stresses are computed using the 2-D model as described in Section B4.5C-2. The loading distribution and boundary conditions are shown on Figures B4.5C-21 and B4.5C-22. The 22 G inertia load due to 40" drop is applied as body acceleration. The contents inertia load is applied as equivalent pressure on the lid as follow:

Contents weight = 19,120 lbs

$P = 19{,}120 \times 22 / \pi\ (12.595)^2 = 844.05$ psi

Elastic Analysis:

ANSYS computer Code is used for the analysis. A stress run was made using the above noted loads and boundary conditions. STIF 42 (Axisymmetric) finite element was used in the analysis.

The stress are linearized at critical sections. The maximum membrane and maximum membrane plus bending stress intensities are as follow:

Section at Node number (Figure B4.5C-23)	P_m (psi)	$P_m + P_b$ (psi)
84	12,560	83,280
94	10,880	85,010
93	5,275	70,560
92	30,780	57,550
91	25,430	59,960

The maximum membrane stress intensity calculated for this load is 30,780 psi at node number 92. This stress is below the allowable membrane stress intensity of 47,670 psi. The maximum membrane plus bending stress intensity is 85,010 psi at node number 94. This stress exceeds the allowable membrane plus bending stress intensity of 68,100 psi (at temperature 150^{0}F). Therefore, a elastic-plastic analysis was performed to recalculate the stresses.

Plastic Analysis:

A plastic analysis was performed (using the same finite element model, boundary conditions, and loads). The stress-strain properties used for the stainless steel are given in Figure B4.5C-24. The total load (22 G inertia and 844.05 psi) was divided in eight load steps for a proper converged solution.

The maximum membrane and maximum membrane plus bending stress intensities are as follow:

Section at Node number (Figure B4.5C-23)	P_m (psi)	$P_m + P_b$ (psi)
84	2,934	45,030
94	3,326	46,620
93	6,889	42,140
92	25,470	36,060
91	26,350	40,780

The maximum membrane stress intensity calculated for this load is 26,350 psi at node number 91. This stress is below the allowable membrane stress intensity of 47,670 psi ($0.7S_u$). The maximum membrane plus bending stress intensity is 46,620 psi at node number 94. This stress is below the allowable membrane plus bending stress intensity of 61,290 psi ($0.9S_u$). The analysis shows the stresses are within the ASME Code allowables.

Figure B4.5C-21
Load Distribution - Puncture at Center of Lid

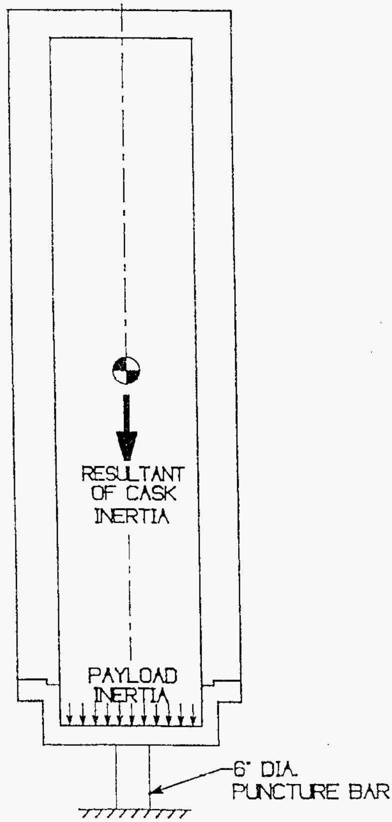


Figure B4.5C-22
Boundary Conditions - Puncture at Center of Lid

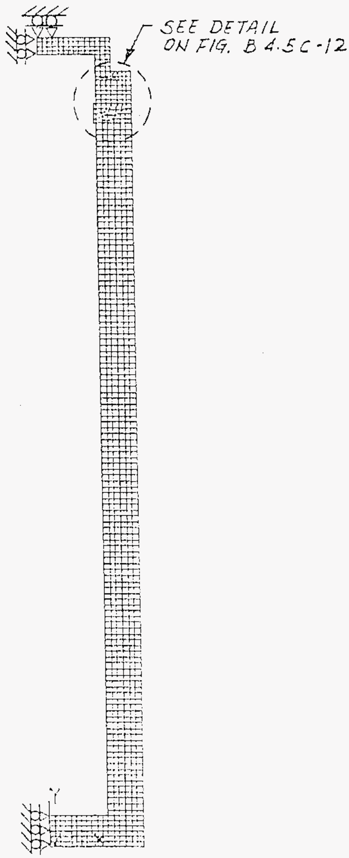


Figure B4.5C-23
Stress Reporting Locations - Puncture at Center of Lid

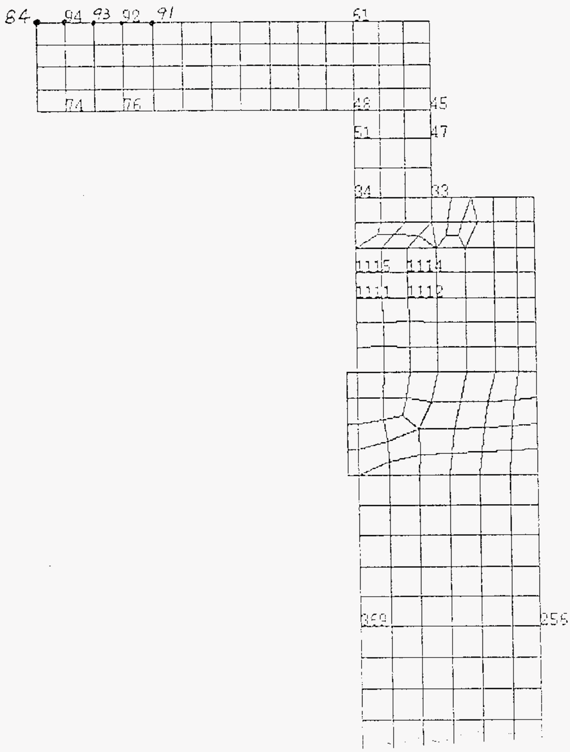
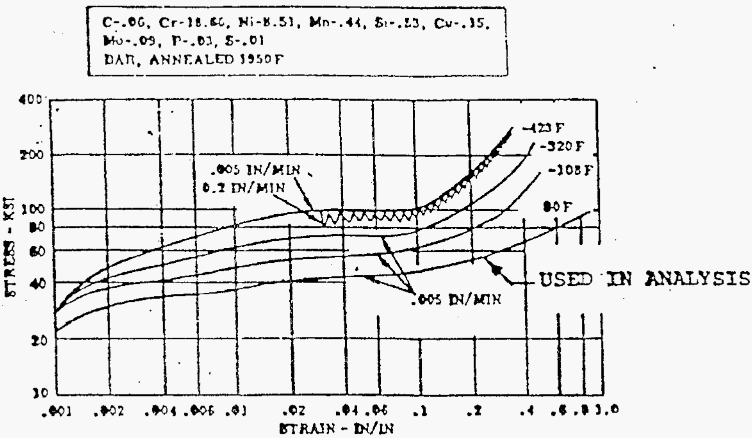


Figure B4.5C-24
Stress - Stain Curve for 304 Stainless Steel



STRESS-STRAIN CURVES FOR TYPE 304 STAINLESS STEEL (49)

B4.5C-5 STRESS RESULTS

Detailed stresses and displacements in the ANSYS model of the cask body are obtained and stored (on magnetic tape) for every node location for each individual load case. These stored results are postprocessed to printout the stresses at 29 standard locations on the cask body structure shown in Figure B4.5C-25. The locations selected as shown in Figure B4.5C-25 are key points that, when carefully studied, indicate the behavior of the entire structure. The maximum stress may occur at a different location for each individual load. Since the individual load cases are linearly elastic, their results can be scaled and superimposed as required in order to perform the normal and hypothetical accident condition load combinations.

The individual load cases analyzed are listed in Table B4.5C-2. Linear elastic analyses were performed for all load cases. The nodal stress intensities for each of the ten load cases are reported in Tables B4.5C-3 to B4.5C-12 as listed in Table B4.5C-2. The magnitude of loads used in each individual load case and summary of the maximum stresses are described in the Table B4.5C-1. There are no specific limits for individual load stresses for comparison with allowable stresses.

It should be noted that, for the axisymmetric analyses, the stress is constant around the cask at every location. For asymmetric analyses with significant differences in stress magnitudes on opposite sides of the cask, the stresses at locations on both sides of the cask (contacting side and side opposite contact during impact) are reported in stress tables.

Figure B4.5C-25
Standard Stress Reporting Locations

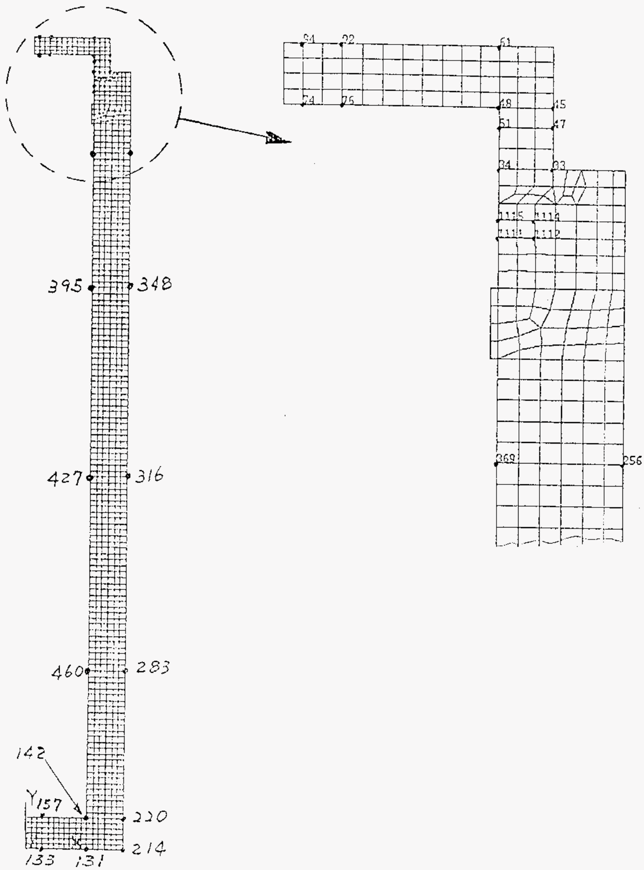


Table B4.5C-1
Cask Body Stresses - Summary of Individual Load Analyses

Load Case	Loading	Calculated Stress intensity (psi)	Reference Table No.
Bolt Preload	25,000 psi	313	B4.5C-3
Internal Pressure	161.2 psi	1,675	B4.5C-4
External Pressure	20 psi	208	B4.5C-5
Vibration	.6G v, .3G , .3G	138	B4.5C-6
1 Foot Bottom End Drop	25 G	1,200	B4.5C-7
30 Foot Bottom End Drop	30 G	1,440	B4.5C-7
1 Foot Lid End Drop	25 G	3,625	B4.5C-8
30 Foot Lid End Drop	30 G	4,350	B4.5C-8
1 Foot Side Drop (Envelop Slap Down)	24 G	3,091	B4.5C-9
30 Foot Side Drop (Envelop Slap Down)	40 G	5,152	B4.5C-9
1 Foot Lid End Corner Drop	18 G	13,468	B4.5C-10
30 Foot Lid End Corner Drop	20 G	14,964	B4.5C-10
Thermal Stress (Hot)	115° F Environment	1,197	B4.5C-11
Thermal Stress (Cold)	- 27° F Environment	23	B4.5C-12
Puncture	22 G	46,620	Section B4.5C-4

Table B4.5C-2
Individual Load Cases For TN-WHC Cask Body Analysis

Load Case Number	Individual Load Description	Stress Result Table
1	Bolt Preload (25,000 psi)	B4.5C-3
2	Internal Pressure (p = 161.2 psi)	B4.5C-4
3	External Pressure (p = 20 psi)	B4.5C-5
4	Vibration (.3G long., .3G hor. , .6G vert.)	B4.5C-6
5	Drop on Bottom/ Gravity Load (1 G)	B4.5C-7
6	Drop on Lid End (1 G)	B4.5C-8
7	Drop on Side (1 G)	B4.5C-9
8	Drop over Corner, Lid End (1 G)	B4.5C-10
9	Thermal Stress (hot)	B4.5C-11
10	Thermal Stress (cold)	B4.5C-12

Table B4.5C-3
Cask Body Stresses For Bolt Preload (25,000 psi)

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	0
	131	0
	214	0
	157	0
	142	0
	220	0
Cask Cylinder	460	0
	427	0
	395	1
	369	26
	283	0
	316	0
	348	1
	256	13
Cask Flange	1111	69
	1112	64
	1115	50
	1114	180
Lid	34	313
	33	307
	51	236
	47	118
	74	93
	76	95
	48	128
	45	78
	94	24
	92	24
	61	19

* See Figure B4.5C-25 for the node locations

Table B4.5C-4
Cask Body Stresses For 161.2 psi Internal Pressure

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	563
	131	290
	214	67
	157	210
	142	448
	220	106
Cask Cylinder	460	540
	427	535
	395	536
	369	516
	283	218
	316	215
	348	215
	256	216
Cask Flange	1111	410
	1112	252
	1115	401
	1114	401
Lid	34	421
	33	293
	51	1,569
	47	449
	74	1,055
	76	932
	48	889
	45	108
	94	1,675
	92	1,551
	61	853

* See Figure B4.5C-25 for the node locations

Table B4.5C-5
Cask Body Stresses For 20 psi External Pressure

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	70
	131	36
	214	9
	157	27
	142	56
	220	13
Cask Cylinder	460	67
	427	66
	395	66
	369	64
	283	27
	316	27
	348	27
	256	27
Cask Flange	1111	51
	1112	31
	1115	50
	1114	49
Lid	34	52
	33	36
	51	195
	47	56
	74	131
	76	115
	48	110
	45	75
	94	208
	92	193
	61	106

* See Figure B4.5C-25 for the node locations

Table B4.5C-6
Cask Body Stresses For Vibration Loadings (.6g vert., .3g long., .3g lat.)

Location		Nodal Stress Intensity (psi)	
Cask Body Component	Node	0 Degree	90 Degree
Cask Bottom	133	138	43
	131	28	20
	214	16	33
	157	134	35
	142	52	42
	220	16	28
Cask Cylinder	460	26	27
	427	22	18
	395	24	28
	369	4	15
	283	34	25
	316	30	17
	348	13	11
	256	3	9
Cask Flange	1111	3	4
	1112	2	4
	1115	4	4
	1114	3	4
Lid	34	2	6
	33	2	7
	51	4	8
	47	2	5
	74	8	6
	76	4	5
	48	2	7
	45	2	4
	94	7	7
	92	6	7
	61	5	4

* See Figure B4.5C-25 for the node locations

Table B4.5C-7
Cask Body Stresses For Bottom End Drops and Gravity Load
1 G results, to be ratioed for 1 foot (25 G) and 30 foot (30 G) drops

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	40
	131	45
	214	48
	157	40
	142	47
	220	46
Cask Cylinder	460	37
	427	26
	395	14
	369	7
	283	37
	316	26
	348	14
	256	7
Cask Flange	1111	4
	1112	4
	1115	4
	1114	5
Lid	34	5
	33	4
	51	11
	47	2
	74	9
	76	8
	48	7
	45	3
	94	11
	92	10
	61	6

* See Figure B4.5C-25 for the node locations

Table B4.5C-8
Cask Body Stresses For Lid End Drops
1 G results, to be ratioed for 1 foot (25 G) and 30 foot (30 G) drops

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	7
	131	4
	214	1
	157	7
	142	7
	220	2
Cask Cylinder	460	13
	427	25
	395	36
	369	53
	283	13
	316	25
	348	36
	256	46
Cask Flange	1111	106
	1112	72
	1115	115
	1114	121
Lid	34	83
	33	111
	51	145
	47	129
	74	33
	76	33
	48	114
	45	118
	94	34
	92	33
	61	33

* See Figure B4.5C-25 for the node locations

Table B4.5C-9
Cask Body Stresses For Side Drops
1 G results, to be ratioed for 1 foot (24 G) and 30 foot (40 G) drops

Location		Nodal Stress Intensity (psi)	
Cask Body Component	Node Number*	Contact Side	Opp. Cont.
Cask Bottom	133	98	48
	131	41	12
	214	29	17
	157	127	65
	142	94	3
	220	33	13
Cask Cylinder	460	124	50
	427	129	56
	395	125	54
	369	109	40
	283	69	34
	316	72	50
	348	71	41
	256	62	24
Cask Flange	1111	82	22
	1112	34	10
	1115	82	20
	1114	39	14
Lid	34	60	14
	33	45	11
	51	56	12
	47	18	7
	74	15	18
	76	13	19
	48	52	16
	45	20	4
	94	31	59
	92	14	26
	61	22	5

* See Figure B4.5C-25 for the node locations

Table B4.5C-10
Cask Body Stresses For Corner Drops
1G results, to be ratioed for 1 foot (18 G) and 30 foot (20 G) drops

Location		Nodal Stress Intensity (psi)	
Cask Body Component	Node Number*	Contact Side	Opp. Cont.
Cask Bottom	133	59	58
	131	15	9
	214	11	9
	157	71	71
	142	16	23
	220	5	8
Cask Cylinder	460	6	20
	427	19	31
	395	46	28
	369	105	27
	283	3	26
	316	15	36
	348	47	26
	256	83	20
Cask Flange	1111	215	51
	1112	145	41
	1115	234	58
	1114	270	55
Lid	34	249	63
	33	251	65
	51	748	132
	47	127	48
	74	590	614
	76	503	232
	48	493	132
	45	59	50
	94	334	479
	92	508	207
	61	332	133

* See Figure B4.5C-25 for the node locations

Table B4.5C-11
Cask Body Stresses For Normal Hot Condition

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	73
	131	632
	214	1197
	157	918
	142	342
	220	844
Cask Cylinder	460	674
	427	664
	395	823
	369	1,135
	283	505
	316	496
	348	599
	256	870
Cask Flange	1111	506
	1112	480
	1115	342
	1114	500
Lid	34	553
	33	396
	51	366
	47	255
	74	22
	76	273
	48	239
	45	148
	94	230
	92	236
	61	427

* See Figure B4.5C-25 for the node locations

Table B4.5C-12
Cask Body Stresses For Normal Cold Condition

Location		Nodal Stress Intensity (psi)
Cask Body Component	Node Number*	
Cask Bottom	133	0
	131	0
	214	0
	157	0
	142	0
	220	0
Cask Cylinder	460	0
	427	0
	395	0
	369	1
	283	0
	316	0
	348	0
	256	1
Cask Flange	1111	5
	1112	3
	1115	6
	1114	4
Lid	34	15
	33	23
	51	11
	47	5
	74	4
	76	4
	48	6
	45	4
	94	2
	92	1
	61	1

* See Figure B4.5C-25 for the node locations

B4.5C-6 REFERENCES

1. Performance Specification for TN-WHC Cask and Transportation System, WHC-S-0396, Rev1, 1995.

2. ANSYS Engineering Analysis system, User's Manual Volumes 1 to 4, Revision 5.2

3. Cask Designers Guide " A Guide for the Design, Fabrication, and Operation of Shipping Casks for nuclear applications". ORNL-NSIC-68.

4. Charles R. Adams " A Comparison of Analytical Techniques for Analyzing a Nuclear-Spent-Fuel Shipping Cask Subjected to An end-On Impact" NUREG/CR-1018.

APPENDIX B4.5D

CASK LIFTING ATTACHMENT

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APPENDIX B4.5D

CASK LIFTING ATTACHMENT

B4.5D-1 INTRODUCTION

This appendix presents the structural analysis of cask lifting attachment. The lifting attachment consists of two trunnions which are attached to the cask lid by a set of brackets and gussets. The geometry and dimensions of lifting attachment are based on Reference 1. The details of the lifting attachment components are shown in Figure B4.5D-1. All components are made of 304 stainless steel.

Two analysis methods are used in the structural evaluation of the cask lifting attachment;

- Hand-calculations to analyze the trunnion
- ANSYS[2] finite element method to analyze the bracket, gusset and lid

B4.5D-2 LOADING

Hanford Specification[3] requires that the lifting attachments are to be designed per ANSI N14.6 with a factor of safety of three to yield or five to ultimate strength, whichever is most restrictive Since 304 stainless steel has 30 ksi yield and 75 ksi ultimate strength, the factor 3 to yield is more severe. Accordingly, a factor of 3 is used on the load and the resulting stresses are compared to the yield strength.

B4.5D-3 TRUNNION ANALYSIS

Maximum Cask Weight = 60,000 lbs. (Reference 4)

Load/Trunnion = 60,000 x 3 /2 = 90,000 lbs.

(a) Stresses at Section B-B (See Figure B4.5D-2a)

Shear Stress, $S_s = 90000 / [\pi (2)^2] = 7{,}162$ psi

Shear stress is less than the allowable $0.42\ S_u = 31{,}500$ psi , . . O.K

Moment of Inertia

$$I = \pi (2)^4 / 4 = 12.57 \text{ in}^4$$

Bending Stress

$$S_b = M\ C / I = 90{,}000 \times 1.505 \times 2 / 12.57 = 21{,}552 \text{ psi}$$

Combined Stress Intensity

$$SI = [\ S_b^2 + 4\ (S_s)^2\ ]^{0.5} = [21552^2 + 4\ (7162)^2\ ]^{0.5} = 25{,}878 \text{ psi}$$

This stress is less than the allowable $S_y = 30{,}000$ psi, ... O.K.

(b) Stresses at Section A-A (Weld) (See Figure B4.5D-2b)

Weld Thickness = 1 in.

Moment of Inertia

$$I = \pi /64\ [\ d^4_o - d^4_i\ ] = \pi /64\ [7^4 - 5^4] = 87.18 \text{ in}^4$$

Bending Stress

$$S_b = M\ C\ /\ I = 90{,}000 \times 5.505 \times 3.5 /87.18 = 19{,}890 \text{ psi}$$

Shear Stress

$$S_s = 90{,}000/(\pi /4\ [7^2 - 5^2] = 4{,}775 \text{ psi}$$

Combined Stress Intensity

$$SI = [19890^2 + 4\ (4775)^2\ ]^{0.5} = 22{,}065 \text{ psi}$$

This stress is less than the allowable $S_y = 30{,}000$ psi, ... O.K.

(c) Bearing Stresses at Crane Hook Location (See Figure B4.5D-2c)

Bearing area is based on 40 degrees (on each side of center line) contact between the hook and trunnion .

Hook Depth = 2.25 in
Bearing Area = 2[2.0 sin 40°] x 2.25 = 5.785 in^2
Bearing Stress = 90,000/5.785 = 15,560 psi

This stress is less than the allowable $S_y = 30{,}000$ psi . . . . O.K.

(d) Stresses at Weld Between brackets, gussets and Lid

The weld section properties, I = 317.58 in^4, e = 4.85 in.

The maximum bending moment = 90,000 (5.505 + 4.85) = 931,950 in-lb

The maximum stress at bracket weld is:

$F/A + MC/I = 90000/9.279 + 931950(4.85)/317.58 = 23{,}932$ psi $\leq 30{,}000$ psi ...........O.K.

The maximum stress at gusset weld is:
$F/A + MC/I = 90000/9.279 - 931950(9.4)/317.58 = -17{,}886$ psi $\leq 30{,}000$ psi ...........O.K.

B4.5D-4 BRACKET, GUSSET AND LID ANALYSIS

An ANSYS three-dimensional finite element model of bracket, gusset and lid is constructed using SOLID45 element (see Figure B4.5D-3). Since the loading and structure are symmetric, only one quarter of structure is modeled. All nodes at the lid bottom are fixed. Symmetry boundary conditions are applied at all the cut surfaces. The force of 45000 lbs. (in Z-direction) is applied as a concentrated load at the trunnion. The resulting stress intensity distribution in the model is shown in Figure B4.5D-4. The figure shows that the maximum stress intensity in bracket, gusset and lid is in the range of 10,000 to 15,000 psi. All the stresses are less than the allowable stress of 30,000 psi.

B4.5D-5 CONCLUSION

Based on the results of analyses, it is concluded that the design of the cask lifting attachment is structurally adequate to withstand the maximum lifting loads.

Figure B4.5D-1
Cask Lifting Attachment Components

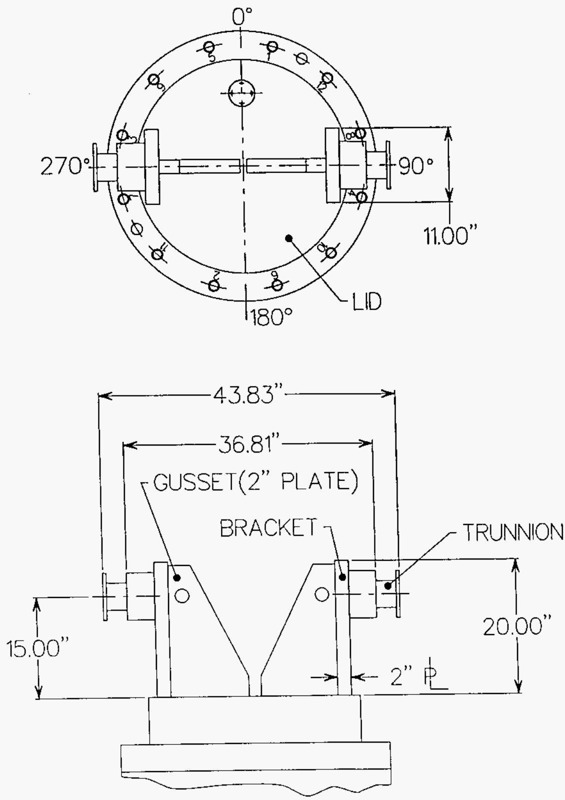
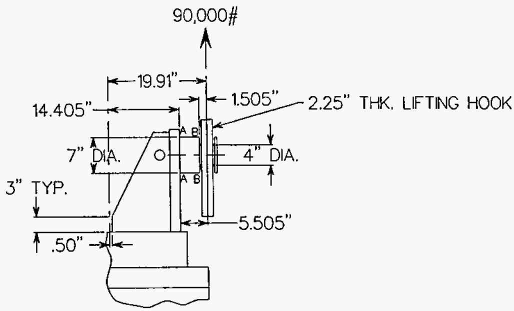
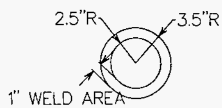


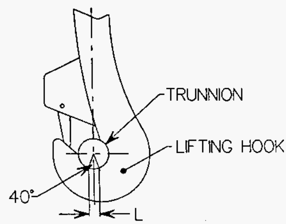
Figure B4.5D-2
Trunnion Analysis



a) TRUNNION ASSEMBLY



b) SECTION A–A



c) BEARING AREA

Figure B4.5D-3
ANSYS Finite Element Model For Cask Lifting Attachment

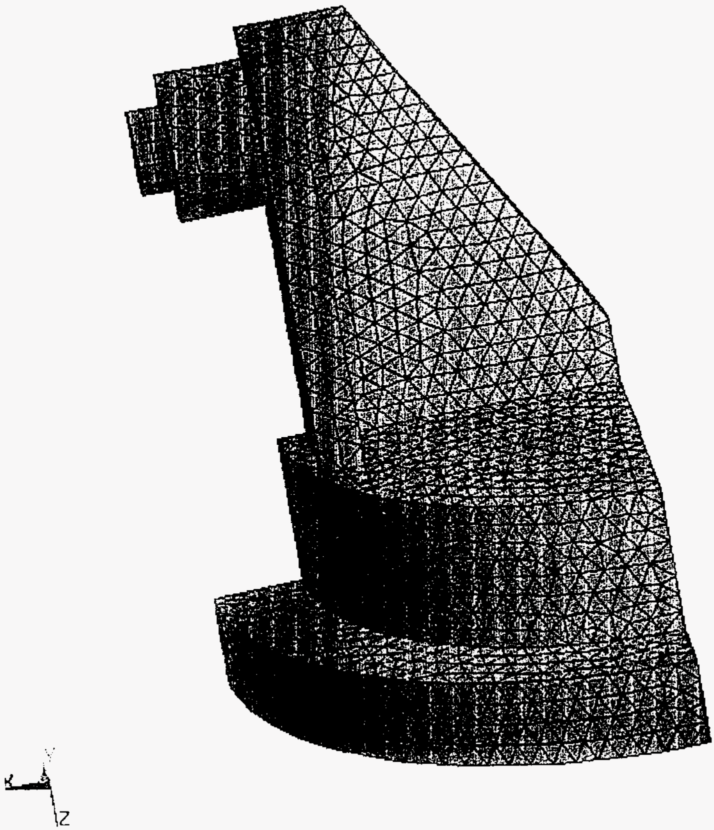
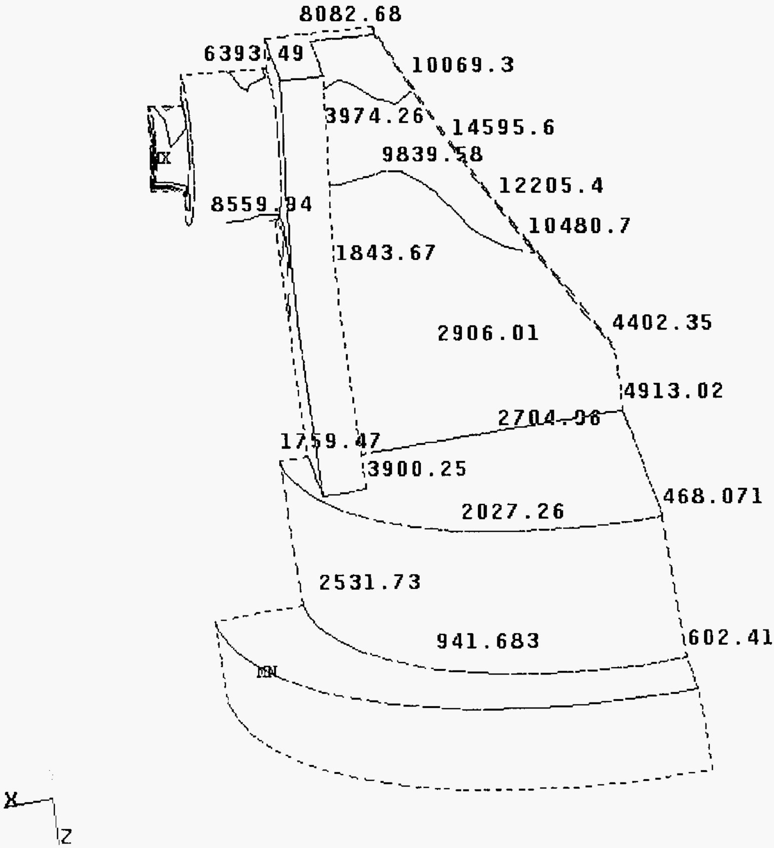


Figure B4.5D-4
ANSYS Finite Element Model - Nodal Stress Intensity Distribution



B4.5D-6 REFERENCES

1. TN-DRAWING NO. 3035-3, Rev. 4, Sheet 4.

2. ANSYS Engineering Analysis System User's Manual, Volumes 1 to 4, Revision 5.2.

3. Specification for TN-WHC Cask and Transportation System, WHC-S-0396, Rev. 1,1995

4. TN Calculation No. 3035-4, Rev.1,"TN-WHC Weight and C.G. Calculations.

B5.0 THERMAL EVALUATION

B5.1 INTRODUCTION

The cask is designed to passively reject payload decay heat under normal conditions of transport and hypothetical accident conditions while maintaining appropriate package temperatures and pressures within specified limits. An evaluation of the cask thermal performance is presented in this chapter. Objectives of the thermal analyses performed for this evaluation are:

- Determination of package temperatures with respect to containment system material limits;
- Determination of package component temperature gradients to support calculation of thermal stresses;
- Determination of the cask cavity temperature to support containment pressurization calculations;
- Determination of the maximum MCO temperature.

The package components considered in the thermal evaluation are the cask body, the lid and the MCO. The cask body consists of a cylindrical stainless steel shell which surrounds the MCO. The lid and the bottom are fabricated from stainless steel plate material as described in Part A, Section 1.0. Temperatures calculated for the components in the package support thermal stress calculations and permit selection of appropriate temperature dependent mechanical properties used in the structural analyses. Temperatures are also calculated to demonstrate that specified limits for seal materials are not exceeded.

B5.2 THERMAL SOURCE SPECIFICATION

The thermal source term for the payload within the MCO is defined as a surface heat flux at the inside boundaries of the MCO.

B5.2.1 Normal Conditions of Transport

The range of anticipated heat flux at the inside surfaces of the MCO under normal conditions of transport is defined in the table below. The defined sidewall surface heat flux occurs over the lower 11.5 ft of the MCO.

Payload	Surface Heat Flux At MCO Sidewalls	Surface Heat Flux At MCO Top	Surface Heat Flux at MCO Bottom	Total Power
Maximum	12.7 Watts/ft^2	6.0 W/ft^2	0	950 W
Minimum	0	0	0	0

B5.2.2 Hypothetical Accident Conditions

Due to possible chemical reaction of the spent fuel at elevated temperatures, the maximum surface heat flux will vary during the hypothetical accident conditions from that defined for the normal conditions of transport. This variation in surface heat flux at the inside boundaries of the MCO is defined in the table below. The surface heat fluxes for normal conditions are to be used in establishing the steady-state conditions preceding the hypothetical accident condition.

Payload	Heat Flux at Center 28 in Section of Sidewall	Surface Heat Flux at Remainder of Sidewall	Surface Heat Flux at MCO Top	Surface Heat Flux at MCO Bottom	Total Power
Maximum	30 W/ft^2	12.7 W/ft^2	6.0 W/ft^2	0	1200 W
Minimum	0	0	0	0	0

B5.3 SUMMARY OF THERMAL PROPERTIES OF MATERIALS

The thermal properties of materials used in the thermal analyses are listed below. The values are listed as given in the corresponding references. The analysis uses interpolated values for intermediate temperatures where the temperature dependency of a specific parameter is deemed significant. The interpolation assumes a linear relationship between the reported values.

Thermal radiation at the external surface of the package is considered. The external surfaces of the cask are assumed to have an emissivity of 0.85, a typical value for weathered stainless steel surfaces[1]. For solar absorptivity, a value of 0.5 is used.

a. Helium [(1)]
Used for: Gaps between cask and MCO

Temperature (deg F)	Conductivity (Btu/hr-ft-F)	Density (lb/cu. in)	Heat Capacity (Btu/lb-F)
0	0.078	6.94 E-6	1.24
200	0.097	4.83 E-6	1.24
400	0.115	3.70 E-6	1.24
600	0.129	3.01 E-6	1.24
800	0.138	2.52 E-6	1.24

b. Air [(1)]
Used for: Convection coefficients on cask surface

Temperature (deg F)	Conductivity (Btu/hr-ft-F)	$g\beta\rho^2/\mu^2$ (1/F-cu. ft)	Prandlt No.
100	0.0154	1.76 E6	0.72
200	0.0174	0.85 E6	0.72
---	---	---	---
800	0.0286	49.8 E3	0.697
900	0.0303	36.0 E3	0.705
1000	0.0319	26.5 E3	0.713
1500	0.0400	7.45 E3	0.739

Note that the analyses used air properties in the range of 100°F - 200°F, and 800°F - 1500°F only.

c. Stainless Steel (18Cr - 8Ni)
Used for: MCO shell and cask body

Temperature (deg F)	Conductivity [3] (Btu/hr-ft-F)	Density [1] (lb/cu. in)	Heat Capacity [1] (Btu/lb-F)
70	8.6	0.282	0.110
100	8.7	0.282	0.110
200	9.3	0.282	0.110
300	9.8	0.282	0.110
400	10.4	0.282	0.110
500	10.9	0.282	0.110
600	11.3	0.282	0.110
800	12.2	0.282	0.110
1000	13.2	0.282	0.110
1200	14.0	0.282	0.110

B5.4 THERMAL EVALUATION FOR NORMAL TRANSFER CONDITIONS

B5.4.1 Conditions Evaluated

For conditions normally incident to transport, the thermal analyses evaluated the package design for its ability to maintain component temperatures below the design limits. The operational temperatures will occur in conditions that have been bounded by the environmental conditions provided below:

The ambient temperatures at the Hanford Site for the peak summer month are tabulated in Table B5.4-1.

- Maximum heat generation rate of worst-case source from Section B5.2 plus maximum solar heat load (see Table B5.4-2) plus ambient air temperatures from Table B5.4-1.

- Minimum air temperature of -27 °F plus maximum heat generation rate from worst-case source in Section B5.2.

- Minimum air temperature of -27 °F and zero heat generation rate.

Table B5.4-1 Hanford Air Temperature

Time	Temperature (°F)	Time	Temperature (°F)
12 a.m.	82	2 p.m.	111
2 a.m.	78	4 p.m.	115
4 a.m.	75	6 p.m.	113
6 a.m.	74	8 p.m.	100
8 a.m.	85	10 p.m.	89
10 a.m.	97	12 p.m.	82
12 p.m.	103		

Table B5.4-2 Maximum Solar Radiation Received (Btu/hr-ft^2)

Time	Vertical surfaces facing								Horizontal surface facing up
	N	NE	E	SE	S	SW	W	NW	
4 a.m.	0	0	0	0	0	0	0	0	0
6 a.m.	57	192	211	105	17	17	17	17	64
8 a.m.	35	173	268	208	42	32	32	32	127
10 a.m.	42	56	177	213	126	45	42	42	281
12 noon	45	45	49	120	167	120	49	45	314
2 p.m.	42	42	42	45	126	213	177	56	281
4 p.m.	35	32	32	32	42	208	268	173	127
6 p.m.	57	17	17	17	17	105	211	192	64
8 p.m.	0	0	0	0	0	0	0	0	0

B5.4.2 Acceptance Criteria

Several thermal design criteria have been established for the cask.

- Containment of radioactive material is a major design requirement for the cask. Therefore, seal temperatures must be maintained within specified limits to satisfy the required containment criteria under normal conditions. The operating temperature range recommended by the potential manufacturer (Parker[4]) of the butyl seals is -75°F to 250°F. This range applies to all containment boundary seals used in the cask closure lid and containment penetrations.

- Maximum normal operating outside surface temperature of the cask shall be less than 180°F in maximum air temperature and in the shade.

- Maximum temperatures of containment structural components must not adversely affect the containment function.

- Maximum temperatures of the package must not adversely affect the shielding function.

- The maximum MCO shell temperature allowed under normal conditions of transport shall be 167°F.

In general, all the thermal criteria are associated with maximum temperatures. The ability of the containment system structural materials to function properly under the lowest service temperature conditions is discussed in Section 4.3.

B5.4.3 Thermal Model

A two-dimensional axisymmetric finite element computer model of the TN-WHC cask and payload (MCO) was used to model the thermal performance of the cask. The ANSYS computer program[5] was utilized for the analyses. This program is a large scale, general purpose finite element code which can perform steady-state and transient thermal analyses using linear and non-linear material properties.

The thermal model represents the TN-WHC cask standing vertically. The model includes the cask and the MCO shell. The interior region of the MCO is not modeled, as per reference 2. The areas between the MCO and the cask were modeled with helium, which is the assumed fill gas. Heat transfer between the MCO and the cask was conservatively assumed to be via gaseous conduction only. The MCO is assumed to be centered in the cask. Figure B5.4.3-1 shows the thermal model.

The bottom of the cask does not receive any heat from the sun and it is in good thermal contact with the transporter when it is being transported. From the perspective of heat transfer, the transporter will behave like a fin, which will allow the cask to conduct heat through its bottom and into the environment. The magnitude of this effect is difficult to quantify, as it depends on the emissivity and absorptivity of the transporter coatings, the materials, and the geometry of the transporter. Therefore, the analysis conservatively assumed that the bottom of the cask was an adiabatic surface.

The ANSYS axisymmetric thermal solid element, PLANE55, was used to model the MCO, the cask, and the helium between the two. At the surface of the cask, two dimensional surface effect elements, SURF19, were overlaid on the mesh. The solar radiation data given in Table B5.4-2 was applied to these elements, after accounting for the solar absorptivity of the cask surface. The data for the vertical surfaces was averaged circumferentially so that it could be applied to the axisymmetric model.

The decay heat of the MCO contents was simulated by applying an elemental heat flux on the inside of the sidewalls and top of the MCO of 12.7 W/ft^2 and 6.0 W/ft^2, respectively, as per section B5.2.1.

The cask rejects heat passively through its outer surfaces. This was simulated by applying a convection load directly on the outer face of the PLANE55 elements on the surface of the cask. A effective heat transfer coefficient for the convection load was determined for each of the twelve time ranges given in Table B5.4-1. The effective heat transfer coefficient, h_{eff}, depends on natural convection and radiation at the cask surface, and varies with the ambient temperature, T_{amb}, the surface temperature, T_s, and the properties of air, which are evaluated at the average temperature, $(T_s + T_{amb})/2$. An environmental view factor of 1.0 and an environmental emissivity of 1.0 are assumed. The relationship is given below:

$$h_{eff} = h_{conv} + h_{rad}$$

$$h_{conv} = C_1 \; k \; [\; Pr \; (T_s - T_{amb}) \; (g\beta\rho^2/\mu^2)]^{1/3}$$

$$h_{rad} = \sigma_b \; e \; [\; T_s^4 - T_{amb}^4 \;] \; / \; (T_s - T_{amb}) \qquad \text{(with T in °R)}$$

where, C_1 = 0.130 for vertical cylindrical surfaces[1], and
0.156 for horizontal surfaces facing up[1]
e = 0.85 for weathered stainless steel[1]

B5.4.4 Thermal Analysis

A transient analysis was performed to account for the time varying nature of the solar heat load. The model was solved in steady-state mode with 8 AM ambient temperature and insolation data to generate the initial conditions for the transient analysis. The 8 AM conditions were chosen as a good approximation of the average ambient temperature and insolation that the cask experiences. The transient run began with midnight ambient temperature and insolation data and stepped changed the ambient temperature and insolation data every two hours for two full cycles (48 hours).

Figure B5.4.4-1 shows the temperature history across the cask (radially) at the hottest MCO node and the outer surface of the cask at this axial location. This location is approximately centered between the cask lid and bottom. Comparison of the temperatures of the model at N hours and N+24 hours shows very little change, which demonstrates that the initial conditions for the transient analysis were appropriately chosen. Note that there is a phase lag between the two curves, which is due to the thermal inertia of the system.

Figure B5.4.4-2 shows the temperature distribution of the MCO and cask at the time that the maximum temperature of the MCO is reached. This occurs at 9:17 PM. Referring to Figure B5.4.4-1, the maximum cask temperature at the same axial location occurs at 8 PM. This is consistent with the behavior expected based on an examination of the ambient temperature and insolation data of Tables B5.4-1 and B5.4-2. The difference in time between the peak MCO temperature and the peak adjacent cask surface temperature is due to the thermal inertia of the system, as noted above.

Figure B5.4.4-3 shows the temperature distribution of the cask at the time that the maximum temperature of the cask is reached. This occurs at 2:00 PM, when solar insolation on the top of the cask has been at its maximum value for two hours (from noon to 2 PM).

B5.4.4.1 Internal Temperatures

The maximum MCO temperature under normal conditions of transport is 155°F. This is less than the design limit of 167°F. The minimum temperature is -27°F.

The maximum cask temperature under normal conditions of transport is 140°F. This is less than the seal temperature limit of 250°F. The minimum temperature is -27°F, which above the minimum seal temperature of -75°F. The containment and shielding functions of the stainless steel cask and the seals are not compromised at the temperature range calculated.

B5.4.4.2 Maximum Surface Temperatures

The normal conditions of transport maximum surface temperature is 140°F. This is less than the temperature limit of 180°F.

B5.5 THERMAL EVALUATION FOR ACCIDENT CONDITIONS

B5.5.1 Conditions Evaluated

The hypothetical fire accident condition is defined as the exposure of the cask for 30 minutes to a 1475°F fire that has an emissivity coefficient of 0.9. The surface absorptivity of the package is the greater of the anticipated absorptivity or 0.8. The surface convective heat transfer for the package is assumed to be natural convection. The decay heat of the MCO during the thermal accident is defined in section B5.2.2. The package is actively cooled following the 30 minutes fire. The active cooling consists of quenching the outer package surfaces using a water spray from a fire hose. The quenching water flows at 125 gallons per minute for 45 minutes, followed by a flow rate of 50 gpm for an additional 100 minutes. The temperature of the quenching water is 85°F. Thereafter normal conditions are assumed to prevail.

B5.5.2 Acceptance Criteria

The following acceptance criteria have been established:

- The MCO shell temperature may exceed the temperature limit for the normal conditions of transport for a time period not to exceed 180 minutes following the fire.
- The maximum MCO shell temperature should not be significantly above 252°F to minimize gas generation.
- There is no requirement that the cask maintain containment of the MCO during the thermal accident. This means that the cask seals may exceed their operational temperature limits during the thermal accident. However, the cask must maintain confinement of the MCO within the cask at all times.

B5.5.3 Thermal Model

The thermal model that was developed for the normal conditions of transport was reused with a single modification; the SURF 19 elements on the outer surface of the cask were removed because there are no solar insolation loads during the thermal accident. The analysis assumed that the bottom of the cask was adiabatic during the establishment of the initial conditions, the fire, and the quench.

During the establishment of the initial conditions, the decay heat of the MCO contents is represented as the normal conditions of transport decay heat flux. During and after the 30 minute fire, the decay heat of the MCO contents was simulated by applying an elemental heat flux of 30 W/ft^2 on the center 28" section of the MCO sidewall, 12.7 W/ft^2 on the remainder of the sidewall, and 6.0 W/ft^2 on the top of the MCO.

During establishment of the initial conditions, the cask rejects heat passively through its outer surfaces. This was simulated by applying a convection load directly on the outer face of the PLANE55 elements on the surface of the cask. A effective heat transfer coefficient for the convection load was determined for an ambient temperature of 115°F. The effective heat transfer coefficient, h_{eff}, depends on natural convection and radiation at the cask surface, and varies with the surface temperature, T_s, and the properties of air, which are evaluated at the average temperature, $(T_s + T_{amb})/2$. An environmental view factor of 1.0 and an environmental emissivity of 1.0 are assumed. The relationships are as given in B5.4.3, with T_{amb} = 115°F = 575°R.

During the 30 minute fire, heat transfer between the cask and the environment is a combination of natural convection and radiation. The absorptivity of the cask for radiation from a 1475°F fire is taken to be 0.8. The natural convection relationship is the same as that given in B5.4.3. The radiative heat transfer coefficient is given below:

$$h_{rad} = \sigma_b e_c [T_s^4 - e_f (1475°R)^4] / (T_s - 1475°R) \quad \text{(with } T_s \text{ in °R)}$$

where, $e_c = 0.8$
$e_f = 0.9$

The post-fire active cooling, or quench, was modeled as a convection load on the surface of the cask. The analysis assumed an effective heat transfer coefficient of 50 Btu/hr-ft^2-°F at 85°F, increasing linearly with temperature to 2000 Btu/hr-ft^2-°F at 212°F, and constant at 2000 Btu/hr-ft^2-°F for temperatures greater than 212°F[(1)].

B5.5.4 Thermal Analysis

A transient analysis was performed to account for the time varying nature of the loading. The package was assumed to be initially at steady state using the maximum ambient temperature of 115°F, the normal conditions of transport decay heat rates as defined in Section B5.2.2, and no solar insolation. The solution to the model with these loading conditions formed the initial conditions for the accident condition analysis.

The accident conditions MCO decay heat loading together with the 1475°F fire's effective heat transfer coefficient was imposed on the model for 30 minutes. This was followed by the accident conditions MCO decay heat loading combined with the active cooling heat transfer coefficient for 145 minutes.

Figure B5.5.4-1 shows thermal model, depicting the cross-sectional locations that appear in the following two figures. Figure B5.5.4-2 shows the temperature history of a cross-section of the model at the location that the MCO reaches its maximum temperature. Figure B5.5.4-3 shows the temperature history of the top corner cross-section. The maximum cask temperature lies along this cross-section.

Figure B5.5.4-4 shows the temperature distribution of the MCO and cask at time zero. This is the starting point for the transient analysis.

Figure B5.5.4-5 shows the temperature distribution of the MCO and cask at the end of the fire. The helium has been removed from the plot for clarity. The maximum cask temperature occurs at this time.

Figure B5.5.4-6 shows the temperature distribution of the MCO and cask at the time that the maximum temperature of the MCO is reached. Again, the helium has been removed for clarity. This occurs approximately 54 minutes after the end of the fire.

B5.5.5.1 Internal Temperatures

The maximum MCO temperature during the accident conditions is 256°F and is within the temperature range of 250°F to 260°F.

During accident conditions (start of fire to end of water quench), the maximum MCO shell temperature exceeds the 167°F normal temperature limit for less than 180 minutes, and meets the acceptance criteria.

B5.5.5.2 Maximum Surface Temperatures

The maximum cask surface temperature occurs at the end of the fire. The cask reaches a temperature of 1068°F in the upper corner - see Figure B5.5.4-5. The cask maintains confinement of the MCO at these temperatures, thereby meeting the design requirements with regards to confinement.

B5.6 THERMAL EVALUATION AND CONCLUSIONS

The thermal evaluation for normal conditions of transport concludes that the TN-WHC design meets all the applicable requirements. The maximum temperatures calculated using conservative assumptions are relatively low (140°F). The minimum temperature is -27°F. This temperature range has no adverse effect on the performance of the cask components (including seals). During accident conditions, the temperatures calculated in the cask components will not compromise the structural integrity of the cask. The cask will continue to maintain its confinement function. The MCO temperatures remain below 260°F during fire accident conditions.

Figure B5.4.3-1 Normal Conditions Thermal Model

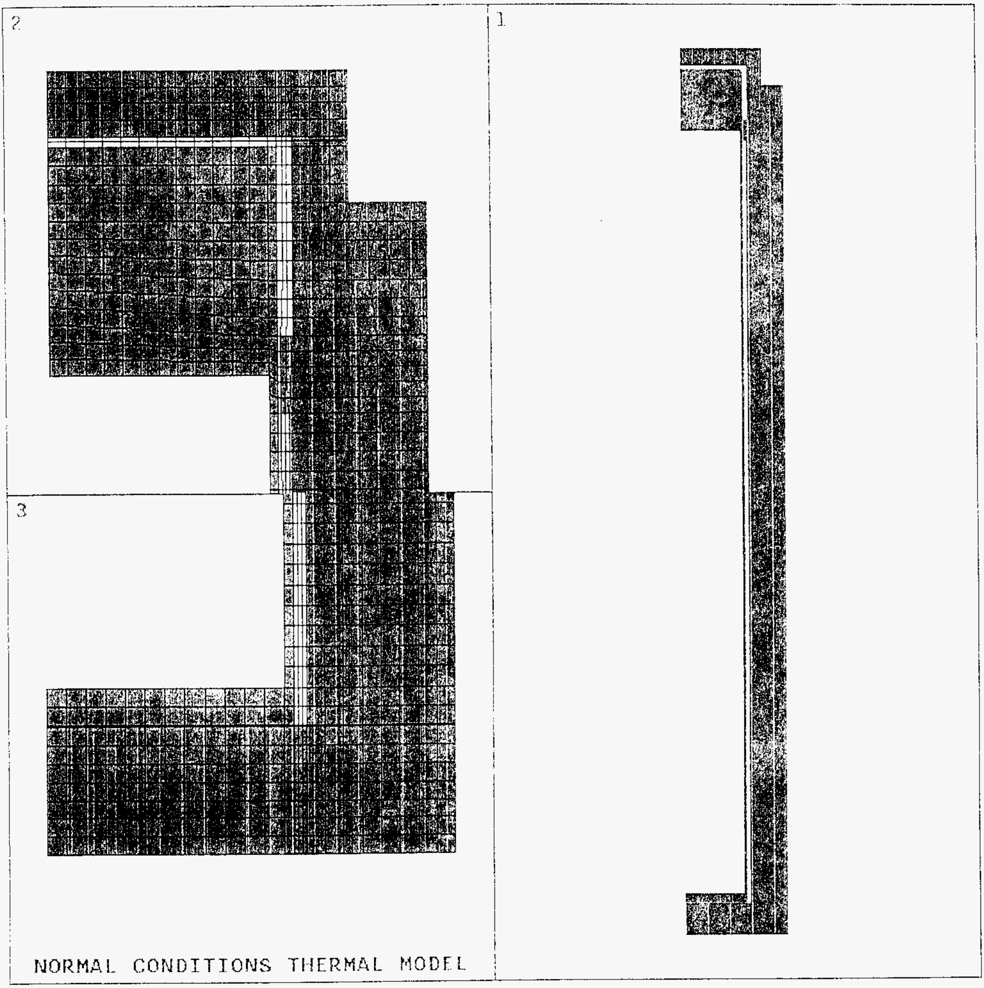


Figure B5.4.4-1 Normal Conditions Temperature History at Hottest MCO location

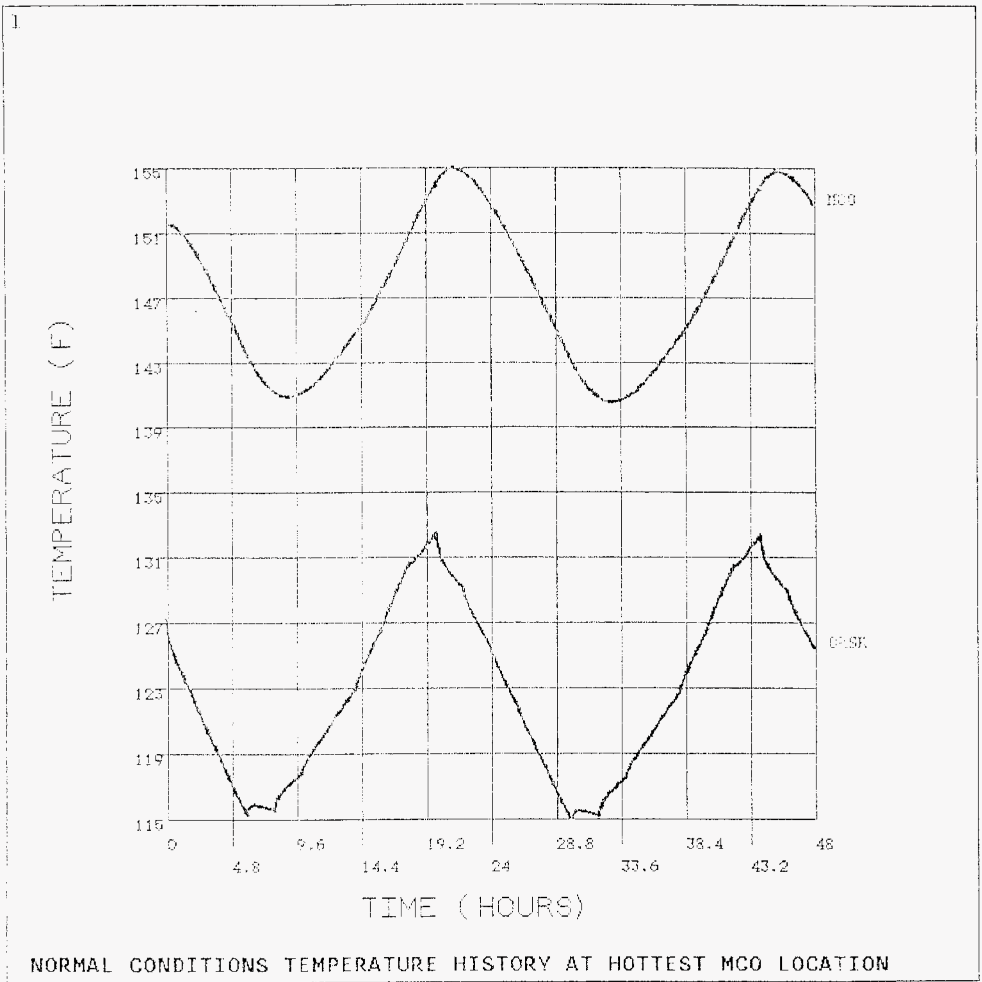
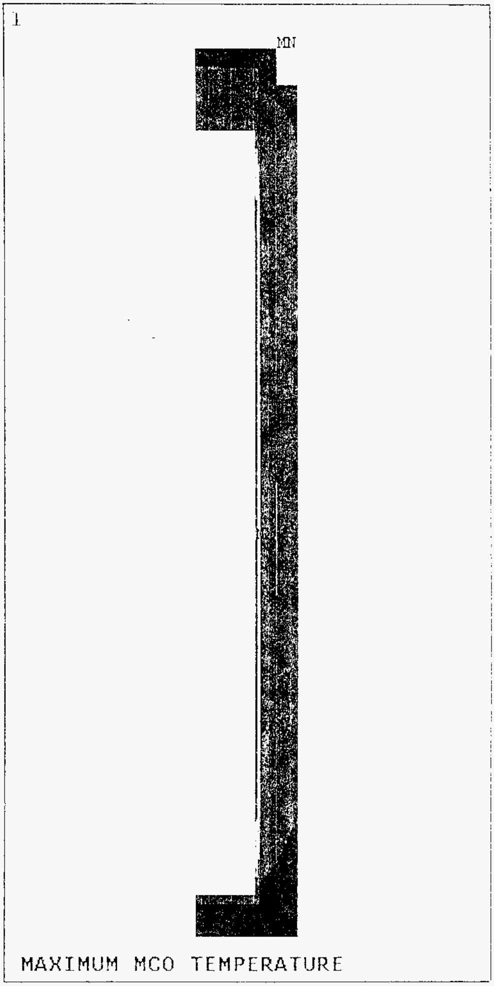


Figure B5.4.4-2 Normal Conditions MCO and Cask Temp. Distribution - Maximum MCO Temperature



ANSYS 5.2
OCT 30 1996
10:37:53
NODAL SOLUTION
TIME=21.287
TEMP
SMN =124.924
SMX =154.931

124.924
128.258
131.592
134.926
138.26
141.595
144.929
148.263
151.597
154.931

Figure B5.4.4-3 Normal Conditions Cask Temperature Distribution - Maximum Cask Temperature

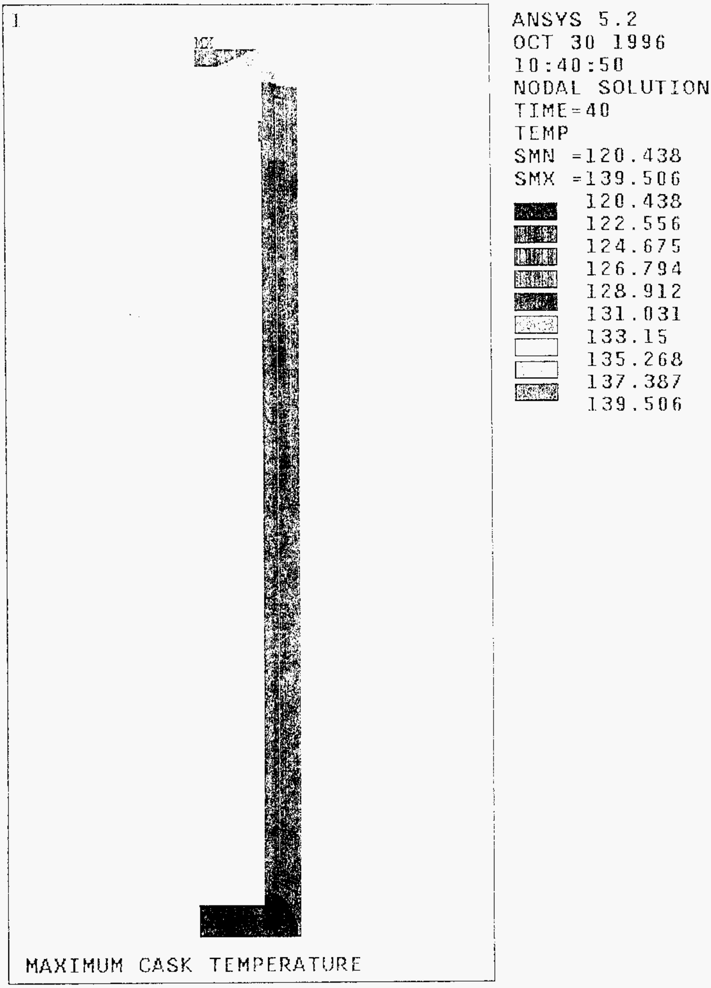


Figure B5.5.4-1 Accident Conditions Thermal Model

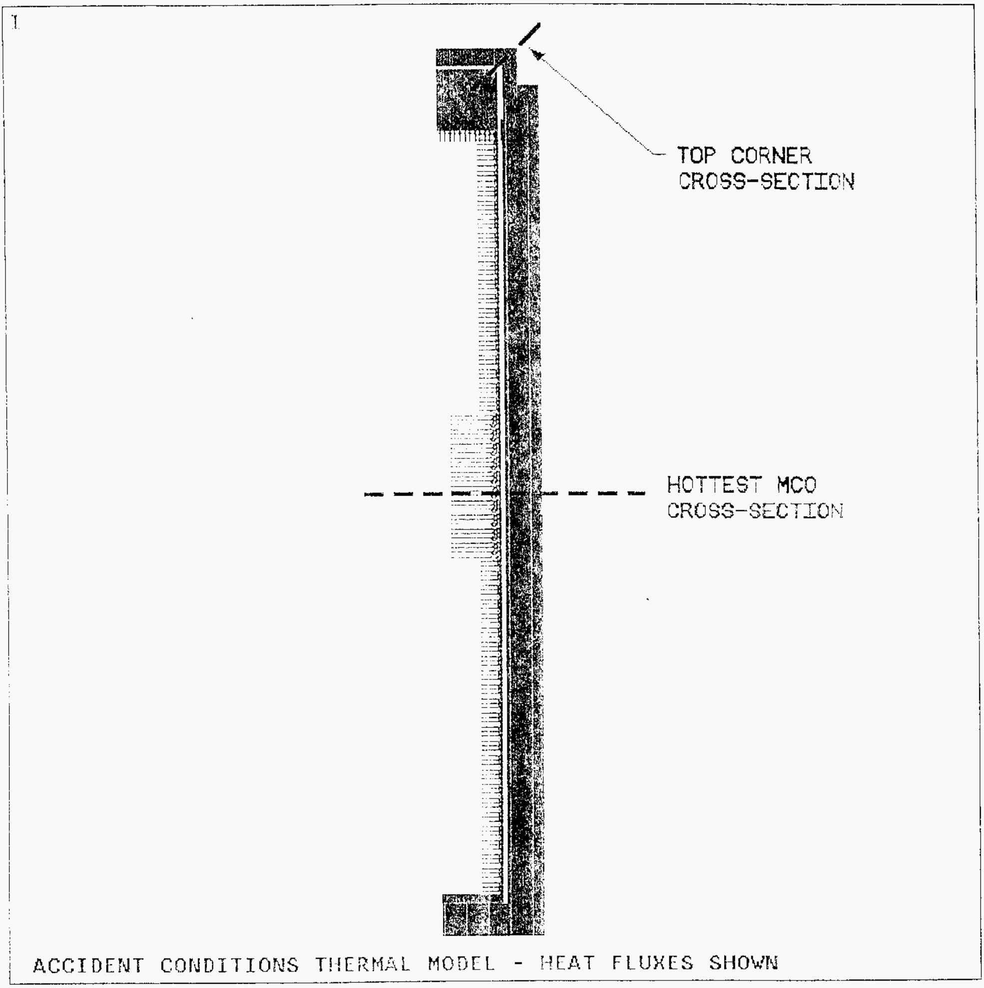
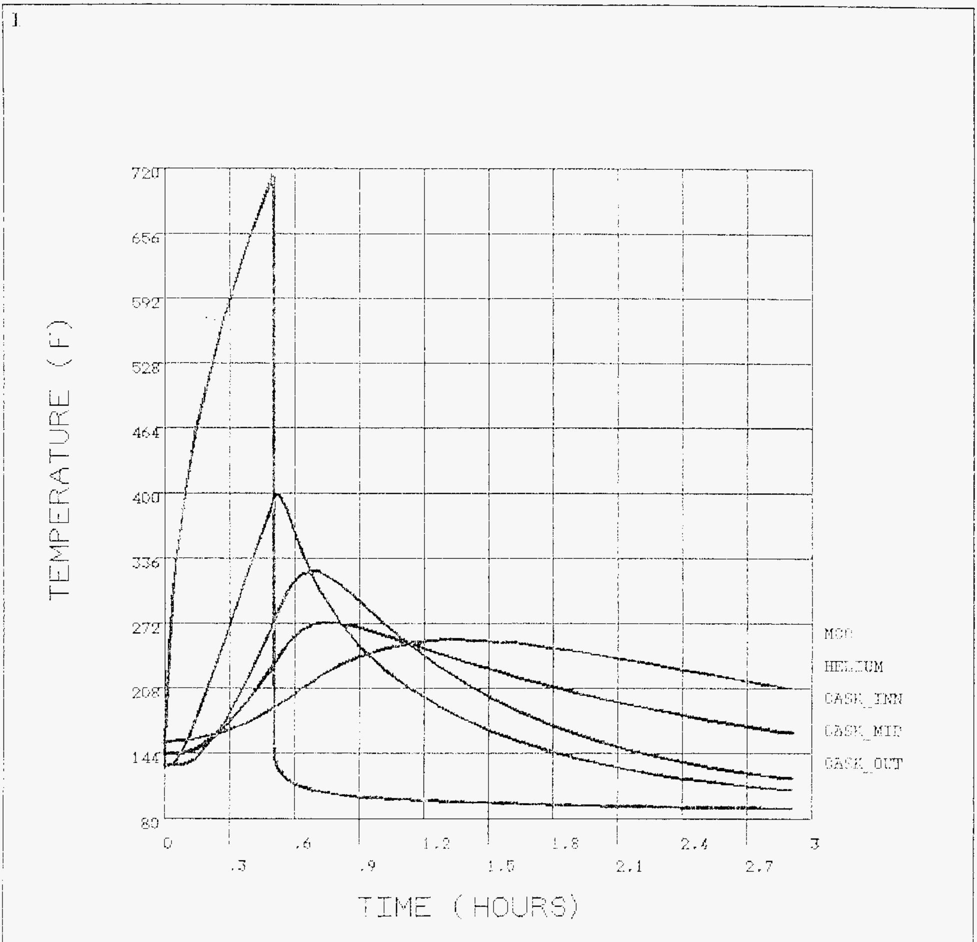
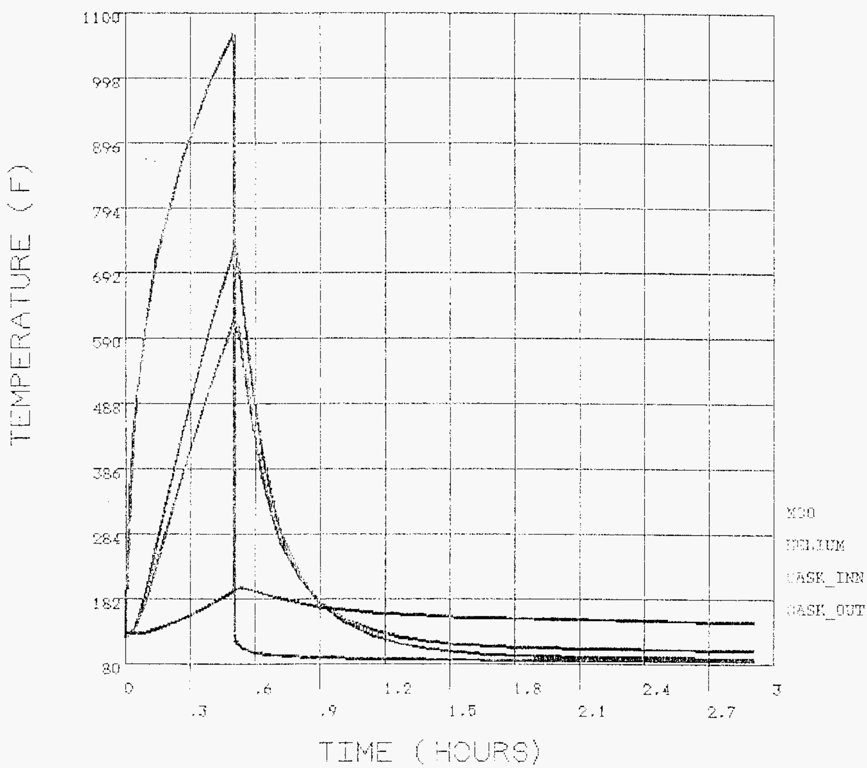


Figure B5.5.4-2 Accident Conditions Temperature History at Hottest MCO Location



ACCIDENT CONDITIONS TEMPERATURE HISTORY AT HOTTEST MCO LOCATION

Figure B5.5.4-3 Accident Conditions Temperature History at Top Corner (Hottest Cask)



ACCIDENT CONDITIONS TEMPERATURE HISTORY AT TOP CORNER (HOTTEST CASK)

Figure B5.5.4-4 Accident Conditions MCO and Cask Temp. Distribution - Initial Conditions

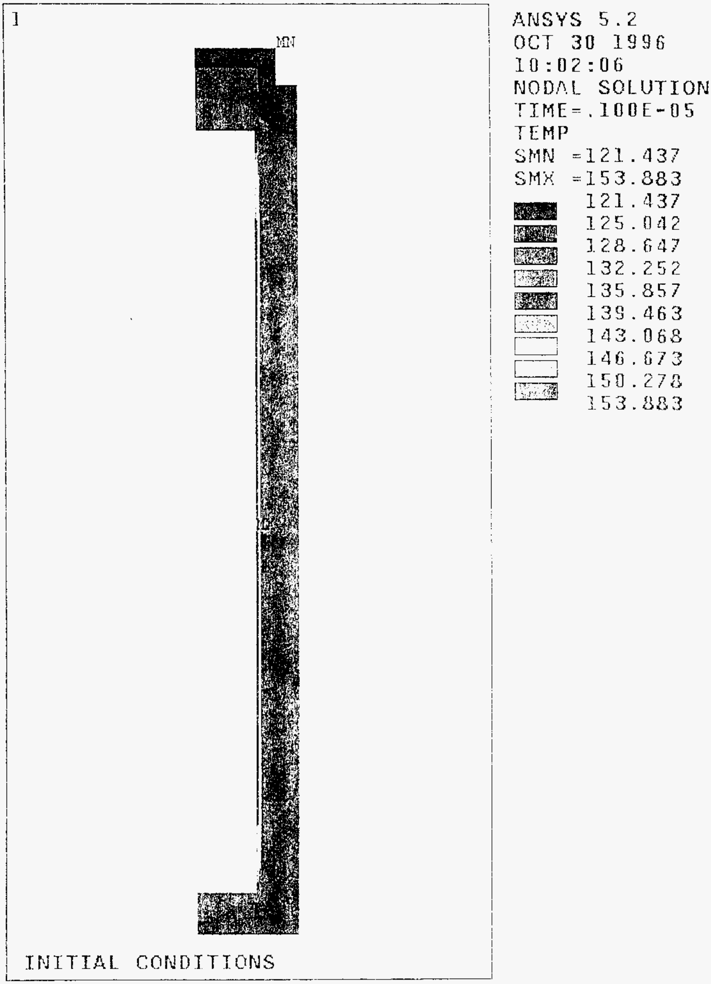


Figure B5.5.4-5 Accident Conditions MCO and Cask Temp. Distribution - End of Fire

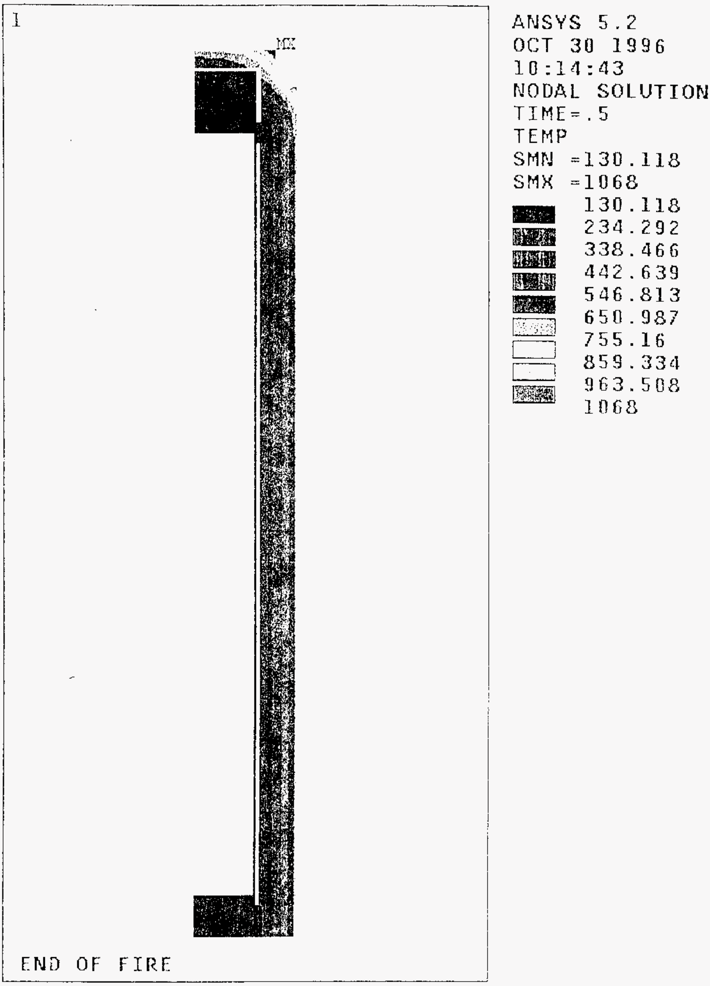
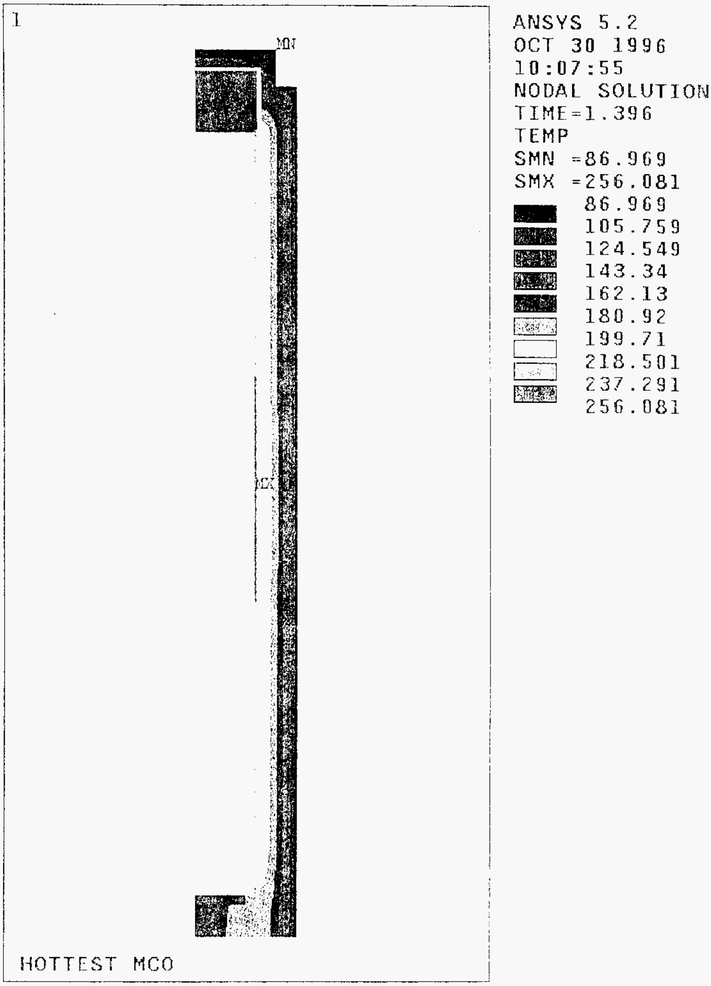


Figure B5.5.4-6 Accident Conditions MCO and Cask Temp. Distribution - Hottest MCO



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1. Kreith, et. al., Principles of Heat Transfer, 3rd Edition, Harper and Row Publishers, 1973.

2. Performance Specification For TN-WHC Cask And Transportation System, WHC-S-0396, Rev. 1, September 1995, and WHC ECN 191402 dated May 22, 1996.

3. ASME Boiler and Pressure Vessel Code, Section III, Appendices, 1992 Ed.

4. Parker O-Ring Handbook, ORD 5700, Parker Seal Group, KY, 1992.

5. Ansys Engineering Analysis System, User's Manuals for ANSYS Rev. 5.2, Ansys, Inc., Houston, PA, 1995.

B6.0 PRESSURE AND GAS GENERATION EVALUATION

B6.1 GAS GENERATION

To be provided by DESH.

B6.2 PACKAGE PRESSURE

The maximum internal working pressure for the cask is 150 psig (1033 kPa) as required by the WHC Specification. The stress due to this pressure is evaluated in Section B4.0.

B6.3 APPENDIX

B7.0 PACKAGE TIEDOWN SYSTEM EVALUATION

B7.1 SYSTEM DESIGN

The basic components of the system are:

- Frames and Beams
- Cask Tiedown Device
- Cask Hold Down Device
- Cask Support Device

The eight frames, two cross beams and two support braces (including the weld attachments of the vertical support frames to the support pads of the trailer) are the major components of the tiedown system. The loads from the cask are transmitted by the frames to the trailer. The cask tiedown device consists of two rotating flanges, six tiedown bolts, and two hold down pins. The cask support device consists of one cylindrical cup, bottom plate, and fourteen (14) attachment bolts. A detailed design drawing for the cask tiedown system is provided in Section A9.1.

The cask is supported by the support device (cylindrical cup) at the bottom and secured by the tiedown device (two rotating flanges) at the top. The two rotating flanges can be opened and closed (by removing the six tiedown bolts and rotated from the hold down pins) for loading and unloading the cask. Figure B7.1-1 shows the opened and closed positions of the rotating flanges of the cask tiedown device. The cask is transported in the vertical orientation with the lid end facing up.

B7.2 ATTACHMENTS AND RATINGS

B7.2.1 Design Load Factors

The tiedown system is used to secure the cask to the trailer during transportation, and is designed to meet the requirements of Hanford Specification[1]. The tiedown systems is capable of resisting the forces for road, as described below:

Table B7.2-1 Load Factors for Tiedown Systems

Mode	Longitudinal	Lateral	Vertical
Road	±2G	± 1G*	3G down, 2G up

* A lateral load factor 1.5G is used for stress calculation of the tiedown system, reference to Appendix B7.3 for detailed loading information.

B7.2.2 Design Weight

The loading condition used for designing the tiedown system includes the total weight of the loaded cask, 60000 lbs, and weight of tiedown system, 5000 lbs, for a total design weight of 65000 lbs.

B7.2.3 Design Loadings

In the transport configuration (Figure B7.2-1), the tiedown loads from the cask are transmitted through the cask hold down devices and the cask surfaces in contact with the tiedown system, to the tiedown system. As described above, the total loading used for designing the tiedown system is 65,000 lbs. The 2G vertical load is shared by the four cask hold down devices and transmitted to the cask tiedown device as shown on Figure B7.2-2. The 3G vertical down load is supported by the cask support device which is directly welded to the trailer main beams. Figure B7.2-3 shows this loading condition. The 1.5G load component which is transverse to the direction of travel is shared between the cask tiedown device and cask support device as shown on Figure B7.2-4. The 2G load component applied in the direction of travel is also shared between the cask tiedown device and cask support device as shown on Figures B7.2-5 and B7.2-6. Figure B7.2-7 shows 1G static load with deflection.

B7.2.4 Summary and Conclusions

Detailed stress analysis of the tiedown system is presented in Appendix B7.3. A summary of critical stresses is presented in Table B7.2-2 and stresses are compared with the allowables. All the allowables are based on ASME Code, Section III, Subsection NF (NF-3322). All the stresses are within the allowables. The interaction between compression and bending are evaluated using Equations 20 and 21 of NF-3322, and interaction between tension and bending are using Equation 21 of NF-3322. Table B7.2-3 shows the results of this calculation. Based on the results of the analysis , it is concluded that the tiedown system is structurally safe for the specified loads.

Table B7.2-2 Summary of Tiedown System Stress Evaluation

Component	Max. Calculated Stress (psi)	Allowable Stress (psi)
Frame- Legs	Max. Direct = 5,073 (Compression) Max. Bending =14,477	26,400 29,040
Cross Beam	Max. Direct = 828 (Tension) Max. Bending = 15,852	26,400 29,040
Welds at Bottom Leg	Max. Tension = 19,224 Max. Shear = 5,707	26,400 17,600
Tiedown device- Clamp	Max. Direct = 2,446 (Tension) Max. Bending = 20,513	23,400 25,740
Bolt	Max. Shear = 23,460 Max. Tension = 36,700	40,400 60,600
Cask Hold Down Device -Arm	Max. Tension = 11,430 Max. Bending = 43,200 Max. Shear = 11,933	43,960 64,480 39,080
-Pin-1.5"Dia.	Max. Bending = 18,420 Max. Shear = 8,490	66,660 40,400
-Bracket	Bearing = 16,000 Tensile = 6000 Shear = 4,570	39,000 17,550 15,600
Cask Support Device -Plate	Max. Bending=18,429	19,400
- Bolt	Max. Shear = 34,560	40,400

Table B7.2-3
Interaction Equation Evaluations

Component	Max. Axial Compression and Bending (NF-3322.1, Equation 20 & 21)	Max. Axial Tension and Bending (NF-3322.1, Equation 21)
Frame Leg	0.522	0.65
Tiedown Clamp		0.902
Hold Down Arm		0.807

Figure B7.1-1 TN-WHC Cask Tiedown System - Opened and Closed Positions

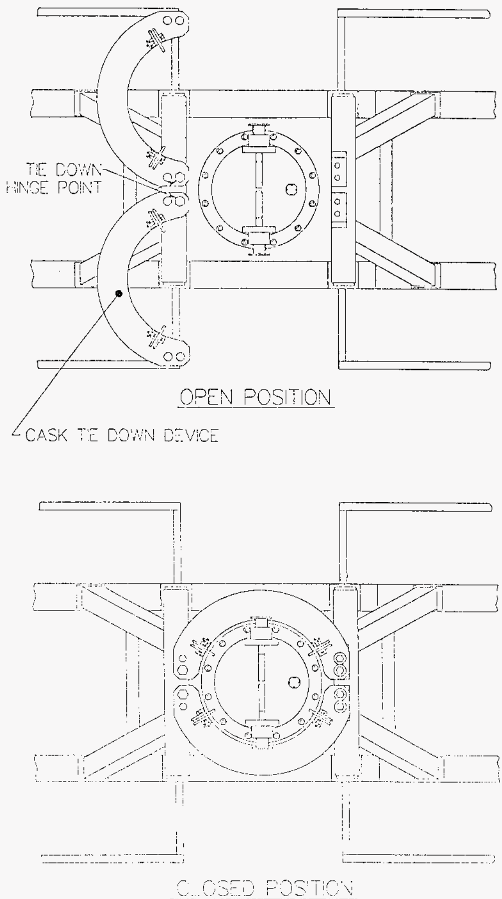
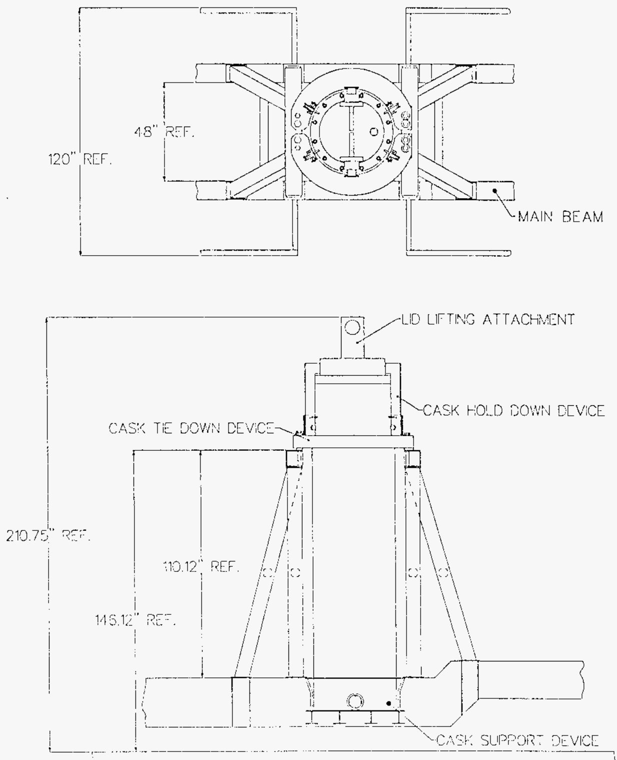


Figure B7.2-1 TN-WHC Cask Transport Configuration



E-15166

Figure B7.2-2 Tiedown Loading Condition - 2G Vertical Up

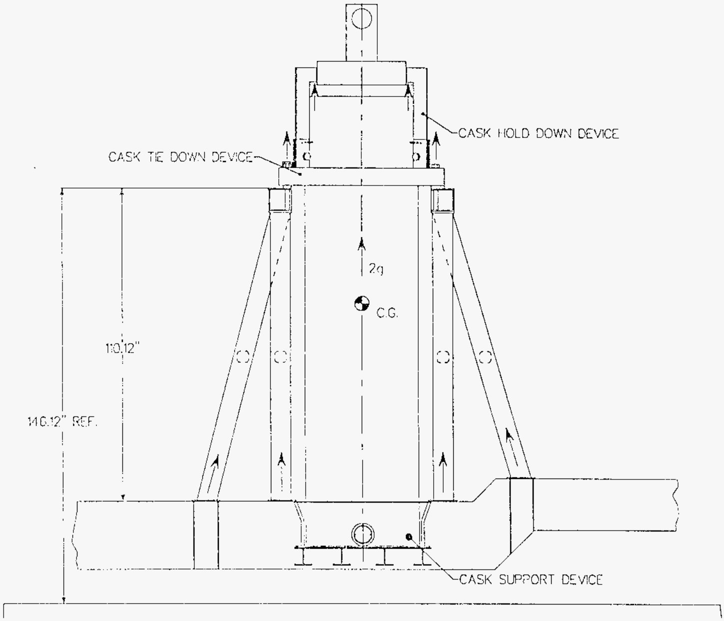


Figure B7.2-3 Tiedown Loading Condition - 3G Down

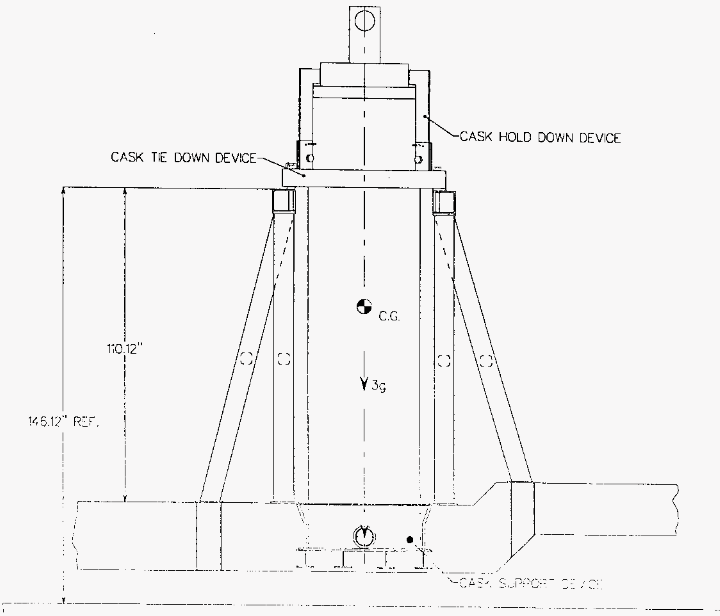


Figure B7.2-4 Tiedown Loading Condition - 1.5G Lateral

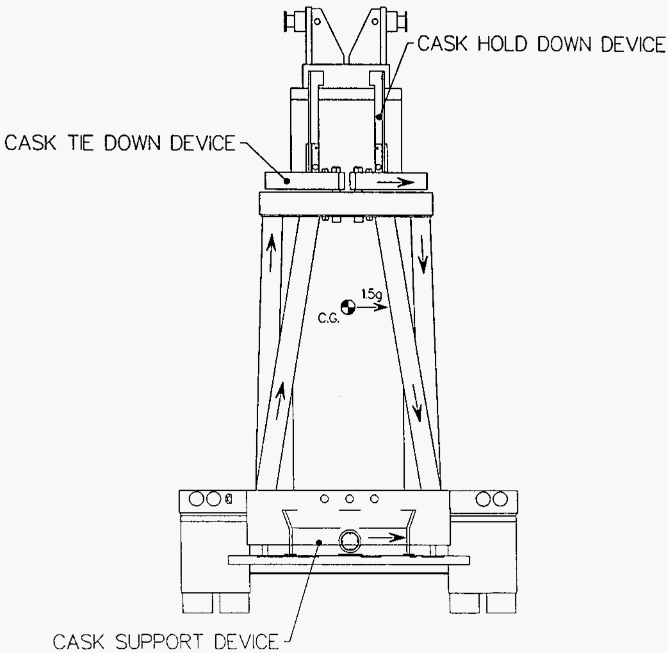


Figure B7.2-5 Tiedown Loading Condition - 2G Longitudinal (fore)

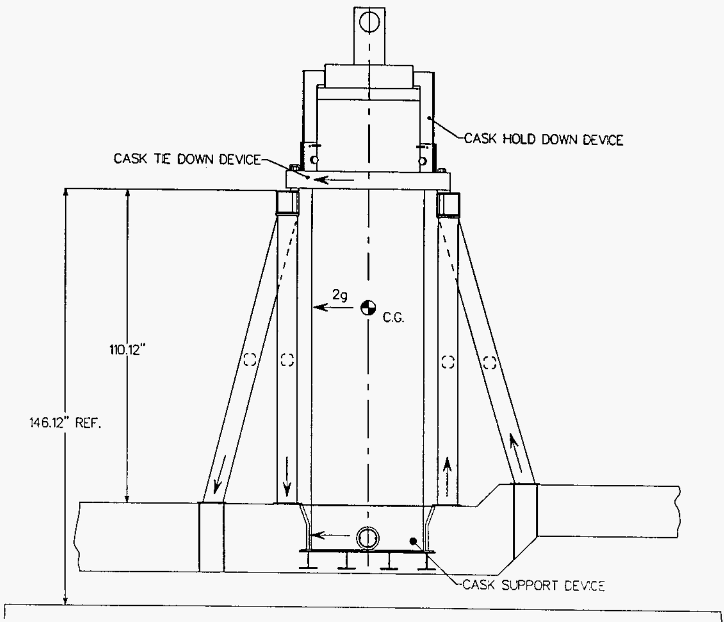


Figure B7.2-6 Tiedown Loading Condition - 2G Longitudinal (aft)

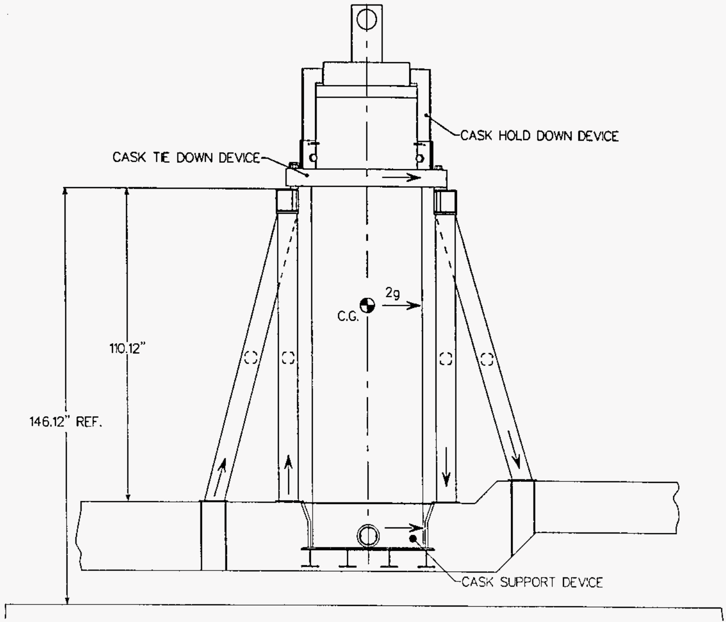
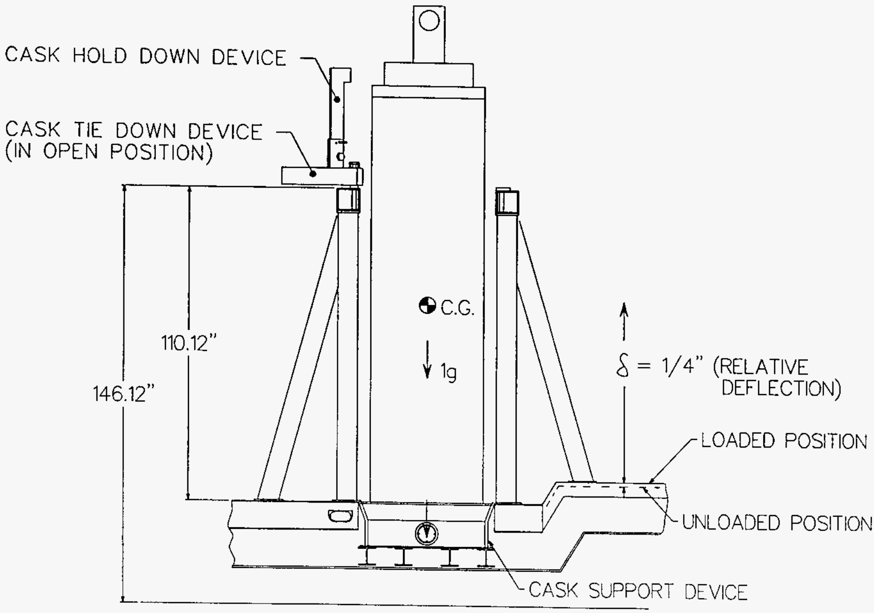


Figure B7.2-7 Tiedown Loading Condition - 1G Static Deflection



References For Section B7.0

1. Performance Specification For TN-WHC Cask And Transportation System, WHC-S-0396, Rev. 1, September 1995.

APPENDIX B7.3

CASK TIEDOWN SYSTEM

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APPENDIX B7.3

CASK TIEDOWN SYSTEM

B7.3-1 INTRODUCTION

The purpose of the tiedown system is to restrain the cask during transportation by road. The tiedown attachments have to resist the forces from the road transportation as described in Hanford Specification(1). The detailed tiedown system design is given in Drawing No. H-1-81539, Sheets 1 to 3 and its operation is described in Section B7.0 of this report. This appendix presents the structural analysis of the tiedown system design for the prescribed loadings. The analysis of the tiedown system components is conducted using a combination of computer finite element techniques and hand-calculations. The terminology of the components, as used in this analysis, is shown in Figure B7.3-1.

B7.3-2 MECHANICAL PROPERTIES OF MATERIALS

The mechanical properties of structural materials used in the tiedown system components are shown on Table B7.3-1. The effect of an elevated temperature of 150° F on yield strength is also shown on Table B7.3-1. The yield and ultimate strengths of the structural steels shown on Table B7.3-1 are the minimum values specified in the material specifications. A modulus of 29×10^6 psi for steel and 10×10^6 psi for aluminum is used in the analyses.

B7.3-3 WEIGHT AND CENTER-OF-GRAVITY

The approximate weight of each tiedown system major component is given on Table B7.3-2. The estimated weight of entire tiedown system is about 5000 lbs. The center of gravity of the loaded cask on the trailer is approximately 104.27" above the ground.

B7.3-4 LOADING

The tiedown system is used to secure the cask to the trailer against the transportation loads. These loads are summarized in Table B7.3-3. The stress analysis of tiedown system components is conducted based on these loadings.

It may be also pointed out that each structural component of the tiedown system is not substantially effected by each load in Table B7.3-3. Stress analyses are conducted only for the loadings from this table which are applicable to that component.

Figure B7.3-1
Tiedown System Components

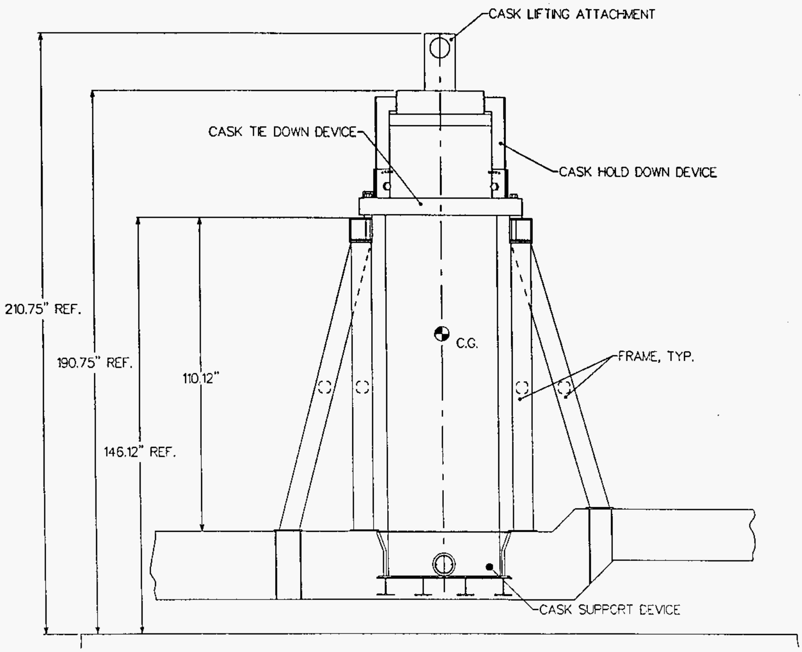


Table B7.3-1
Material Properties of The Tiedown System

Component	Material	Properties @ 70^0F (ksi)	Properties @ 150^0F (ksi)
Frames	A500 Gr.B	$S_y = 46$ $S_u = 58$	$S_y = 44$
Cross Beam	A500 Gr.B	$S_y = 46$ $S_u = 58$	$S_y = 44$
Tie Down Device - Clamp (0.31" plate)	B209-6061T6 Aluminum	$S_y = 40$ $S_u = 45$	$S_y = 39$
Hold Down Device (0.75"plate)	A-514 Gr.B (T1, Type A)	$S_y = 100$ $S_u = 110$	$S_y = 97.7$
Support Device (0.75" plate)	6063-T6 Aluminum	$S_y = 31$ $S_u = 35$	$S_y = 29.4$
Bolts for Support Device	A-193-B7	$S_y = 105$ $S_u = 125$	$S_y = 101$
Pins	A-479 XM19 Hot Rolled Stainless Steel	$S_y = 105$ $S_u = 135$	$S_y = 101$
Bolts for Tiedown device	A-479 XM19 Hot Rolled Stainless Steel	$S_y = 105$ $S_u = 135$	$S_y = 101$

Table B7.3-2
Estimated Weight of The Tiedown System Components

Component	Estimated Weight - lbs.
Frames (8) TS 7"x 7"x 0.5"	2,986
Stiffening Braces (4) TS 4"x 4"x 0.5"	351
Cross Beams (2) -TS 8"x 8"x 0.625" -Plates 61"x 8"x 0.625"	789
Tie Down Device - Clamps (2) - Brackets (8)	175
Hold Down Device - Arms (4)	174
Support t Device (1)	388
Bolts, Pins	120
Total Estimated Weight	4983 (≈5000)

Table B7.3-3
Load Factor for Tiedown System

Case	Load Condition	Longitudinal	Lateral	Vertical
A	Tiedown System	2 G	1 G	3 G down 2 G up
B	Trailer	2 G fore 1.5 G aft	1.5 G	2.5 G down 2.0 G up
C	Design Load Factors for Tiedown System	2 G fore 2 G aft	1.5 G	3 G down 2 G up

B7.3-5 ANALYSIS

The tiedown system has been analyzed by using a combination of computer finite element and hand-calculation methods. For the purpose of structural analyses, the tiedown system is divided in the following main components (see Figure B7.3-1):

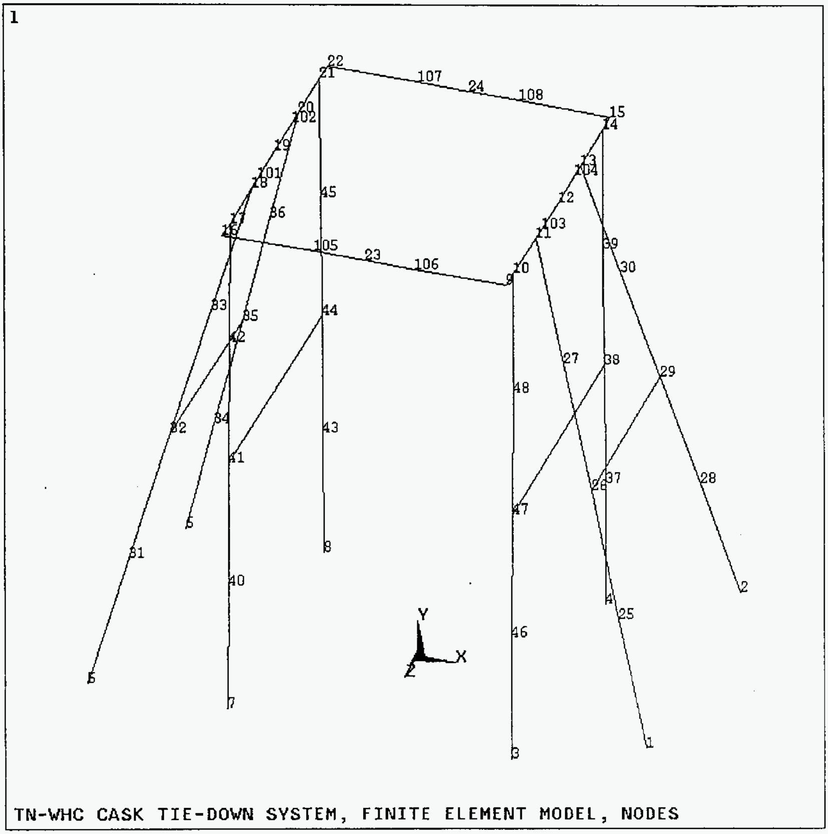
Frame and Cross Beams
Cask Tie down Device
Cask Hold down Device
Cask Support Device

The method of analysis, critical loads, boundary condition and results of analysis of each component are described below:

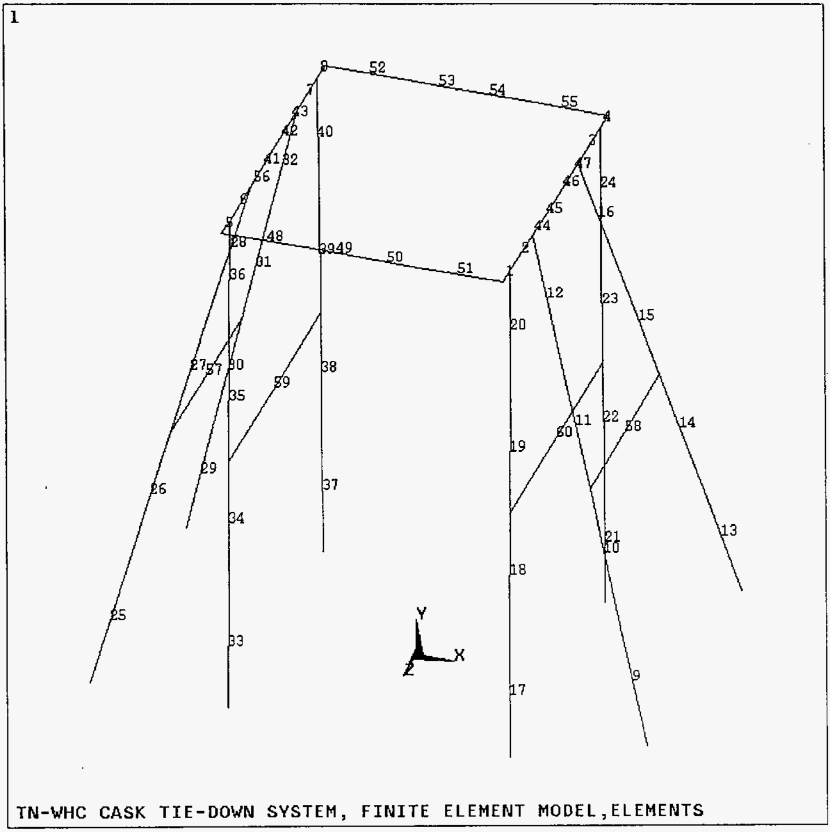
a) Frame and Cross Beams

This component was analyzed by using ANSYS Finite Element Computer Code [(2)]. The finite element model of frames, cross beams and stiffening braces is presented in Figures B7.3-2 (finite element nodes) and B7.3-3 (finite element elements). 3-dimensional beam finite element (BEAM4) was used in the construction of the model. The beam real constants are shown in Figure B7.3-4. It may be pointed out that the cask tiedown device clamp in this frame model was simulated by the beam elements. The beam real constants are given in Table B7.3-4. The analyses were conducted for the load case C of Table B7.3-3. The G loads in this table were converted to forces at C.G. by multiplying the load factor with cask weight of 60,000 lbs. These forces at C.G. were transferred to the appropriate model nodes. The inertia forces due to the frame weight were accounted for by applying the appropriate accelerations. The typical applied boundary condition and forces in each load case are presented in Figures B7.3-5 to B7.3-8. The detailed resulting forces, stresses and displacements in the model are available in computer output files. A summary of maximum stresses in frame legs and cross beams for each loading is shown in Tables B7.3-5 to B7.3-8.

Figures B7.3-2
ANSYS Finite Element Model - Frame (nodes)



Figures B7.3-3
ANSYS Finite Element Model - Frame (elements)



Figures B7.3-4
ANSYS Finite Element Model - Frame (real constants)

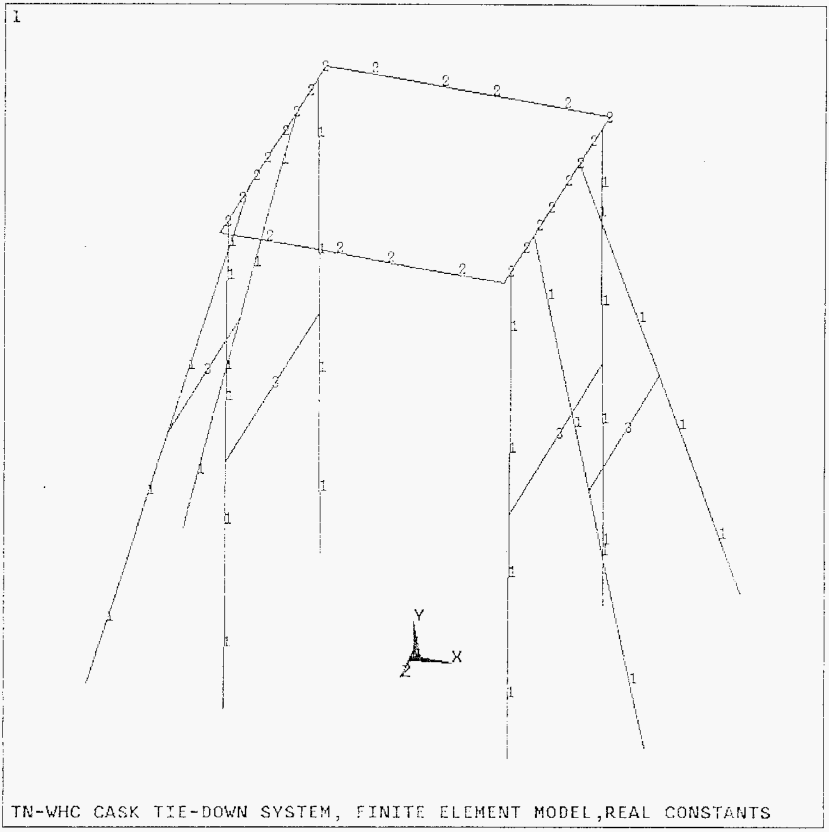


Figure B7.3-5
Frame Model - Loading & Boundary Conditions for Longitudinal 2G (fore) Load Analysis

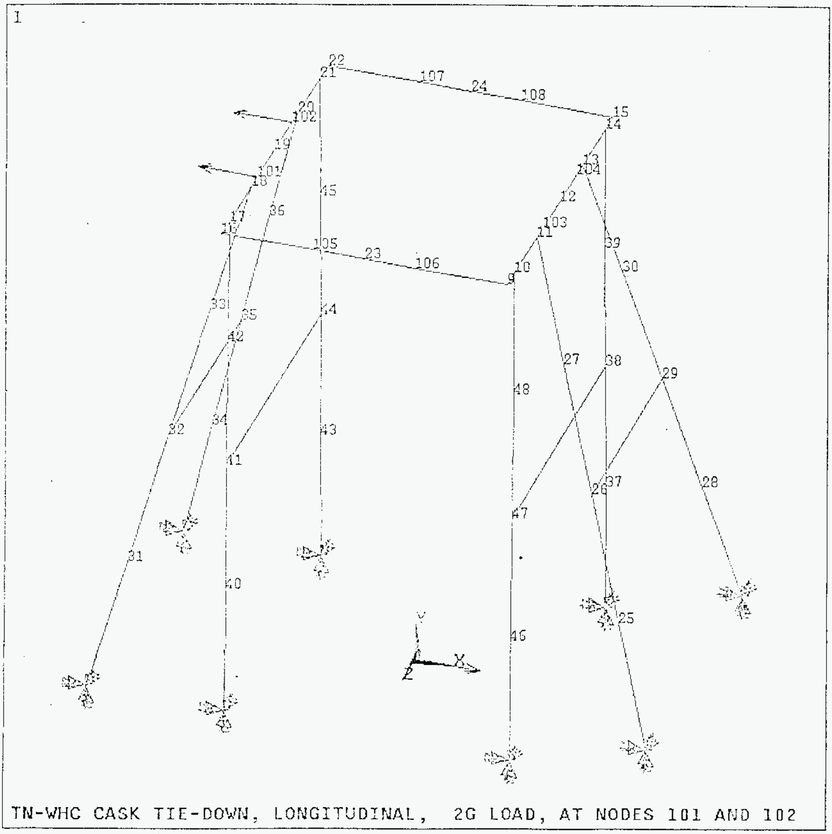


Figure B7.3-6
Frame Model - Loading & Boundary Conditions for Longitudinal 2G (aft) Load Analysis

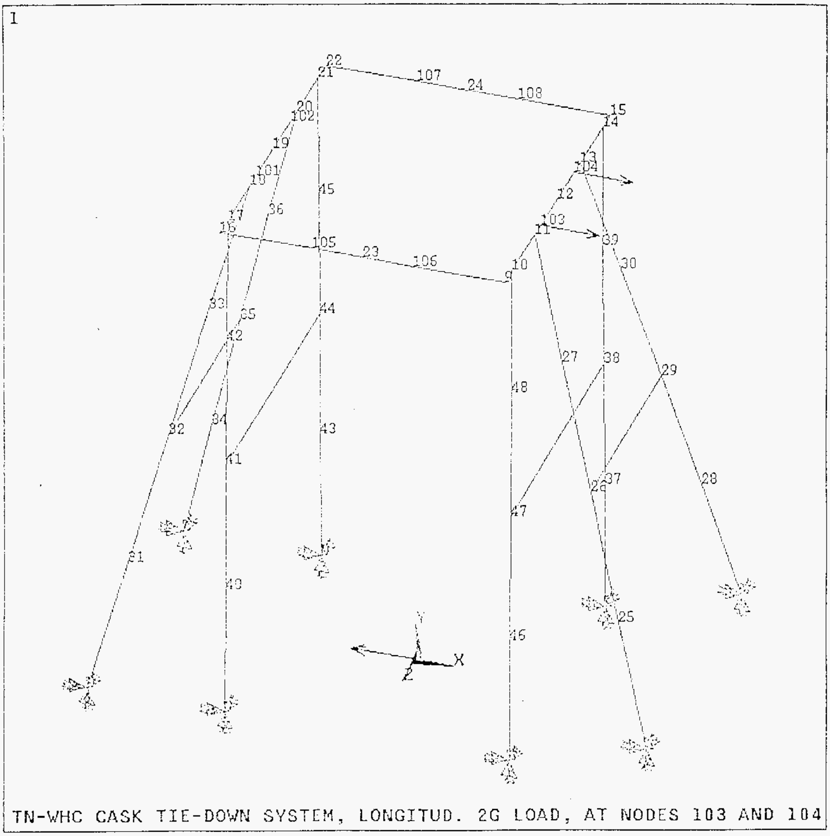


Figure B7.3-7
Frame Model - Loading & Boundary Conditions for Lateral 1.5G Load Analysis

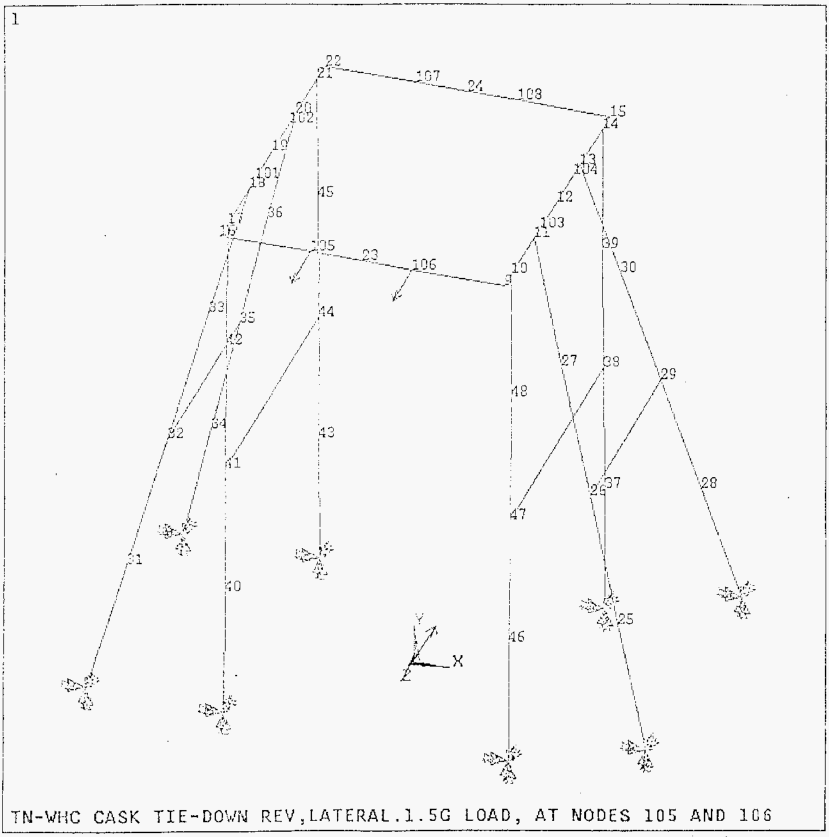


Figure B7.3-8
Frame Model - Loading & Boundary Conditions for Up 2.0G Load Analysis

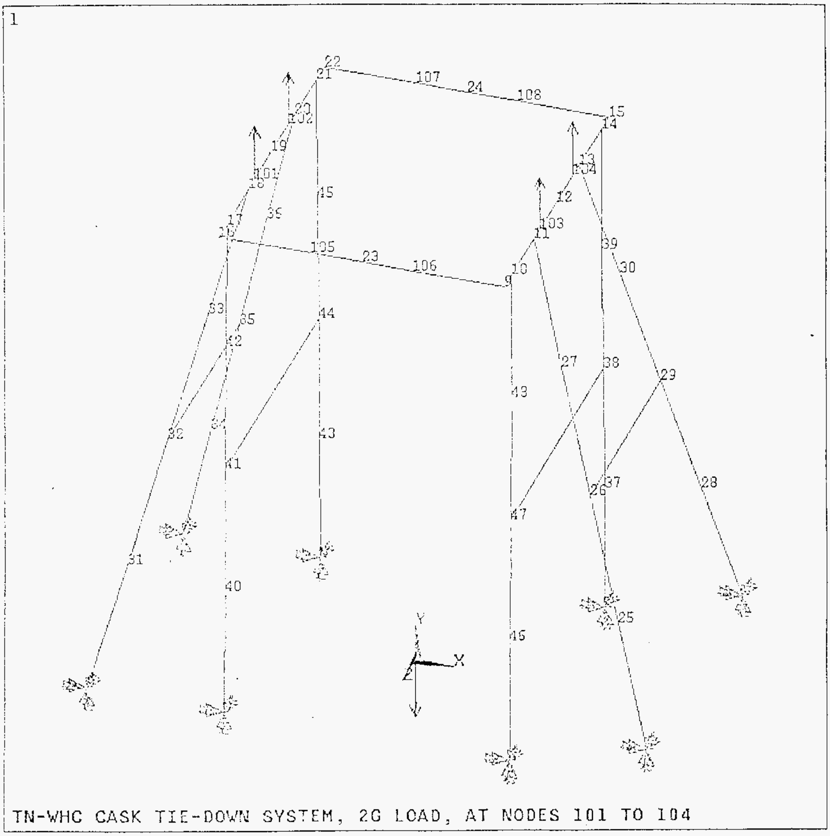


Table B7.3-4
Frame Finite Element Model - Beam Real Constants

Real Constant Number	Section	Area $(in)^2$	Moment of Inertia $(in)^4$	Depth (in)
1	TS - 7" x 7" x 0.5"	12.4	84.6	7.0
2	TS- 8" x 8" x 0.625" with reinforcement plate 8" wide and 0.625" thick	17.4	179.7	8.0
3	TS- 4" x 4" x 0.5"	6.36	12.3	4.0

Table B7.3-5
Frame Members Stresses - Loading Longitudinal 2G (fore)
(Fx at nodes 101 and 102)

Leg (Element)	Location (Node)	Direct Stress (psi)	Bending Stress- y - axis (psi)	Bending Stress- z - axis (psi)	Max. Combined Stress (psi)	Min. Combined Stress (psi)
1 (9)	1	-4562	7605	542	12709	-3586
2 (16)	2	-4562	7605	542	12709	-3586
3 (20)	10	-3451	6566	6604	9718	-16620
4 (24)	14	-3451	6566	6604	9718	-16620
5 (28)	18	-4664	4999	4344	4680	-14007
6 (32)	20	-4664	4999	4344	4680	-14007
7 (36)	17	3641	6831	7317	17788	10506
8 (40)	21	3641	6831	7317	17788	10506
Beam (41)	19	81	7711	7553	15344	-15183

Table B7.3-6
Frame Members Stresses - Loading Longitudinal 2G (aft)
(Fx at nodes 103 and 104)

Leg (Element)	Location (Node)	Direct Stress (psi)	Bending Stress- y - axis (psi)	Bending Stress- z - axis (psi)	Max. Combined Stress (psi)	Min. Combined Stress (psi)
1 (12)	11	-5073	5605	5079	5610	-15757
2 (16)	13	-5073	5605	5079	5610	-15757
3 (20)	10	4001	6516	7961	18479	-10477
4 (24)	14	4001	6516	7961	18479	-10477
5 (28)	16	4059	4615	5050	13724	-5606
6 (32)	20	4059	4615	5050	13724	-5606
7 (36)	17	-3075	6741	5932	9598	-15748
8 (40)	21	-3075	6741	5932	9598	-15748
Beam (45)	12	64	8280	7031	15375	-15247

Table B7.3-7
Frame Members Stresses - Loading Lateral 1.5G
(Fz at nodes 105 and 106)

Leg (Element)	Location (Node)	Direct Stress (psi)	Bending Stress- y - axis (psi)	Bending Stress- z - axis (psi)	Max. Combined Stress (psi)	Min. Combined Stress (psi)
1 (9)	1	-3969	103	9143	5276	-13216
2 (16)	13	3837	185	9633	13654	-5982
3 (19)	3	265	163	7740	8168	-7639
4 (21)	4	-505	230	7862	7588	-8598
5 (25)	5	-3615	322	8748	5453	-12685
6 (32)	20	3490	30	9245	12765	-5786
7 (33)	7	100	234	8384	8719	-8518
8 (37)	8	-348	98	8508	8258	-8954
Beam (44)	11	828	10436	5416	16679	-15025

Table B7.3-8
Frame Members Stresses - Loading Up 2.0G
(Fy at nodes 101,102,103 and 104)

Leg (Element)	Location (Node)	Direct Stress (psi)	Bending Stress- y - axis (psi)	Bending Stress- z - axis (psi)	Max. Combined Stress (psi)	Min. Combined Stress (psi)
1 (12)	11	1694	89	1787	3570	-182
2 (16)	13	1694	89	1787	3570	-182
3 (20)	10	855	58	2284	3197	-1486
4 (24)	14	855	58	2284	3197	-1486
5 (28)	18	1765	52	1633	3449	80
6 (32)	20	1765	52	1633	3449	80
7 (36)	17	797	100	2164	3061	-1467
8 (40)	21	797	100	2164	3061	-1467
Beam (46)	12	328	3103	1386	4828	-4172

b) Cask Tie down Device

The cask tie down device consists of clamps, hinge pins, bolts and pad for hold down brackets. The clamp was analyzed by using ANSYS Finite Element Computer Code. The 3-dimensional beam finite element (BEAM4) was used in the construction of the model. The loading and boundary conditions for the 2G longitudinal, 1.5G lateral and 2G up are presented in Figures B7.3-9, B7.3-10 and B7.3-11, respectively. The critical stresses are presented in Table B7.3-10. The stresses in hinge pin, bolts and pad were hand-calculated. These stresses are also summarized in Table B7.3-10.

Figure B7.3-9
Clamp Model - Loading & Boundary Conditions for Longitudinal 2G Load Analysis

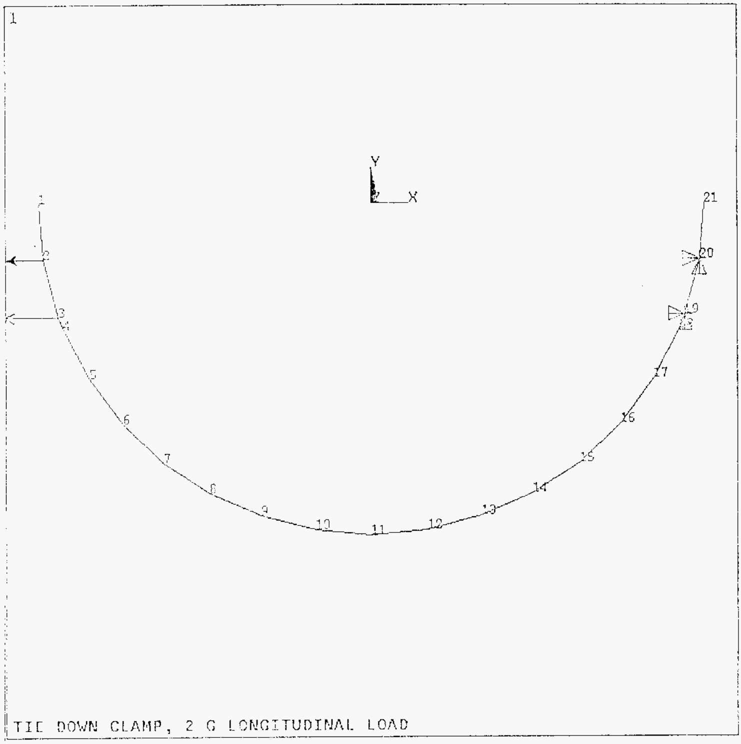


Figure B7.3-10
Clamp Model - Loading & Boundary Conditions for Lateral 1.5G Load Analysis

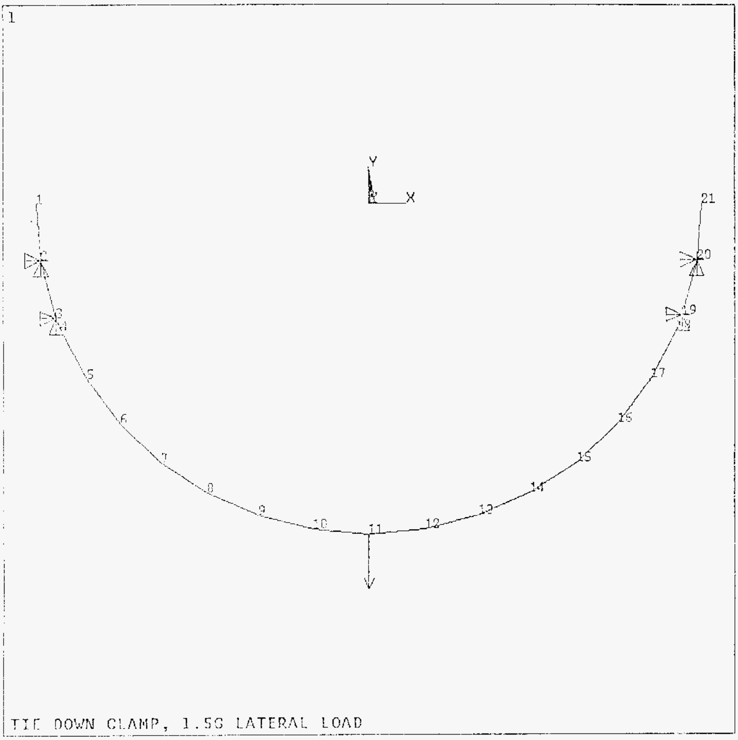
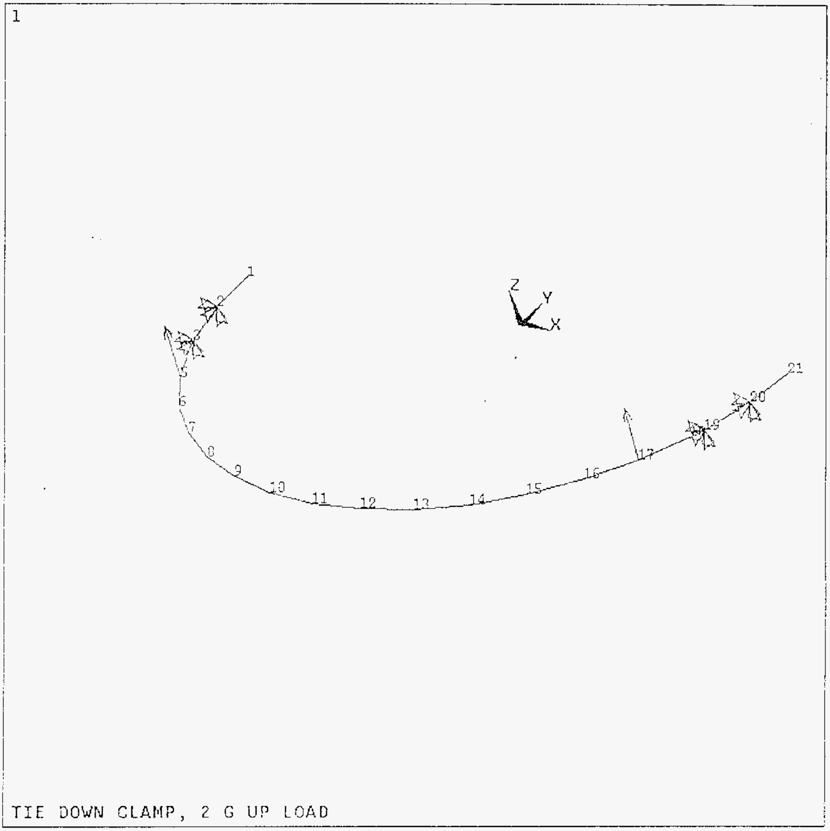


Figure B7.3-11
Clamp Model - Loading & Boundary Conditions for Up 2.0G Load Analysis



c) Cask Hold down Device

The cask hold down device consists of hold down arms, brackets and bolts. The analysis was conducted using hand calculations. The only load that is applicable for these components is 2G upward. The resulting stresses are summarized in Table B7.3-10.

d) Cask Support Device

The cask support device consists of support plate, cup and bolts. The analysis was conducted using ANSYS Finite Element Computer Code. The two end of plate are bolted to the bottom plate which is welded to the support beams, the support beams are welded to the trailer main beams. The plates was modeled using 3-dimensional shell elements. The supporting beams were modeled with 3-dimensional beam elements. The cup was not modeled. The 3G downward load was applied to the cup area as a distributed pressure. The maximum stress intensity in the plate is 18,429 psi . The bolt stresses were hand calculated for a combined loading due to 2G longitudinal and 1.5G lateral accelerations. The maximum shear stress in the bolts is 34,560 psi. All the plate and bolt stresses are within the allowables, as shown in Table B7.3-10.

B7.3-6 DESIGN CRITERIA FOR TIEDOWN SYSTEM

The stress criteria are taken from Section III, Subsection NF (NF-3322) of the ASME Code[3]. There are several types of structural criteria discussed in Subsection NF-3322. These criteria, are to ensure stability under compressive loading, to ensure stability under bending and to prevent failure under combined loading. Table B7.3-9 lists the stress limits of the materials based on this criteria.

Table B7.3-9
Stress Criteria for the Tiedown System

Material	S_y (ksi)	Tension	Bending	Shear	Compression	Interaction Equation
		$0.6\ S_y$*	$0.66\ S_y$	$0.4\ S_y$	NF-3322.1 EQ. 4 or 5	NF-3322.1 EQ. 20 or 21
A500 Gr. B	44	26.4	29.04	17.6		
A514 Gr. B	97.7	58.62	64.48	39.08		
6061-T6	39	23.4	25.74	15.6		
6063-T6	29.4	17.64	19.4	11.76		
A193-B7	101	60.6	66.66	40.4		
A479-XM19 Hot Rolled	101	60.6	66.66	40.4		

* For pin-connected members, using $0.45\ S_y$

B7.3-7 SUMMARY AND CONCLUSIONS

A summary of critical stresses is presented in Table B7.3-10 and stresses are compared with the allowables. All stresses are within the allowables. The interaction between compression and bending are evaluated using Equations 20 and 21 of NF-3322, and interaction between tension and bending are using Equation 21 of NF-3322. Table B7.3-11 shows the results of the calculations. Based on the results of the analyses, it is concluded that tiedown system is structurally safe for the specified loads.

Table B7.3-10
Summary - Stress Evaluation

Component	Max. Calculated Stress (psi)	Allowable Stress (psi)
Frame- Legs	Max. Direct = 5,073 (Compression) Max. Bending =14,477	26,400 29,040
Cross Beam	Max. Direct = 828 (Tension) Max. Bending = 15,852	26,400 29,040
Welds at Bottom Leg	Max. Tension = 19,224 Max. Shear = 5,707	26,400 17,600
Tiedown device- Clamp	Max. Direct = 2,446 (Tension) Max. Bending = 20,513	23,400 25,740
Bolt	Max. Shear = 23,460 Max. Tension = 36,700	40,400 60,600
Cask Hold Down Device -Arm	Max. Tension = 11,430 Max. Bending = 43,200 Max. Shear = 11,933	43,960 64,480 39,080
-Pin-1.5"Dia.	Max. Bending = 18,420 Max. Shear = 8,490	66,660 40,400
-Bracket	Bearing = 16,000 Tensile = 6000 Shear = 4,570	39,000 17,550 15,600
Cask Support Device -Plate	Max. Bending=18,429	19,400
- Bolt	Max. Shear = 34,560	40,400

Table B7.3-11
Interaction Equation Evaluations

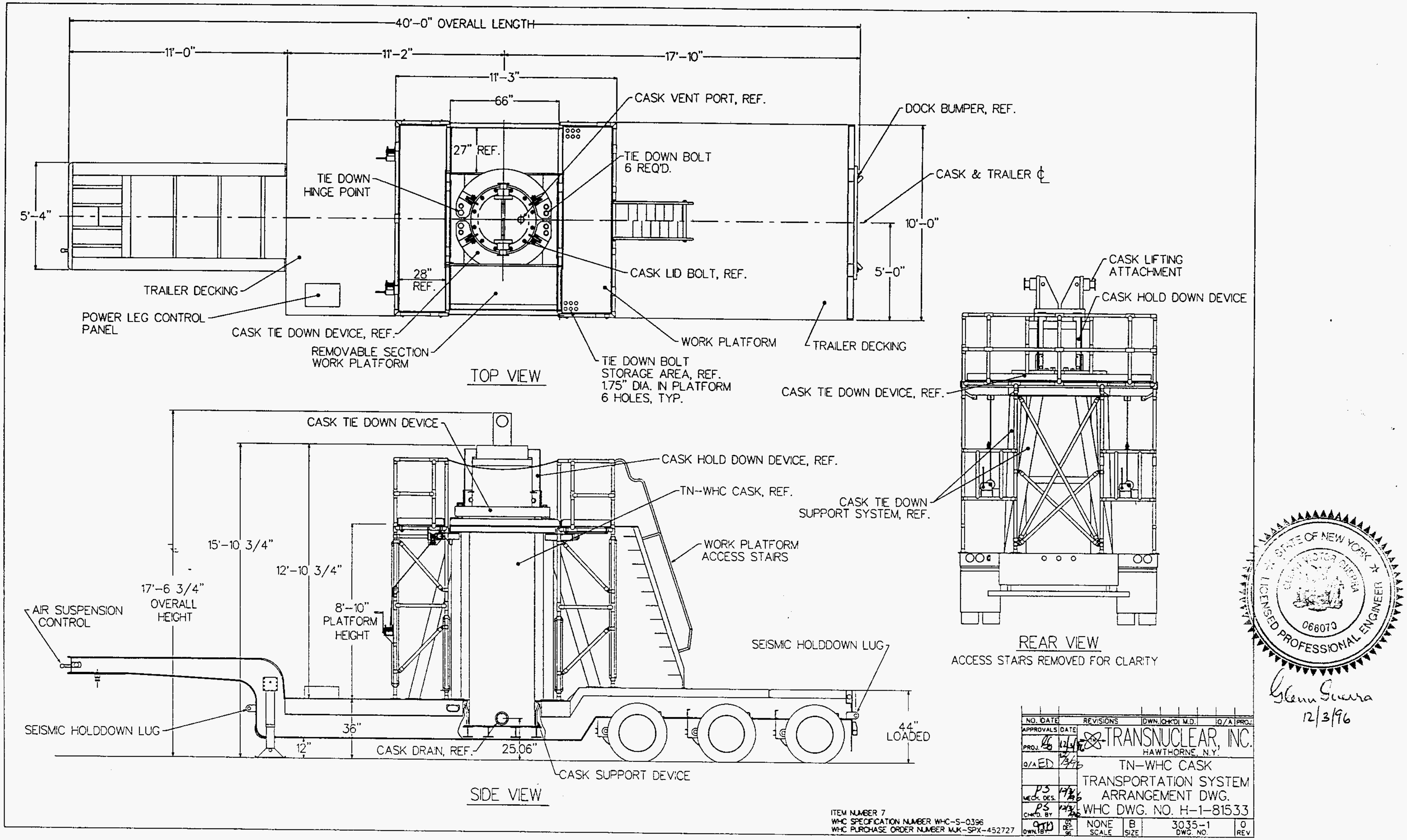
Component	Max. Axial Compression and Bending (NF-3322.1, Equation 20 & 21)	Max. Axial Tension and Bending (NF-3322.1, Equation 21)
Frame Leg	0.522	0.65
Tiedown Clamp		0.902
Hold Down Arm		0.807

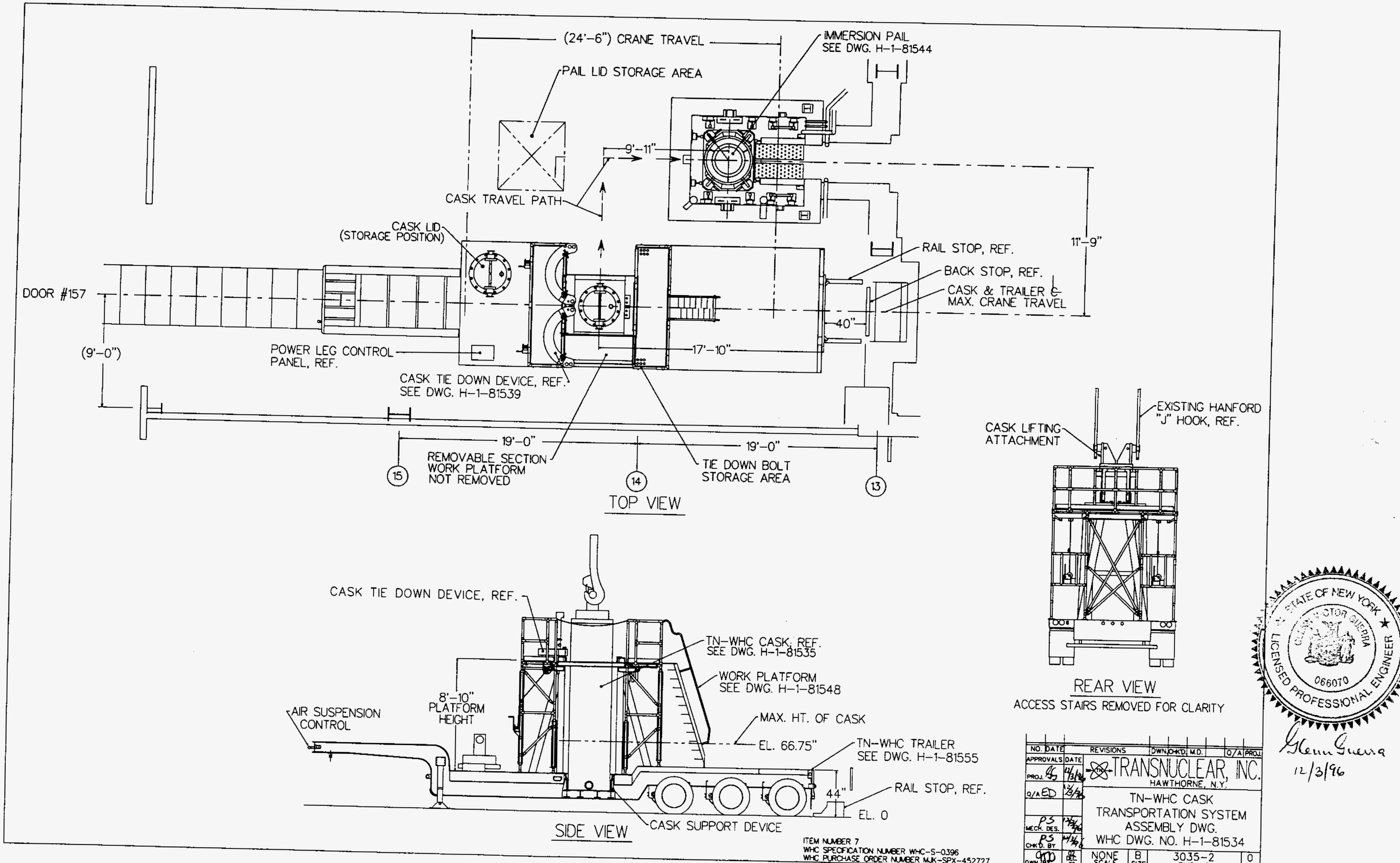
B7.3-7 REFERENCES

1. WHC-S-0396, Revision 1, "Specification For TN-WHC Cask and Transportation System" 1995.

2. ANSYS User's Manual, Revision 5.2, Volumes 1 to 4.

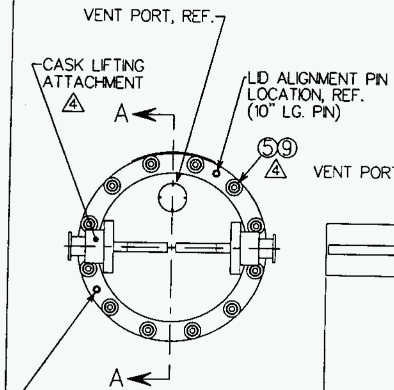
3. ASME Boiler and Pressure Vessel Code 1992, Section III, Subsection NF.


40'-0" OVERALL LENGTH
11'-0"
11'-2"
17'-10"
11'-3"
66"
27" REF.
28" REF.
5'-4"
10'-0"
5'-0"
CASK VENT PORT, REF.
DOCK BUMPER, REF.
TIE DOWN BOLT 6 REQ'D.
CASK & TRAILER ℄
TIE DOWN HINGE POINT
CASK LID BOLT, REF.
TRAILER DECKING
POWER LEG CONTROL PANEL
CASK TIE DOWN DEVICE, REF.
REMOVABLE SECTION WORK PLATFORM
WORK PLATFORM
TRAILER DECKING
TIE DOWN BOLT STORAGE AREA, REF. 1.75" DIA. IN PLATFORM 6 HOLES, TYP.
TOP VIEW
CASK LIFTING ATTACHMENT
CASK HOLD DOWN DEVICE
CASK TIE DOWN DEVICE, REF.
CASK TIE DOWN SUPPORT SYSTEM, REF.
REAR VIEW
ACCESS STAIRS REMOVED FOR CLARITY
CASK TIE DOWN DEVICE
CASK HOLD DOWN DEVICE, REF.
TN-WHC CASK, REF.
WORK PLATFORM ACCESS STAIRS
15'-10 3/4"
12'-10 3/4"
17'-6 3/4" OVERALL HEIGHT
8'-10" PLATFORM HEIGHT
AIR SUSPENSION CONTROL
SEISMIC HOLDDOWN LUG
SEISMIC HOLDDOWN LUG
36"
12"
CASK DRAIN, REF.
25.06"
CASK SUPPORT DEVICE
44" LOADED
SIDE VIEW
ITEM NUMBER 7
WHC SPECIFICATION NUMBER WHC-S-0396
WHC PURCHASE ORDER NUMBER MJK-SPX-452727
TRANSNUCLEAR, INC.
HAWTHORNE, N.Y.
TN-WHC CASK TRANSPORTATION SYSTEM ARRANGEMENT DWG.
WHC DWG. NO. H-1-81533
NONE SCALE
B SIZE
3035-1 DWG. NO.
0 REV
STATE OF NEW YORK
LICENSED PROFESSIONAL ENGINEER
066070
12/3/96

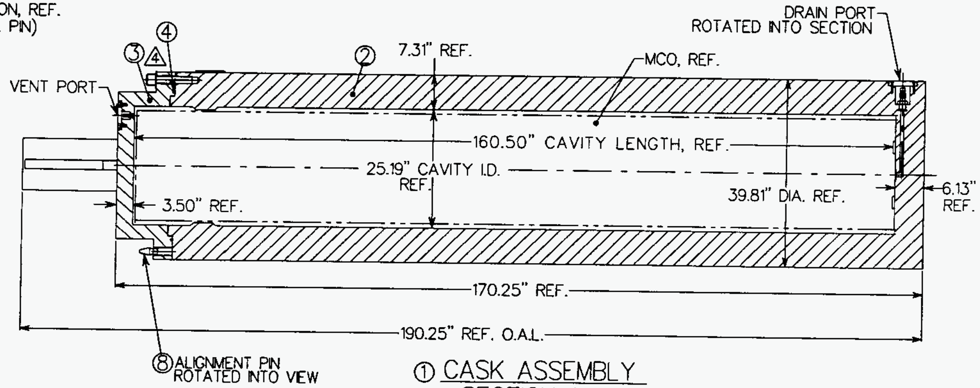


Glenn Guerra
12/3/96

PARTS LIST				
	ITEM NO.	NO. REQ'D	NOMENCLATURE	DESCRIPTION
	1	–	CASK ASSEMBLY	———
	2	1	CASK BODY	SEE DWG. 3035-3 SHEET 2
	3	1	LID	SEE DWG. 3035-3 SHEET 4
	4	1	O-RING SEAL	PARKER .275"DIA. XSECT. X 31.31"I.D. BUTYL # B612 70 OR EQUIV.
NOTE 7	5	12	LID BOLT	SA-479-XM19 HOT ROLLED OR EQUIV.
	6		DELETED	
	7		DELETED	
NOTE 7, NOTE 4 *	8	2	LID ALIGNMENT PIN	SA-193-B8 OR EQUIV.
△4	9	12	WASHER	1.50" DIA. FLAT, SST



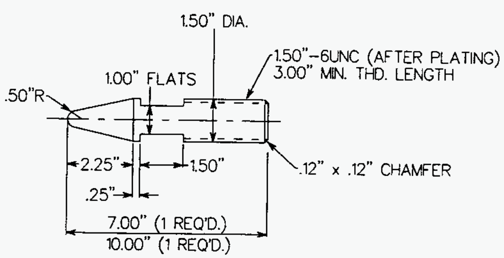
TOP VIEW



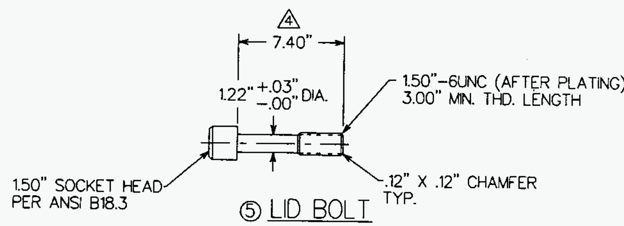
① CASK ASSEMBLY
SECTION A–A

NOTES:

1. DELETED
2. DELETED
3. DELETED
4. * INDICATES NON SAFETY RELATED ITEM.
5. THIS PARTS LIST IS FOR SHEET 1 ONLY.
6. △4 TORQUE REQUIREMENTS:
   LID BOLTS: 300 FT. LBS. ± 10 FT. LBS.
   VENT & DRAIN PORT COVER SCREWS:
   15 FT. LBS. ± 3 FT. LBS.
   ALIGNMENT PINS: 40 FT. LBS. ± 5 FT. LBS.
7. LID BOLTS & ALIGNMENT PINS TO BE CHROMIUM PLATED (THREADS ONLY) PER QQ-C-320-B, CLASS 2, TYPE 1 (.0002" MIN. THK.) BOLT TO BE INSPECTED TO NB-2580 OF ASME B & PV CODE, SECTION III, INCLUDING VT (VISUAL EXAMINATION) & LP (LIQUID PENETRANT EXAMINATION), BEFORE PLATING.
8. LUBRICATE BOLTS WITH NEOLUBE AS NEEDED.



⑧ LID ALIGNMENT PIN
TOLERANCE:+/−.03"
SURFACE FINISH: 125√



⑤ LID BOLT
TOLERANCE:+/−.03"
SURFACE FINISH: 125√

ITEM NO. 7
WHC SPECIFICATION NO. WHC-S-0396
WHC PURCHASE ORDER NO. MJK-SPX-452727

NO.	DATE	REVISIONS	DWN.	CHK'D.	M.D.		Q/A	PROJ.
4	12/3/96	SEE DCN 3035-14	GTD	PS	PS		ED	GG
3	10/19/96	SEE DCN 3035-11	J.T.G.	P.S.	P.S.		E.D.	G.G.
2	9/30/96	SEE DCN 3035-6	J.T.G.	P.S.	P.S.		E.D.	G.G.
1	8/6/96	SEE DCN 3035-1	J.T.G.	P.S.	P.S.		E.D.	G.G.

APPROVALS	DATE
G.G. PROJ.	24 JUNE 96
E.D. Q/A	24 JUNE 96
P.S. MECH. DES.	21 JUNE 96
P.S. CHK'D. BY	21 JUNE 96
J.T.G. DWN. BY.	21 JUNE 96

TRANSNUCLEAR, INC.
HAWTHORNE, N.Y.

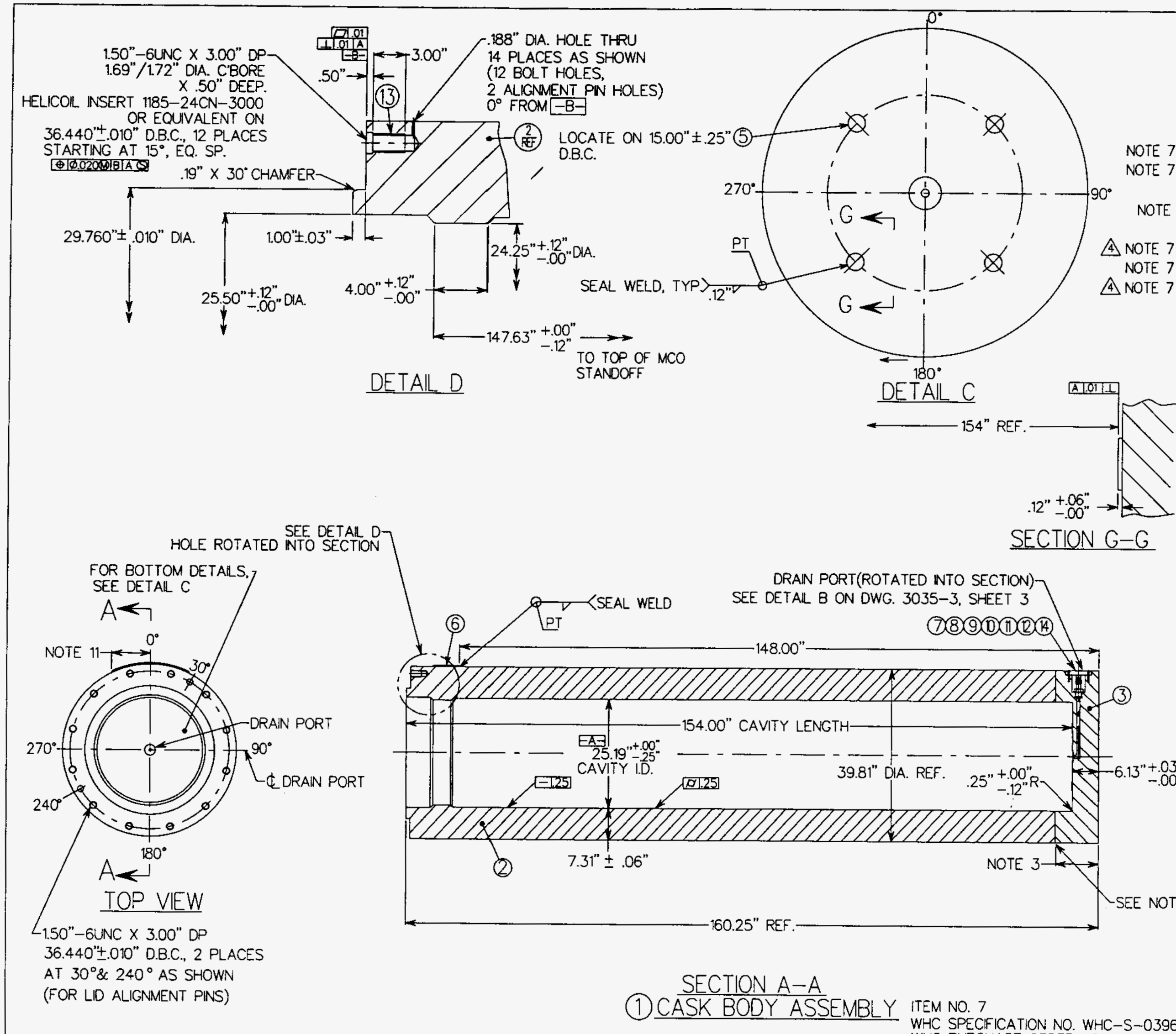
TN-WHC CASK
TRANSPORTATION SYSTEM
ASSEMBLY & PARTS LIST
WHC DWG. NO. H-1-81535

SCALE	SIZE	DWG. NO.	REV.
NONE	B	3035-3	4

SHEET 1 OF 5

STATE OF NEW YORK
GLENN VICTOR GUERRA
066070
LICENSED PROFESSIONAL ENGINEER

Glenn Guerra
12/3/96



① CASK BODY ASSEMBLY

ITEM NO. 7
WHC SPECIFICATION NO. WHC-S-0396
WHC PURCHASE ORDER NO. MJK-SPX-452727

PARTS LIST

	ITEM NO.	NO. REQ'D	NOMENCLATURE	DESCRIPTION	MATERIAL
	1	–	CASK BODY ASSEMBLY	———	———
	2	1	CASK SHELL	SEE FIELD	SA-336,TYPE F304 OR EQUIV.
	3	1	BOTTOM	SEE FIELD	SA-336,TYPE F304 OR EQUIV.
	4		DELETED		
NOTE 7*	5	4	MCO STANDOFF	.12" THK. X 2.00" DIA.	SST
NOTE 7*	6	1	NAME PLATE	SEE DWG. 3035-4	SST
	7	1	COVER	SEE DWG. 3035-3 SHEET 3	304 SST
NOTE 9	8	4	SOC HD CAP SCREW	SEE DWG. 3035-3 SHEET 3	SA-193-B8 OR EQUIV.
	9	1	O-RING	PARKER 2-341 B612-70 OR EQUIVALENT	BUTYL
⚠4 NOTE 7*	10	1	QDISC COUPLING	HANSEN LL6-KP-12 OR EQUIV.	303 SST
NOTE 7*	11	1	COUPLING ADAPTER	SEE DWG. 3035-3 SHEET 3	304 SST
⚠4 NOTE 7*	12	2	O-RING	PARKER 3-912 B612-70 OR EQUIVALENT	BUTYL
	13	12	THREADED INSERT	HELICOIL 1185-24CN-3000 OR EQUIVALENT	SST
	14	4	THREADED INSERT	HELICOIL 1185-8CN-0500 OR EQUIVALENT	SST

NOTES:

1. FOR CASK ASSEMBLY SEE DWG. 3035-3, SHEET 1.
2. TOLERANCE, UNLESS OTHERWISE SPECIFIED: +/-.12" ANGLES: +/-1°
3. NUMBER & LOCATION OF FULL PENETRATION WELDS TO BE SPECIFIED BY FABRICATOR, RT & PT REQUIRED.
4. REMOVE ALL BURRS & WELD SPLATTER AND BREAK ALL SHARP EDGES.
5. SURFACE FINISH, UNLESS OTHERWISE SPECIFIED: 125√
6. DELETED
7. * INDICATES NON SAFETY RELATED ITEM.
8. THIS PARTS LIST IS FOR SHEETS 2 AND 3 ONLY.
9. BOLTS TO BE CHROMIUM PLATED (THREADS ONLY), PER QQ-C-320-B, CLASS 2, TYPE 1 (.0002" MIN. THK.)
10. LUBRICATE BOLTS WITH NEOLUBE AS NEEDED.
11. ⚠4 NAMEPLATE TO BE CENTERED ABOUT 0°AXIS.

NO.	DATE	REVISIONS	DWN.	CHK'D.	M.D.		Q/A	PROJ.
4	12/3/96	SEE DCN 3035-15	JTG	PS	PS		ED	GG
3	10/9/96	SEE DCN 3035-12	J.T.G.	P.S.	P.S.		E.D.	G.G.
2	9/30/96	SEE DCN 3035-7	J.T.G.	P.S.	P.S.		E.D.	G.G.
1	8/6/96	SEE DCN 3035-2	J.T.G.	P.S.	P.S.		E.D.	G.G.

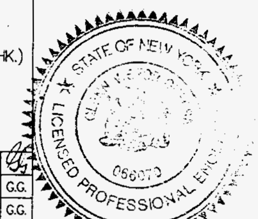
APPROVALS	DATE
PROJ. G.G.	24 JUNE 96
Q/A E.D.	24 JUNE 96
MECH. DES. P.S.	21 JUNE 96
CHK'D. BY P.S.	21 JUNE 96
DWN. BY J.T.G.	21 JUNE 96

TRANSNUCLEAR, INC.
HAWTHORNE, N.Y.

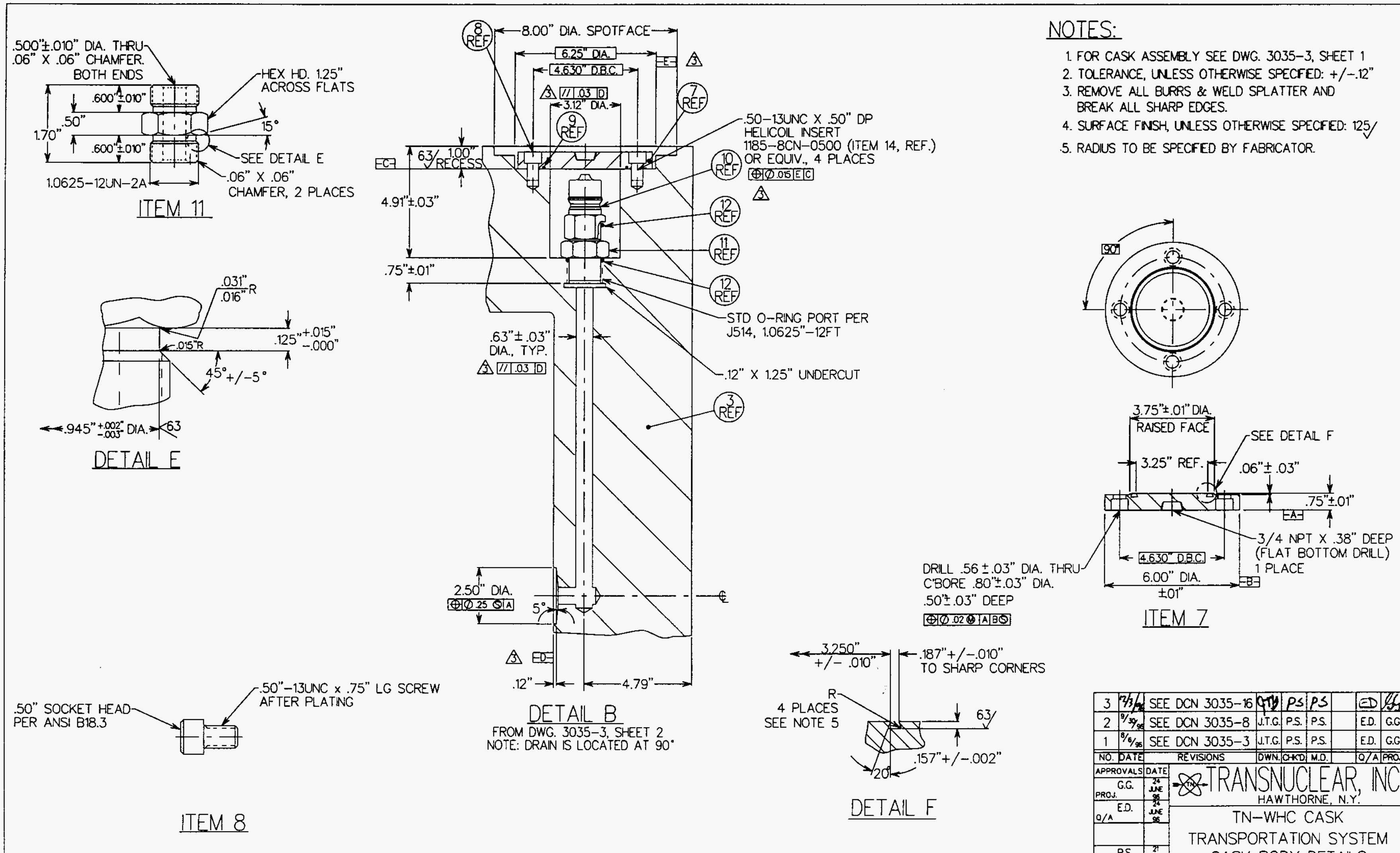
TN-WHC CASK TRANSPORTATION SYSTEM
CASK BODY & PARTS LIST
WHC DWG. NO. H-1-81535

SCALE: NONE | SIZE: B | DWG. NO. 3035-3 | REV. 4

SHEET 2 OF 5



Glenn Guerra
12/3/96



NOTES:

1. FOR CASK ASSEMBLY SEE DWG. 3035-3, SHEET 1
2. TOLERANCE, UNLESS OTHERWISE SPECIFIED: +/-.12"
3. REMOVE ALL BURRS & WELD SPLATTER AND BREAK ALL SHARP EDGES.
4. SURFACE FINISH, UNLESS OTHERWISE SPECIFIED: 125
5. RADIUS TO BE SPECIFIED BY FABRICATOR.

ITEM NO. 7
WHC SPECIFICATION NO. WHC-S-0396
WHC PURCHASE ORDER NO. MJK-SPX-452727

NO.	DATE	REVISIONS	DWN.	CHK'D	M.D.	Q/A	PROJ.
3	12/3/96	SEE DCN 3035-16		PS	PS	ED	GG
2	9/30/96	SEE DCN 3035-8	J.T.G.	P.S.	P.S.	E.D.	G.G.
1	8/6/96	SEE DCN 3035-3	J.T.G.	P.S.	P.S.	E.D.	G.G.

APPROVALS	DATE
PROJ. G.G.	24 JUNE 96
Q/A E.D.	24 JUNE 96
MECH. DES. P.S.	21 JUNE 96
CHK'D. BY P.S.	21 JUNE 96
DWN. BY J.T.G.	21 JUNE 96

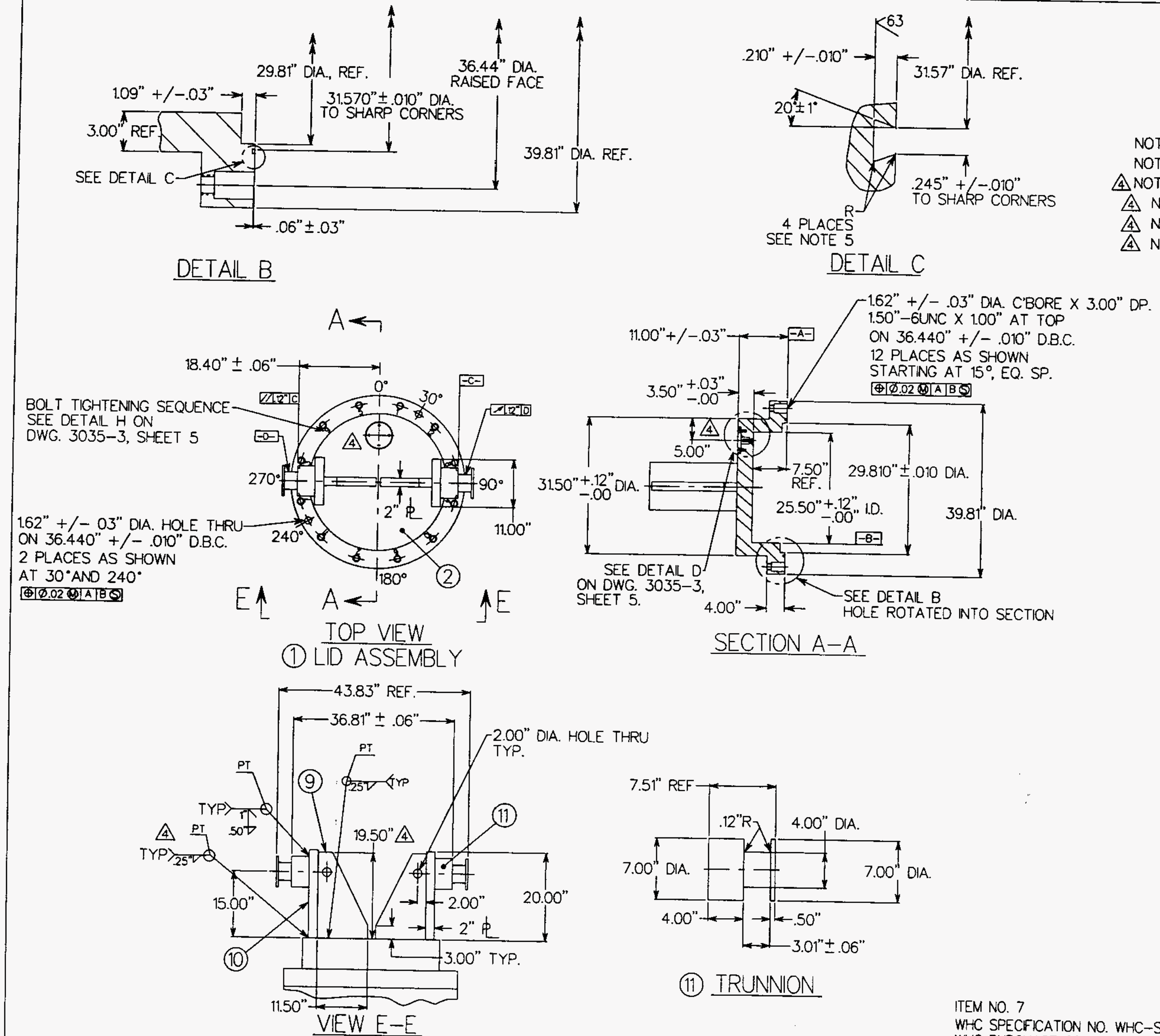
TRANSNUCLEAR, INC.
HAWTHORNE, N.Y.

TN-WHC CASK TRANSPORTATION SYSTEM
CASK BODY DETAILS
WHC DWG. H-1-81535

SCALE: NONE | SIZE: B | DWG. NO.: 3035-3 | REV.: 3

SHEET 3 OF 5

STATE OF NEW YORK — GLENN VICTOR GUERRA — 066070 — LICENSED PROFESSIONAL ENGINEER
Glenn Guerra 12/3/96



ITEM NO.	NO. REQ'D	NOMENCLATURE	DESCRIPTION	MATERIAL
1	–	LID ASSEMBLY	———	———
2	1	LID	SEE FIELD	SA-336, TP F304 OR EQUIV. NOTE 7
3		DELETED		
4	1	PORT COVER	SEE DWG. 3035-3, SHEET 5	304 SST
NOTE 8 * 5	1	QDISC. COUPLING	HANSEN 1-HK-LL1-K-4	303 SST
NOTE 8 * 6	1	COUPLING ADAPTER	SEE DWG. 3035-3, SHEET 5	304 SST
△4 NOTE 8 * 7	2	O-RING (ADAPTER)	PARKER 3-904	BUTYL / B612 70 OR EQUIV.
△4 NOTE 10 8	4	SOC HD CAP SCREW	SEE DWG. 3035-3, SHEET 5	SA-193-B8 OR EQUIV.
△4 NOTE 11 9	2	GUSSET	SEE FIELD	304 SST
△4 NOTE 11 10	2	LIFTING BRACKET	SEE FIELD	304 SST
11	2	TRUNNION	SEE FIELD	304 SST
△4 12	4	HELICOIL THREADED INSERT	# 1185-8CN-0500	SST
△4 13	1	PORT COVER O-RING	PARKER 2-341	BUTYL / B612 70 OR EQUIV.

NOTES:

1. FOR CASK ASSEMBLY SEE DWG. 3035-3, SHEET 1
2. TOLERANCE, UNLESS OTHERWISE SPECIFIED:
   2 PLACE DECIMALS: +/- .12"
   3 PLACE DECIMALS: +/- .010"
   ANGLES: +/- 1°
3. REMOVE ALL BURRS & WELD SPLATTER AND BREAK ALL SHARP EDGES.
4. SURFACE FINISH, UNLESS OTHERWISE SPECIFIED: 125
5. RADIUS TO BE SPECIFIED BY FABRICATOR.
6. DELETED
7. FABRICATOR HAS OPTION TO USE SA-240, TYPE 304 PLATE, WELDED TOGETHER, RT & PT REQUIRED.
8. * INDICATES NON SAFETY RELATED ITEM.
9. THIS PARTS LIST IS FOR SHEETS 4 AND 5 ONLY.
10. BOLTS TO BE CHROMIUM PLATED (THREADS ONLY) PER QQ-C-320-B, CLASS 2, TYPE 1 (.0002" MIN. THK.).
11. △4 TOLERANCE THICKNESS PER PLATE MANUFACTURER SPECIFICATION, DURING FABRICATION, LOCALIZED SURFACE IRREGULARITIES, ETC. PER TOLERANCE FROM NOTE 2.

ITEM NO. 7
WHC SPECIFICATION NO. WHC-S-0396
WHC PURCHASE ORDER NO. MJK-SPX-452727

NO.	DATE	REVISIONS	DWN.	CHK'D.	M.D.	Q/A	PROJ.
4	11/3/96	SEE DCN 3035-17	JTG	PS	PS	ED	GG
3	10/9/96	SEE DCN 3035-14	J.T.G.	P.S.	P.S.	E.D.	G.G.
2	9/30/96	SEE DCN 3035-9	J.T.G.	P.S.	P.S.	E.D.	G.G.
1	8/6/96	SEE DCN 3035-4	J.T.G.	P.S.	P.S.	E.D.	G.G.

APPROVALS		DATE
PROJ.	G.G.	24 JUNE 96
Q/A	E.D.	24 JUNE 96
MECH. DES.	P.S.	21 JUNE 96
CHK'D. BY	P.S.	21 JUNE 96
DWN. BY	J.T.G.	21 JUNE 96

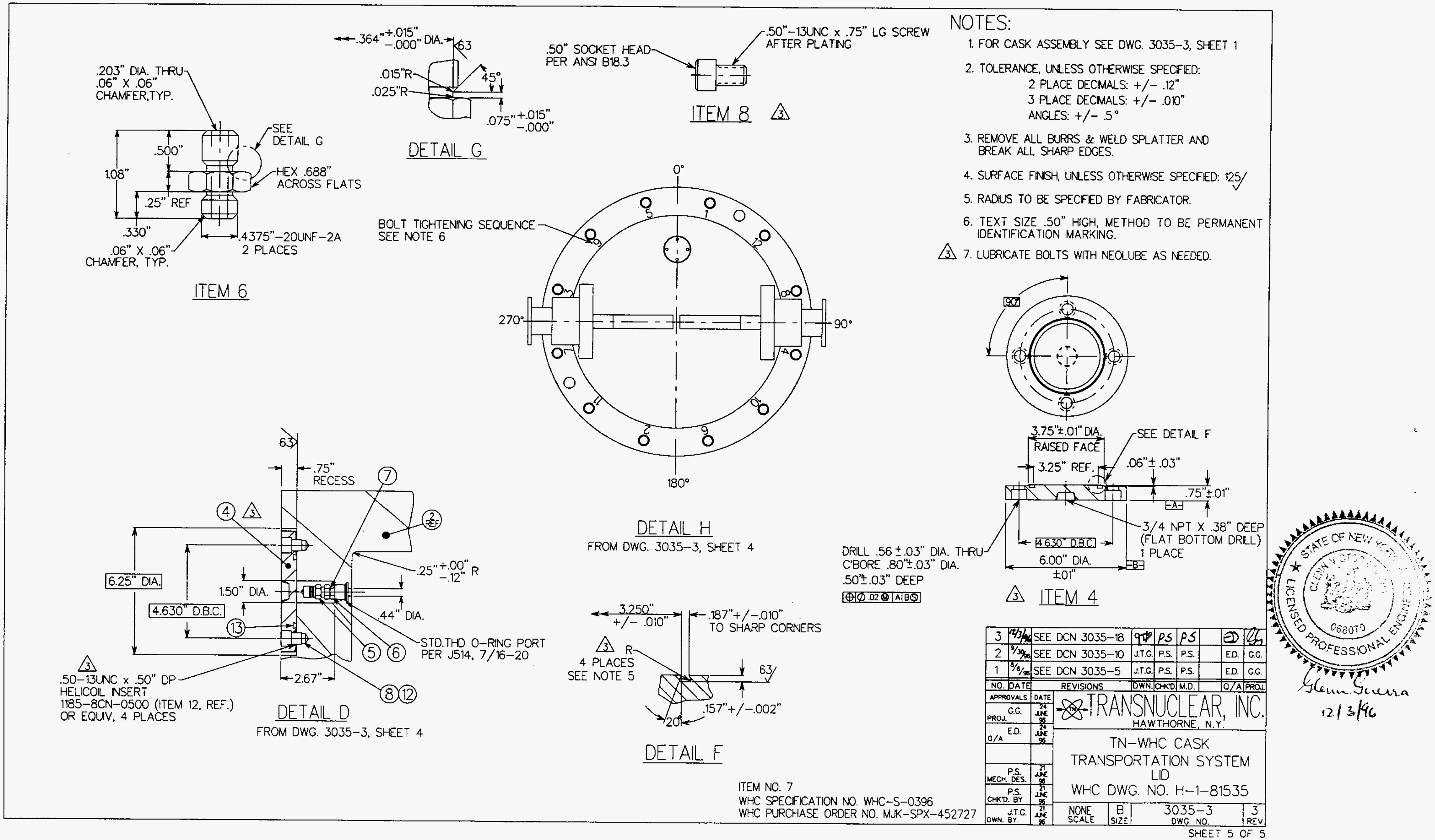
TRANSNUCLEAR, INC.
HAWTHORNE, N.Y.

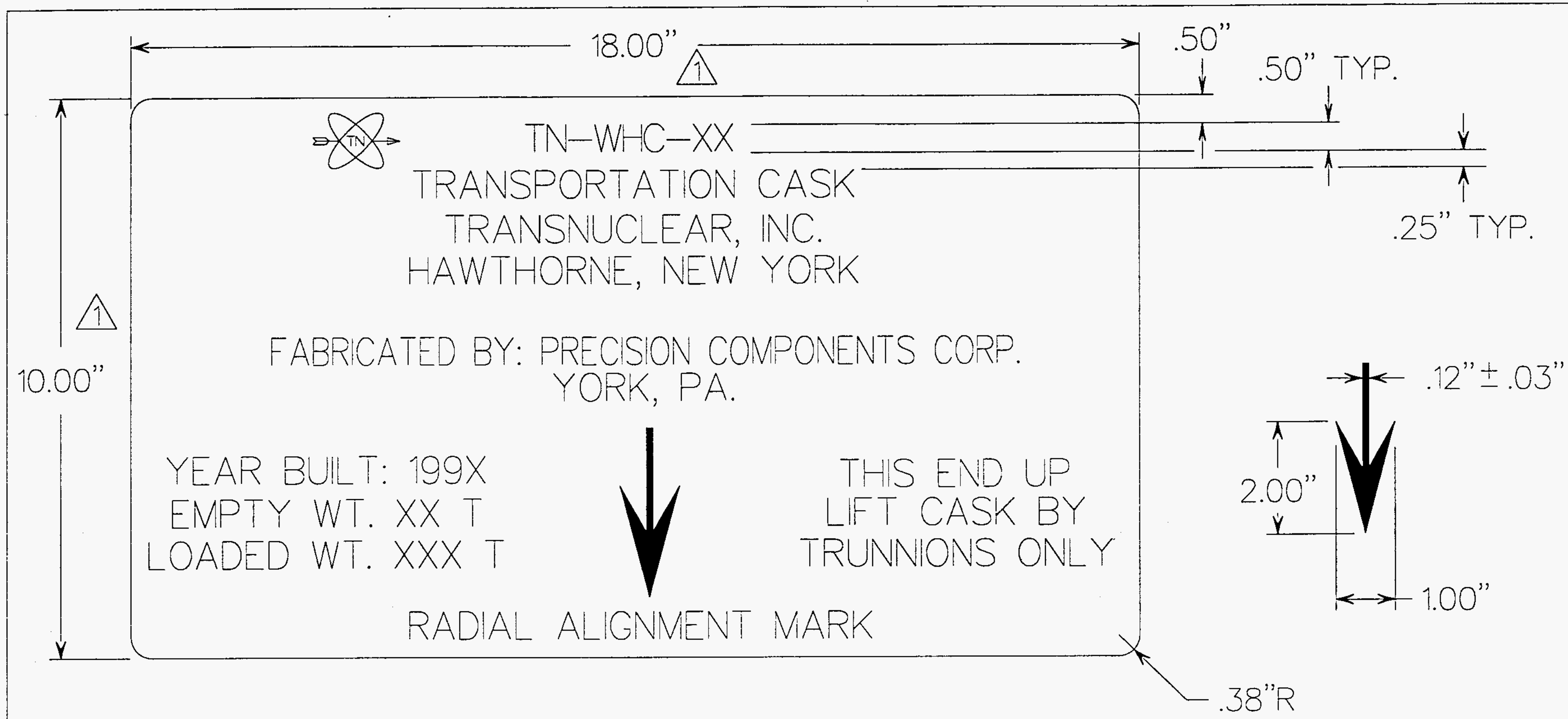
TN-WHC CASK TRANSPORTATION SYSTEM
LID
WHC DWG. NO. H-1-81535

SCALE	SIZE	DWG. NO.	REV
NONE	B	3035-3	4

SHEET 4 OF 5

STATE OF NEW YORK LICENSED PROFESSIONAL ENGINEER 066070
Glenn Guerra 12/3/96


NOTES:
1. FOR CASK ASSEMBLY SEE DWG. 3035-3, SHEET 1
2. TOLERANCE, UNLESS OTHERWISE SPECIFIED:
2 PLACE DECIMALS: +/- .12"
3 PLACE DECIMALS: +/- .010"
ANGLES: +/- .5°
3. REMOVE ALL BURRS & WELD SPLATTER AND BREAK ALL SHARP EDGES.
4. SURFACE FINISH, UNLESS OTHERWISE SPECIFIED: 125
5. RADIUS TO BE SPECIFIED BY FABRICATOR.
6. TEXT SIZE .50" HIGH, METHOD TO BE PERMANENT IDENTIFICATION MARKING.
7. LUBRICATE BOLTS WITH NEOLUBE AS NEEDED.
.203" DIA. THRU
.06" X .06" CHAMFER, TYP.
SEE DETAIL G
HEX .688" ACROSS FLATS
.500"
1.08"
.25" REF
.330"
.06" X .06" CHAMFER, TYP.
.4375"-20UNF-2A 2 PLACES
ITEM 6
.364" +.015" -.000" DIA.
63
.015"R
.025"R
45°
.075" +.015" -.000"
DETAIL G
.50" SOCKET HEAD PER ANSI B18.3
.50"-13UNC x .75" LG SCREW AFTER PLATING
ITEM 8
BOLT TIGHTENING SEQUENCE SEE NOTE 6
0°
90°
180°
270°
DETAIL H
FROM DWG. 3035-3, SHEET 4
90°
3.75"±.01" DIA. RAISED FACE
3.25" REF.
SEE DETAIL F
.06"±.03"
.75"±.01"
-A-
3/4 NPT X .38" DEEP (FLAT BOTTOM DRILL) 1 PLACE
4.630" D.B.C.
6.00" DIA. ±.01"
-B-
DRILL .56±.03" DIA. THRU C'BORE .80"±.03" DIA. .50"±.03" DEEP
ITEM 4
63
.75" RECESS
6.25" DIA.
1.50" DIA.
4.630" D.B.C.
.25" +.00" -.12" R
.44" DIA.
STD.THD O-RING PORT PER J514, 7/16-20
.50-13UNC x .50" DP HELICOIL INSERT 1185-8CN-0500 (ITEM 12, REF.) OR EQUIV, 4 PLACES
2.67"
DETAIL D
FROM DWG. 3035-3, SHEET 4
3.250" +/- .010"
.187"+/-.010" TO SHARP CORNERS
R 4 PLACES SEE NOTE 5
63
.157"+/-.002"
20°
DETAIL F
ITEM NO. 7
WHC SPECIFICATION NO. WHC-S-0396
WHC PURCHASE ORDER NO. MJK-SPX-452727
3 SEE DCN 3035-18
2 9/30/96 SEE DCN 3035-10 J.T.G. P.S. P.S. E.D. G.G.
1 8/6/96 SEE DCN 3035-5 J.T.G. P.S. P.S. E.D. G.G.
NO. DATE REVISIONS DWN. CHK'D M.D. Q/A PROJ.
APPROVALS DATE
PROJ. G.G. 24 JUNE 96
Q/A E.D. 24 JUNE 96
MECH. DES. P.S. 21 JUNE 96
CHK'D. BY P.S. 21 JUNE 96
DWN. BY J.T.G. 21 JUNE 96
TRANSNUCLEAR, INC.
HAWTHORNE, N.Y.
TN-WHC CASK TRANSPORTATION SYSTEM LID
WHC DWG. NO. H-1-81535
NONE SCALE
B SIZE
3035-3 DWG. NO.
3 REV.
SHEET 5 OF 5
STATE OF NEW YORK
LICENSED PROFESSIONAL ENGINEER
068070
12/3/96



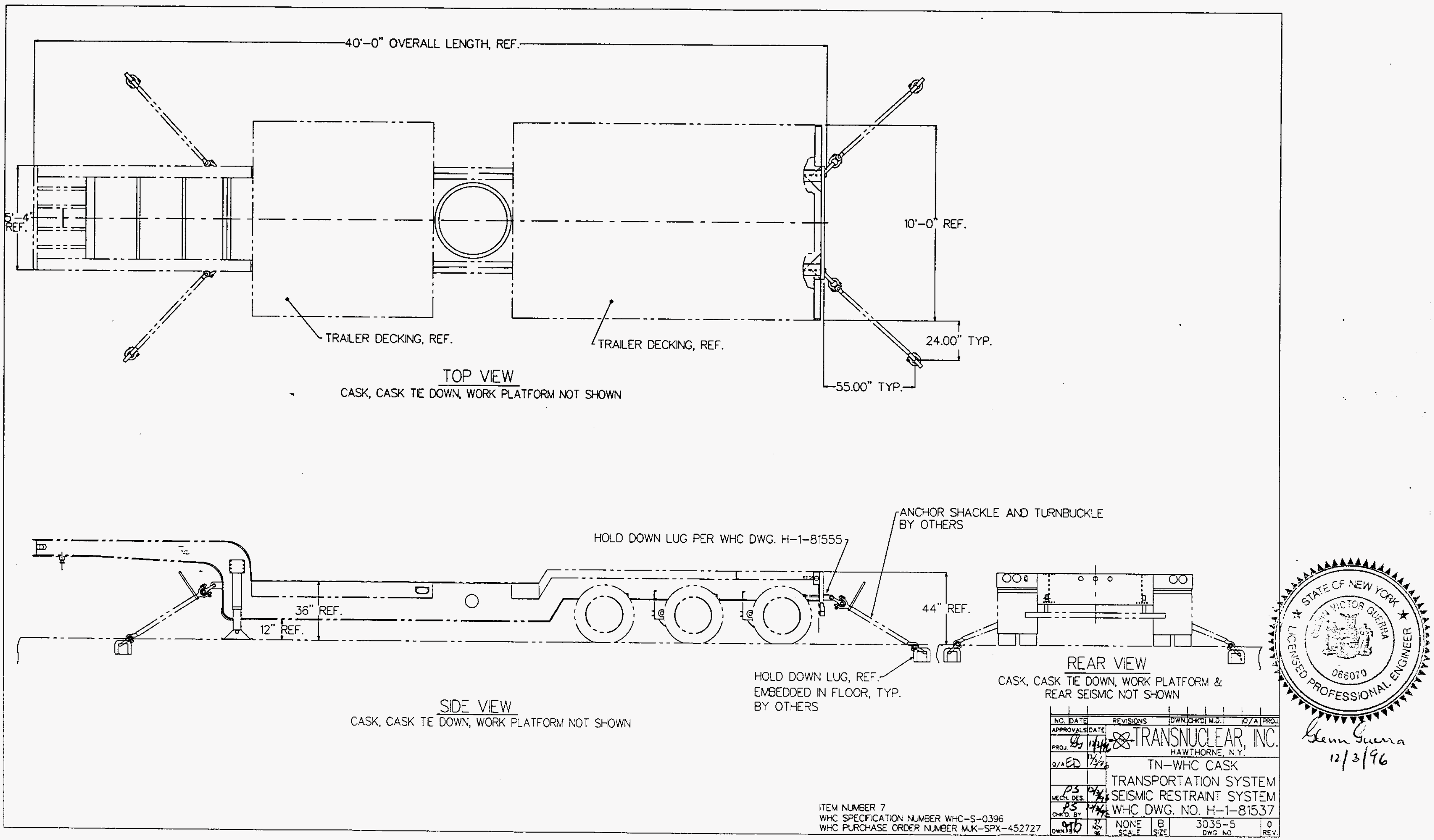
NOTES:

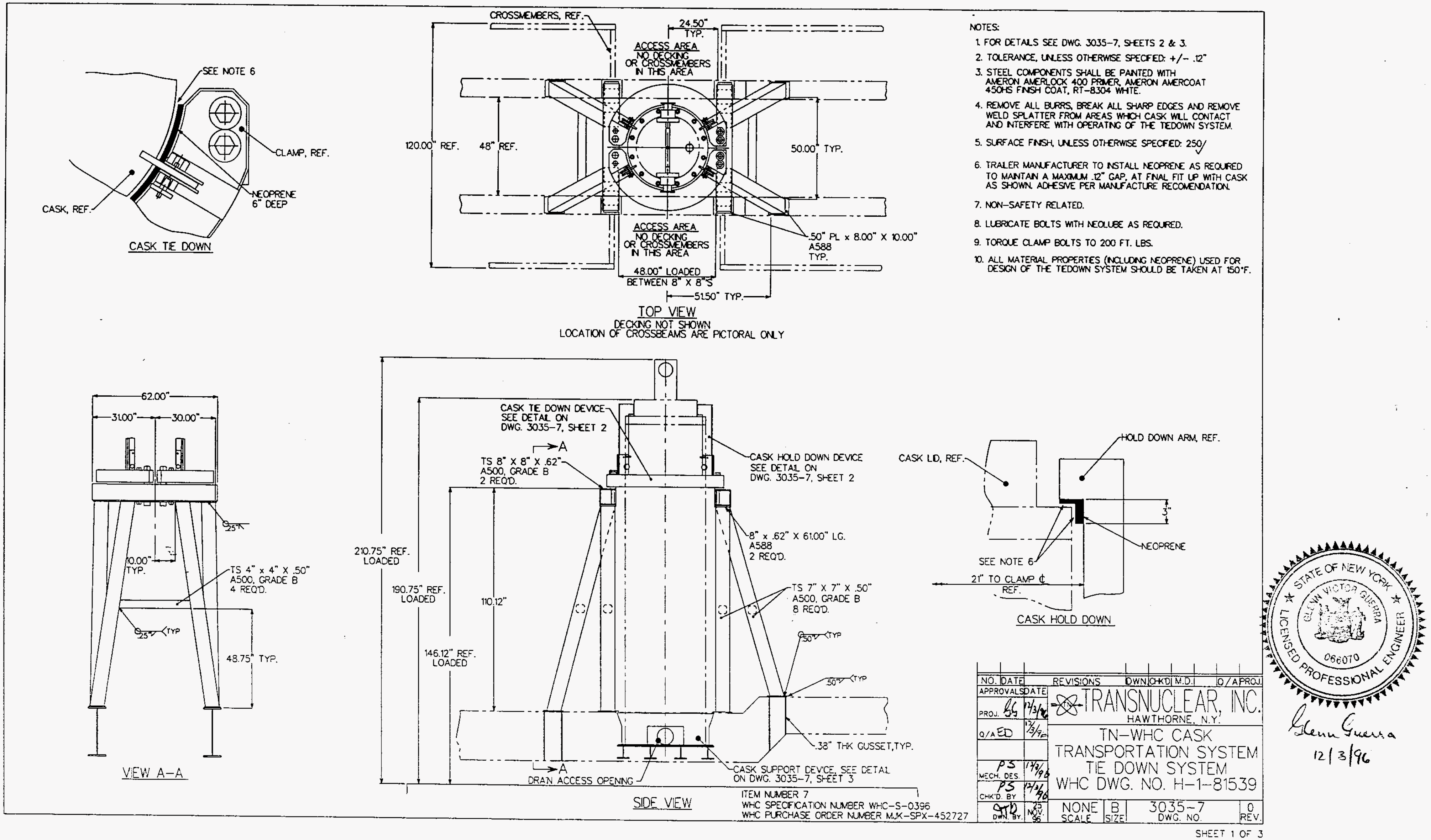
1) FOR ASSEMBLY SEE DWG. 3035-3, SHEET 1
2) MATERIAL: SST, .048" THICK.
3) TOLERANCE, UNLESS OTHERWISE SPECIFIED: +/- .12"
4) LETTERS AND ALIGNMENT MARK TO BE STAMPED THEN MARKED WITH BLACK INDELIBLE MARKER. (1)
5) "XX" SIGNIFIES CASK NUMBER, INSERT APPROPRIATE SEQUENTIAL NUMBER STARTING WITH 01, 02, 03,...ETC. (1)

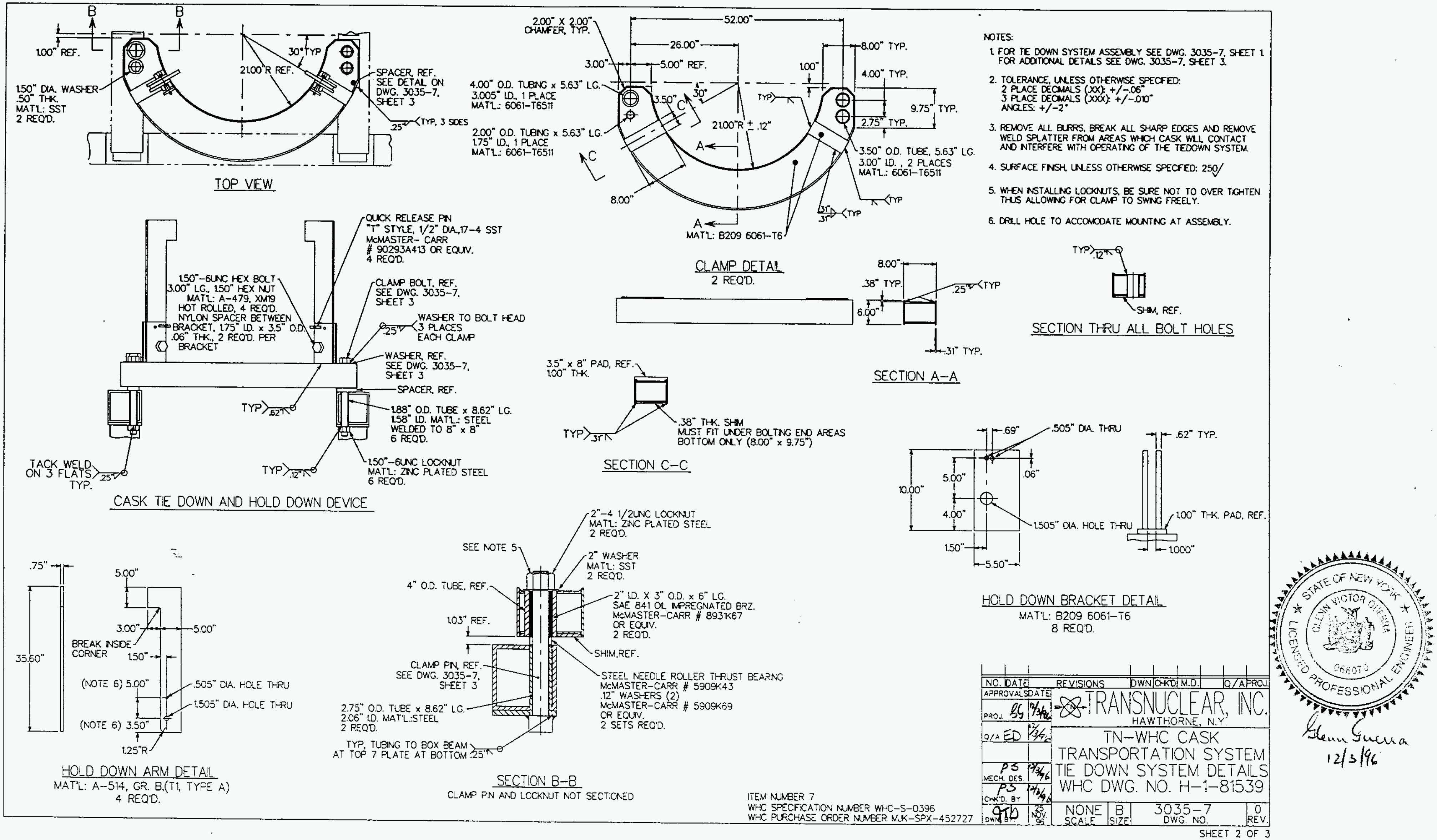
NO.	DATE	REVISIONS	DWN.	CHKD.	M.D.		Q/A	PROJ.
1	10/9/96	SEE DCN 3035-13	JTD	PS	PS		ED	GG

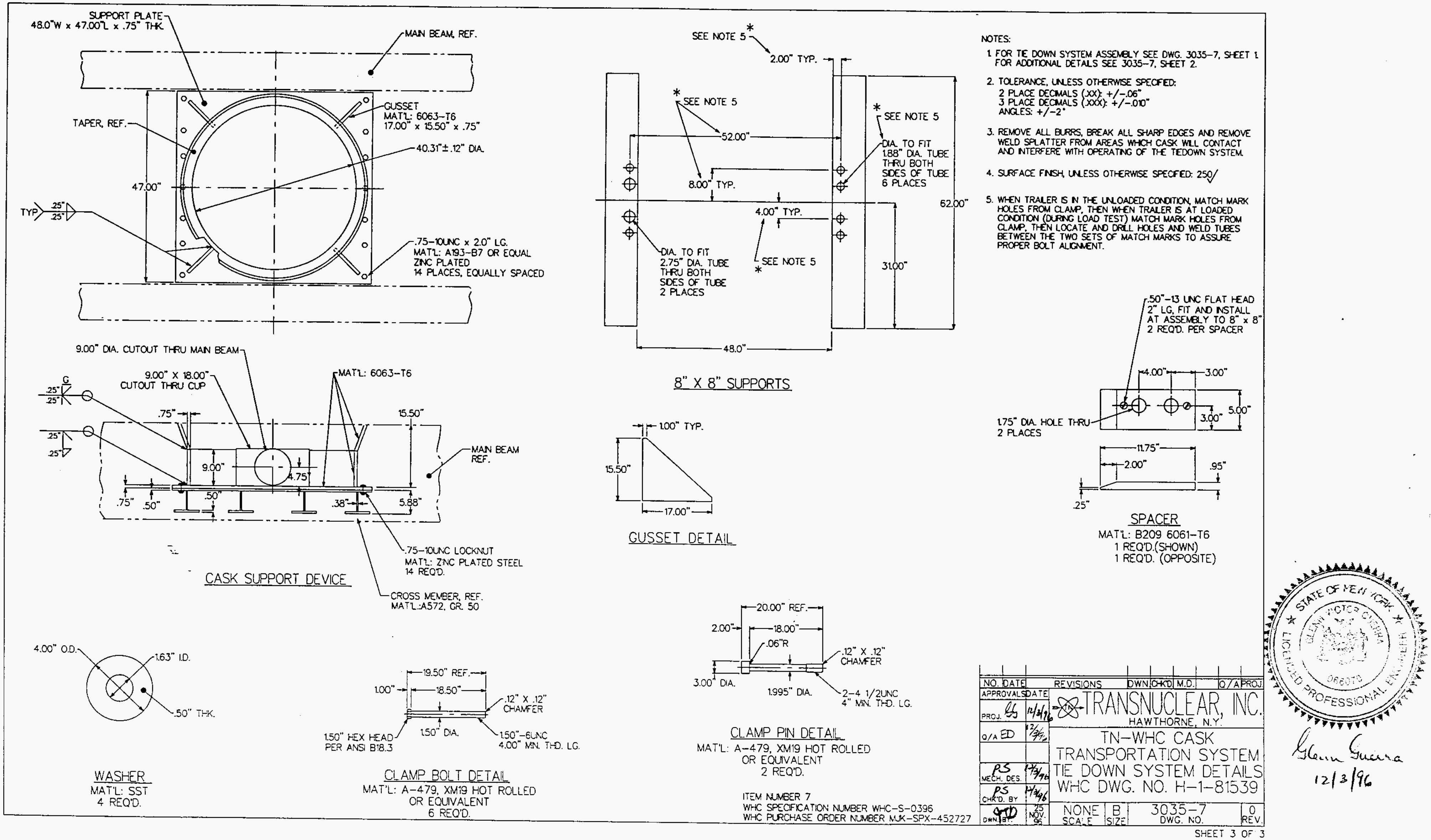
APPROVALS	DATE	
PROJ. G.G.	01 OCT. 96	TRANSNUCLEAR, INC. HAWTHORNE, N.Y.
Q/A E.D.	01 OCT. 96	TN-WHC CASK
		NAME PLATE
MECH DES. P.S.	27 SEPT. 96	WHC DWG. NO. H-1-81536
CHKD. BY P.S.	27 SEPT. 96	
DWN. BY J.T.G.	26 SEPT. 96	SCALE: HALF; SIZE: B; DWG. NO. 3035-4; REV. 1

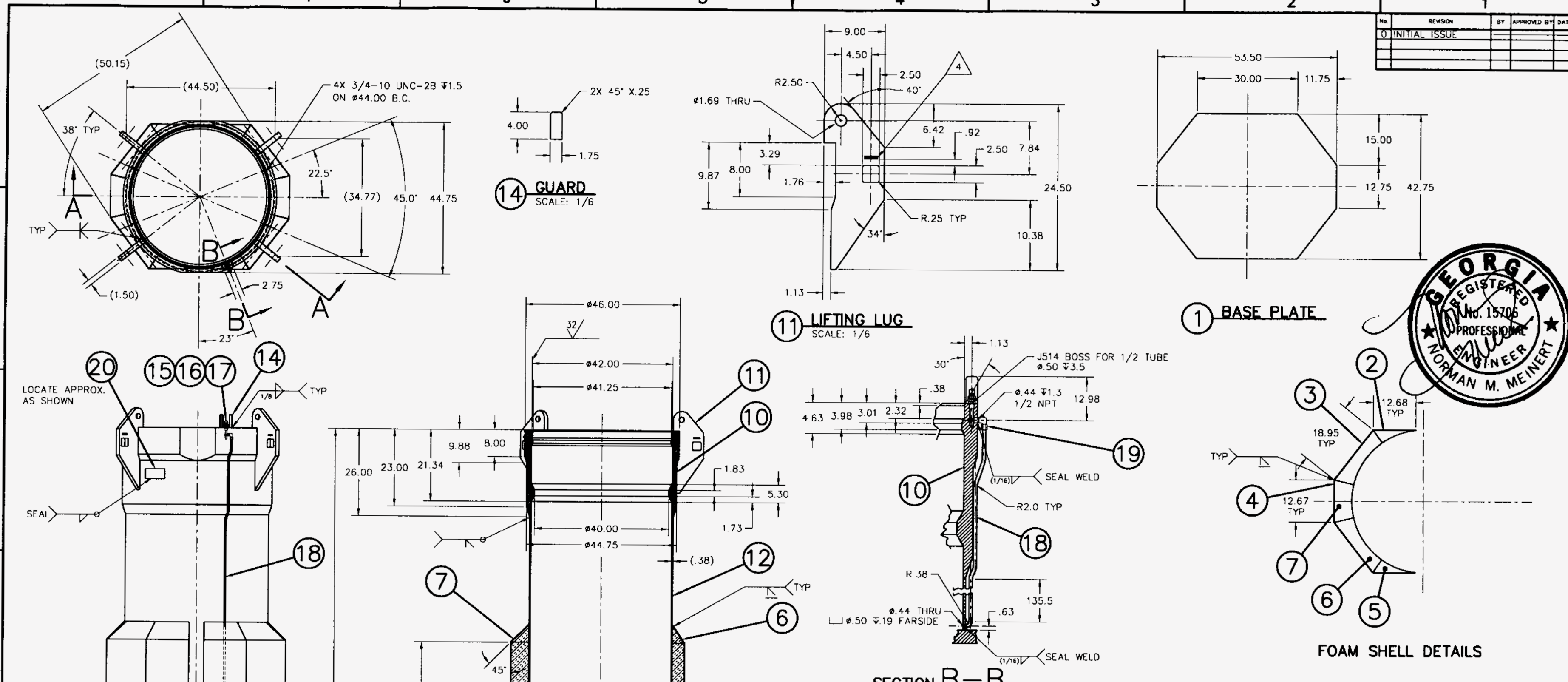
STATE OF NEW YORK LICENSED PROFESSIONAL ENGINEER 063079
Glenn Guerra 12/3/96

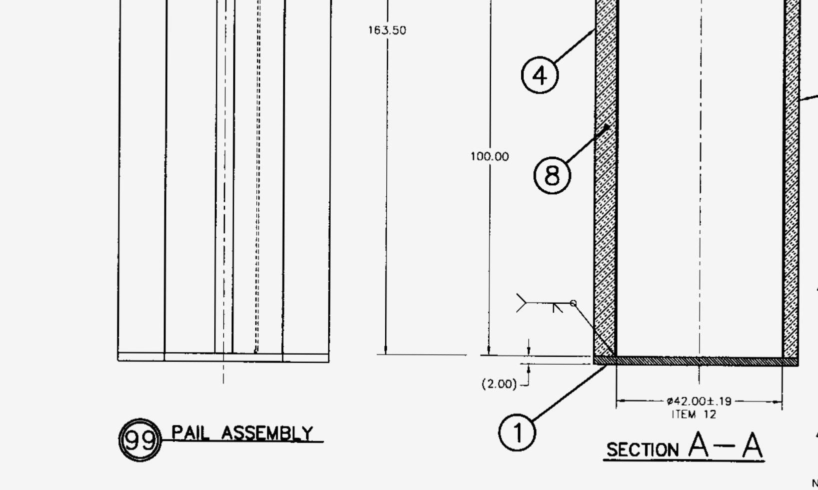

40'-0" OVERALL LENGTH, REF.
5'-4" REF.
10'-0" REF.
24.00" TYP.
55.00" TYP.
TRAILER DECKING, REF.
TRAILER DECKING, REF.
TOP VIEW
CASK, CASK TIE DOWN, WORK PLATFORM NOT SHOWN
ANCHOR SHACKLE AND TURNBUCKLE BY OTHERS
HOLD DOWN LUG PER WHC DWG. H-1-81555
36" REF.
12" REF.
44" REF.
HOLD DOWN LUG, REF. EMBEDDED IN FLOOR, TYP. BY OTHERS
SIDE VIEW
CASK, CASK TIE DOWN, WORK PLATFORM NOT SHOWN
REAR VIEW
CASK, CASK TIE DOWN, WORK PLATFORM & REAR SEISMIC NOT SHOWN
ITEM NUMBER 7
WHC SPECIFICATION NUMBER WHC-S-0396
WHC PURCHASE ORDER NUMBER MJK-SPX-452727
TRANSNUCLEAR, INC.
HAWTHORNE, N.Y.
TN-WHC CASK
TRANSPORTATION SYSTEM
SEISMIC RESTRAINT SYSTEM
WHC DWG. NO. H-1-81537
NONE SCALE
B SIZE
3035-5 DWG NO.
0 REV.
STATE OF NEW YORK
VICTOR GUERRA
066070
LICENSED PROFESSIONAL ENGINEER
12/3/96


CROSSMEMBERS, REF.
24.50" TYP.
ACCESS AREA
NO DECKING OR CROSSMEMBERS IN THIS AREA
120.00" REF.
48" REF.
50.00" TYP.
.50" PL x 8.00" X 10.00" A588 TYP.
48.00" LOADED BETWEEN 8" X 8"S
51.50" TYP.
TOP VIEW
DECKING NOT SHOWN
LOCATION OF CROSSBEAMS ARE PICTORAL ONLY
SEE NOTE 6
CLAMP, REF.
NEOPRENE 6" DEEP
CASK, REF.
CASK TIE DOWN
NOTES:
1. FOR DETAILS SEE DWG. 3035-7, SHEETS 2 & 3.
2. TOLERANCE, UNLESS OTHERWISE SPECIFIED: +/- .12"
3. STEEL COMPONENTS SHALL BE PAINTED WITH AMERON AMERLOCK 400 PRIMER, AMERON AMERCOAT 450HS FINISH COAT, RT-8304 WHITE.
4. REMOVE ALL BURRS, BREAK ALL SHARP EDGES AND REMOVE WELD SPLATTER FROM AREAS WHICH CASK WILL CONTACT AND INTERFERE WITH OPERATING OF THE TIEDOWN SYSTEM.
5. SURFACE FINISH, UNLESS OTHERWISE SPECIFIED: 250
6. TRAILER MANUFACTURER TO INSTALL NEOPRENE AS REQUIRED TO MAINTAIN A MAXIMUM .12" GAP, AT FINAL FIT UP WITH CASK AS SHOWN. ADHESIVE PER MANUFACTURE RECOMENDATION.
7. NON-SAFETY RELATED.
8. LUBRICATE BOLTS WITH NEOLUBE AS REQUIRED.
9. TORQUE CLAMP BOLTS TO 200 FT. LBS.
10. ALL MATERIAL PROPERTIES (INCLUDING NEOPRENE) USED FOR DESIGN OF THE TIEDOWN SYSTEM SHOULD BE TAKEN AT 150°F.
62.00"
31.00"
30.00"
.25
10.00" TYP.
TS 4" x 4" X .50" A500, GRADE B 4 REQ'D.
.25 TYP
48.75" TYP.
VIEW A-A
CASK TIE DOWN DEVICE SEE DETAIL ON DWG. 3035-7, SHEET 2
A
TS 8" X 8" X .62" A500, GRADE B 2 REQ'D.
CASK HOLD DOWN DEVICE SEE DETAIL ON DWG. 3035-7, SHEET 2
210.75" REF. LOADED
190.75" REF. LOADED
110.12"
146.12" REF. LOADED
8" x .62" X 61.00" LG. A588 2 REQ'D.
TS 7" X 7" X .50" A500, GRADE B 8 REQ'D.
.50 TYP
.50 TYP
.38" THK GUSSET,TYP.
A
DRAIN ACCESS OPENING
CASK SUPPORT DEVICE, SEE DETAIL ON DWG. 3035-7, SHEET 3
SIDE VIEW
ITEM NUMBER 7
WHC SPECIFICATION NUMBER WHC-S-0396
WHC PURCHASE ORDER NUMBER MJK-SPX-452727
CASK LID, REF.
HOLD DOWN ARM, REF.
NEOPRENE
SEE NOTE 6
21" TO CLAMP ℄ REF.
CASK HOLD DOWN
NO. DATE REVISIONS DWN CHK'D M.D.I. Q/A PROJ.
APPROVALS DATE
PROJ. 12/3/96
Q/A ED 12/3/96
MECH. DES. PS 12/3/96
CHK'D. BY PS 12/3/96
DWN. BY 25 NOV. 96
TRANSNUCLEAR, INC.
HAWTHORNE, N.Y.
TN-WHC CASK TRANSPORTATION SYSTEM TIE DOWN SYSTEM
WHC DWG. NO. H-1-81539
NONE SCALE
B SIZE
3035-7 DWG. NO.
0 REV.
SHEET 1 OF 3
STATE OF NEW YORK
GLENN VICTOR GUERRA
066070
LICENSED PROFESSIONAL ENGINEER
Glenn Guerra
12/3/96


TOP VIEW
CASK TIE DOWN AND HOLD DOWN DEVICE
CLAMP DETAIL
2 REQ'D.
SECTION A-A
SECTION THRU ALL BOLT HOLES
SECTION C-C
HOLD DOWN BRACKET DETAIL
MAT'L: B209 6061-T6
8 REQ'D.
HOLD DOWN ARM DETAIL
MAT'L: A-514, GR. B,(T1, TYPE A)
4 REQ'D.
SECTION B-B
CLAMP PIN AND LOCKNUT NOT SECTIONED
NOTES:
1. FOR TIE DOWN SYSTEM ASSEMBLY SEE DWG. 3035-7, SHEET 1. FOR ADDITIONAL DETAILS SEE DWG. 3035-7, SHEET 3.
2. TOLERANCE, UNLESS OTHERWISE SPECIFIED: 2 PLACE DECIMALS (.XX): +/-.06" 3 PLACE DECIMALS (.XXX): +/-.010" ANGLES: +/-2°
3. REMOVE ALL BURRS, BREAK ALL SHARP EDGES AND REMOVE WELD SPLATTER FROM AREAS WHICH CASK WILL CONTACT AND INTERFERE WITH OPERATING OF THE TIEDOWN SYSTEM.
4. SURFACE FINISH, UNLESS OTHERWISE SPECIFIED: 250
5. WHEN INSTALLING LOCKNUTS, BE SURE NOT TO OVER TIGHTEN THUS ALLOWING FOR CLAMP TO SWING FREELY.
6. DRILL HOLE TO ACCOMODATE MOUNTING AT ASSEMBLY.
ITEM NUMBER 7
WHC SPECIFICATION NUMBER WHC-S-0396
WHC PURCHASE ORDER NUMBER MJK-SPX-452727
TRANSNUCLEAR, INC.
HAWTHORNE, N.Y.
TN-WHC CASK TRANSPORTATION SYSTEM TIE DOWN SYSTEM DETAILS
WHC DWG. NO. H-1-81539
NONE SCALE
B SIZE
3035-7 DWG. NO.
0 REV.
SHEET 2 OF 3
STATE OF NEW YORK
GLENN VICTOR GUERRA
LICENSED PROFESSIONAL ENGINEER
066070
12/3/96


SUPPORT PLATE 48.0"W x 47.00"L x .75" THK.
MAIN BEAM, REF.
TAPER, REF.
GUSSET MAT'L: 6063-T6 17.00" x 15.50" x .75"
40.31"±.12" DIA.
47.00"
TYP .25" .25"
.75-10UNC x 2.0" LG. MAT'L: A193-B7 OR EQUAL ZINC PLATED 14 PLACES, EQUALLY SPACED
9.00" DIA. CUTOUT THRU MAIN BEAM
9.00" X 18.00" CUTOUT THRU CUP
MAT'L: 6063-T6
.75"
15.50"
MAIN BEAM REF.
9.00"
4.75"
.75" .50" .50" .38" 5.88"
.75-10UNC LOCKNUT MAT'L: ZINC PLATED STEEL 14 REQ'D.
CROSS MEMBER, REF. MAT'L:A572, GR. 50
CASK SUPPORT DEVICE
SEE NOTE 5
2.00" TYP.
SEE NOTE 5
SEE NOTE 5
52.00"
DIA. TO FIT 1.88" DIA. TUBE THRU BOTH SIDES OF TUBE 6 PLACES
8.00" TYP.
4.00" TYP.
62.00"
DIA. TO FIT 2.75" DIA. TUBE THRU BOTH SIDES OF TUBE 2 PLACES
SEE NOTE 5
31.00"
48.0"
8" X 8" SUPPORTS
1.00" TYP.
15.50"
17.00"
GUSSET DETAIL
NOTES:
1. FOR TIE DOWN SYSTEM ASSEMBLY SEE DWG. 3035-7, SHEET 1. FOR ADDITIONAL DETAILS SEE 3035-7, SHEET 2.
2. TOLERANCE, UNLESS OTHERWISE SPECIFIED: 2 PLACE DECIMALS (.XX): +/-.06" 3 PLACE DECIMALS (.XXX): +/-.010" ANGLES: +/-2°
3. REMOVE ALL BURRS, BREAK ALL SHARP EDGES AND REMOVE WELD SPLATTER FROM AREAS WHICH CASK WILL CONTACT AND INTERFERE WITH OPERATING OF THE TIEDOWN SYSTEM.
4. SURFACE FINISH, UNLESS OTHERWISE SPECIFIED: 250
5. WHEN TRAILER IS IN THE UNLOADED CONDITION, MATCH MARK HOLES FROM CLAMP, THEN WHEN TRAILER IS AT LOADED CONDITION (DURING LOAD TEST) MATCH MARK HOLES FROM CLAMP. THEN LOCATE AND DRILL HOLES AND WELD TUBES BETWEEN THE TWO SETS OF MATCH MARKS TO ASSURE PROPER BOLT ALIGNMENT.
.50"-13 UNC FLAT HEAD 2" LG, FIT AND INSTALL AT ASSEMBLY TO 8" x 8" 2 REQ'D. PER SPACER
4.00" 3.00"
1.75" DIA. HOLE THRU 2 PLACES
3.00" 5.00"
11.75"
2.00" .95"
.25"
SPACER
MAT'L: B209 6061-T6
1 REQ'D.(SHOWN)
1 REQ'D. (OPPOSITE)
4.00" O.D.
1.63" I.D.
.50" THK.
WASHER
MAT'L: SST
4 REQ'D.
19.50" REF.
1.00"
18.50"
.12" X .12" CHAMFER
1.50" HEX HEAD PER ANSI B18.3
1.50" DIA.
1.50"-6UNC 4.00" MIN. THD. LG.
CLAMP BOLT DETAIL
MAT'L: A-479, XM19 HOT ROLLED OR EQUIVALENT
6 REQ'D.
20.00" REF.
2.00"
18.00"
.06"R
.12" X .12" CHAMFER
3.00" DIA.
1.995" DIA.
2-4 1/2UNC 4" MIN. THD. LG.
CLAMP PIN DETAIL
MAT'L: A-479, XM19 HOT ROLLED OR EQUIVALENT
2 REQ'D.
ITEM NUMBER 7
WHC SPECIFICATION NUMBER WHC-S-0396
WHC PURCHASE ORDER NUMBER MJK-SPX-452727
NO. DATE REVISIONS DWN CHK'D M.D. Q/A PROJ
APPROVALS DATE
PROJ. 12/3/96
Q/A ED 12/3/96
MECH. DES. PS 12/3/96
CHK'D. BY PS 12/3/96
DWN. BY 25 NOV. 96
TRANSNUCLEAR, INC.
HAWTHORNE, N.Y.
TN-WHC CASK TRANSPORTATION SYSTEM TIE DOWN SYSTEM DETAILS WHC DWG. NO. H-1-81539
NONE SCALE
B SIZE
3035-7 DWG. NO.
0 REV.
SHEET 3 OF 3
STATE OF NEW YORK
LICENSED PROFESSIONAL ENGINEER
Glenn Guerra
12/3/96





PROJECT INFORMATION
WHC SPECIFICATION NO.: WHC-S-0396
ITEM 7
WHC P.O. NO.: MJK-SPX-452727
TRANSNUCLEAR, INC. PROJECT NO.: 3035

4. ENGRAVE STRIPE .50 WIDE X 2.00 LONG X .03 DEEP AND FILL WITH RED WEATHER RESISTANT PAINT. TYPICAL BOTH SIDES.

3. REMOVE ALL OIL AND GREASE FROM SURFACES PER SSPC-S-1. ABRASIVE BLAST PER SSPC-SP 10. PRIME AND PAINT WITH ONE COAT OF AMERCOAT NUMBER 64 PRIMER AND FINISH WITH TWO COATS OF WHITE AMERCOAT NUMBER 66 SEAL GLOSS TOPCOAT.

2. INDICATES SAFETY RELATED LOAD PATH COMPONENT.

1. FABRICATE PER NAC SPECIFICATION 457-S-02.

NOTES:

97 ASSY	98 ASSY	99 ASSY	ITEM	NAME	MATERIAL	SPEC	DRAWING No.	DESCRIPTION
		1	20	NAMEPLATE			457-111-39	
		1	19	TUBE FITTING	ST. STL.	COML		PARKER #SS-8-8 CBU
		1	18	VENT TUBE	304 ST. STL.	ASTM A269		1/2 DIA X .035 WALL
		1	17	O-RING	EPDM	COML		PARKER 3-908E515-80
		1	16	QUICK DISCONNECT	ST. STL.	COML		HANSEN #LL3-K-8
		1	15	ADAPTER			457-103-10	
		2	14	GUARD	304 ST. STL.	ASTM A240		1/4 PLATE
			13					
		1	12	PAIL SHELL	304 ST. STL.	ASTM A240		3/8 PLATE
		4	11	LIFTING LUG	CARBON STEEL	ASTM A533, GR B, CL1		1 1/2 PLATE
		1	10	TOP SHELL	304 ST. STL.	ASTM A182		FORGING
			9					
		AR	8	FOAM	POLYURETHANE	COML		LAST-A-FOAM FR-6700 6#/CU.FT
		2	7	SHELL TOP	304 ST. STL.	ASTM A240		11 GA SHEET
		4	6	SHELL TOP	304 ST. STL.	ASTM A240		11 GA SHEET
		4	5	SHELL TOP	304 ST. STL.	ASTM A240		11 GA SHEET
		2	4	SHELL SIDE	304 ST. STL.	ASTM A240		11 GA SHEET
		4	3	SHELL SIDE	304 ST. STL.	ASTM A240		11 GA SHEET
		4	2	SHELL SIDE	304 ST. STL.	ASTM A240		11 GA SHEET
		1	1	BASE PLATE	304 ST. STL.	ASTM A240		2 PLATE

QUANTITY

No.	REVISION	BY	APPROVED BY	DATE
0	INITIAL ISSUE			

SYM.	GEOMETRY
⏥	FLATNESS
—	STRAIGHTNESS
∠	ANGULARITY
⊥	PERPENDICULARITY
//	PARALLELISM
◎	CONCENTRICITY
⌖	TRUE POSITION

TOLERANCES UNLESS OTHERWISE SPECIFIED

3 PLACE DEC.	TOL.	2 PLACE DEC.	TOL.
UNDER 3	±.003	UNDER 6	±.02
3-12	±.005	6-18	±.03
OVER 12	±.010	OVER 18	±.06
1 PLACE DEC.	±.1	FILLETS .015 TO .030	
FINISH (√)-AA-125 MICRO IN		ANGLES ±.5°	
THREADS-UNIFIED CL2A-2B			

RADIUS CORNERS .015-.030

TYPE OF DRAWING: ENGINEERING

GROUP	NAME	DATE
DRAWN	[signature]	12/2/96
CHECK	[signature]	12/2/96
DESIGN AND ANALYSIS	[signature]	12-2-96
LICENSING	N/A	
PROJECTS	[signature]	12-2-96
QUALITY	[signature]	12-2-96
V.P. ENGINEERING	[signature]	12/2/96
NEXT ASSEMBLY	457-104	

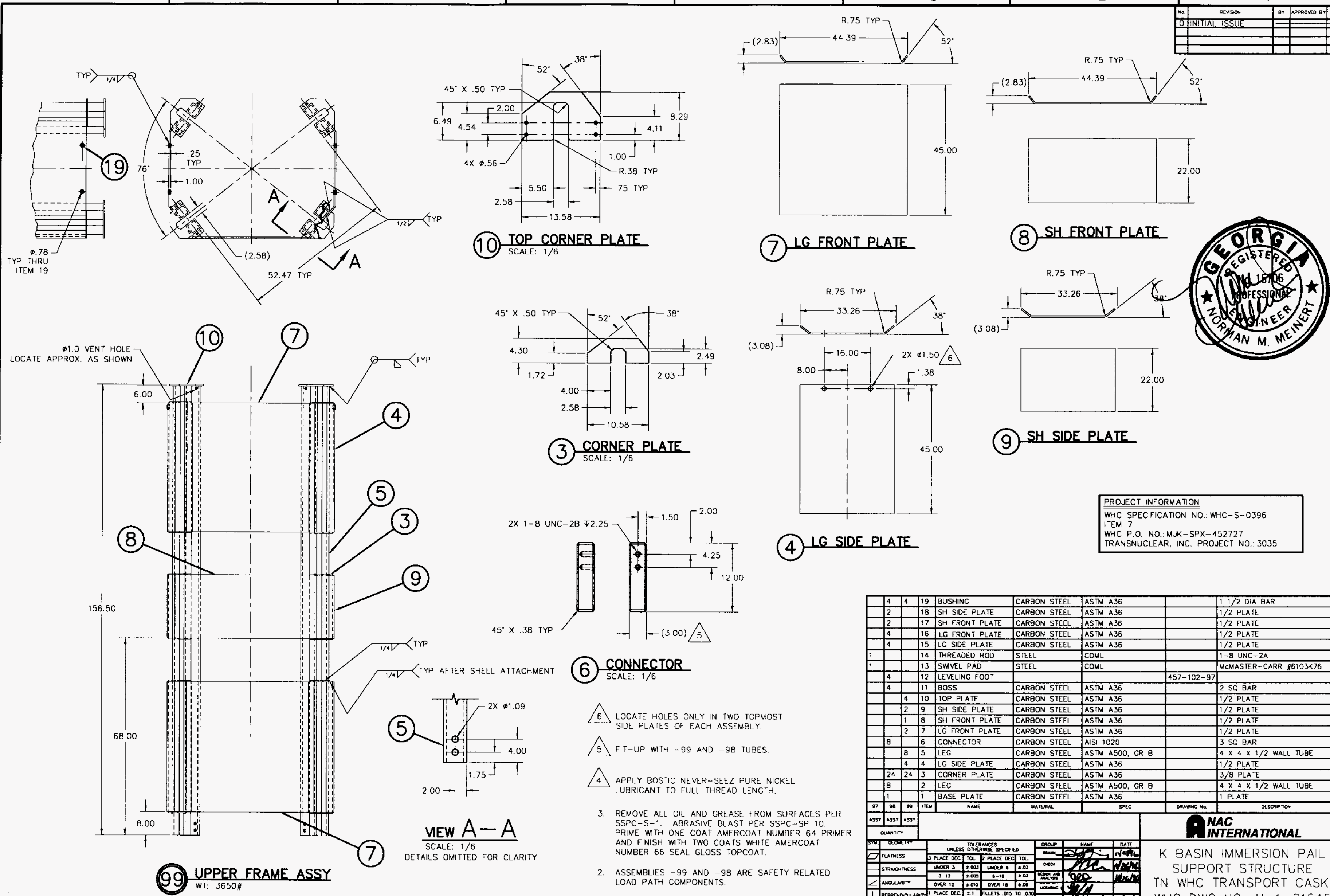
NAC INTERNATIONAL

K BASIN IMMERSION PAIL
TN WHC TRANSPORT CASK,
WHC DWG NO: H-1-81544

PROJECT 457	DESIGN PACKAGE	DRAWING 101	REV 0
SCALE 1/12	EST.WT. 5700#	SH 1 OF 1	2:55PM 12-2-96

GEORGIA REGISTERED No. 15706 PROFESSIONAL ENGINEER NORMAN M. MEINERT

No.	REVISION	BY	APPROVED BY	DATE
0	INITIAL ISSUE			



PROJECT INFORMATION
WHC SPECIFICATION NO.: WHC-S-0396
ITEM 7
WHC P.O. NO.: MJK-SPX-452727
TRANSNUCLEAR, INC. PROJECT NO.: 3035

6 LOCATE HOLES ONLY IN TWO TOPMOST SIDE PLATES OF EACH ASSEMBLY.

5 FIT-UP WITH -99 AND -98 TUBES.

4 APPLY BOSTIC NEVER-SEEZ PURE NICKEL LUBRICANT TO FULL THREAD LENGTH.

3. REMOVE ALL OIL AND GREASE FROM SURFACES PER SSPC-S-1. ABRASIVE BLAST PER SSPC-SP 10. PRIME WITH ONE COAT AMERCOAT NUMBER 64 PRIMER AND FINISH WITH TWO COATS WHITE AMERCOAT NUMBER 66 SEAL GLOSS TOPCOAT.

2. ASSEMBLIES -99 AND -98 ARE SAFETY RELATED LOAD PATH COMPONENTS.

1. FABRICATE PER NAC SPECIFICATION 457-S-02.

NOTES:

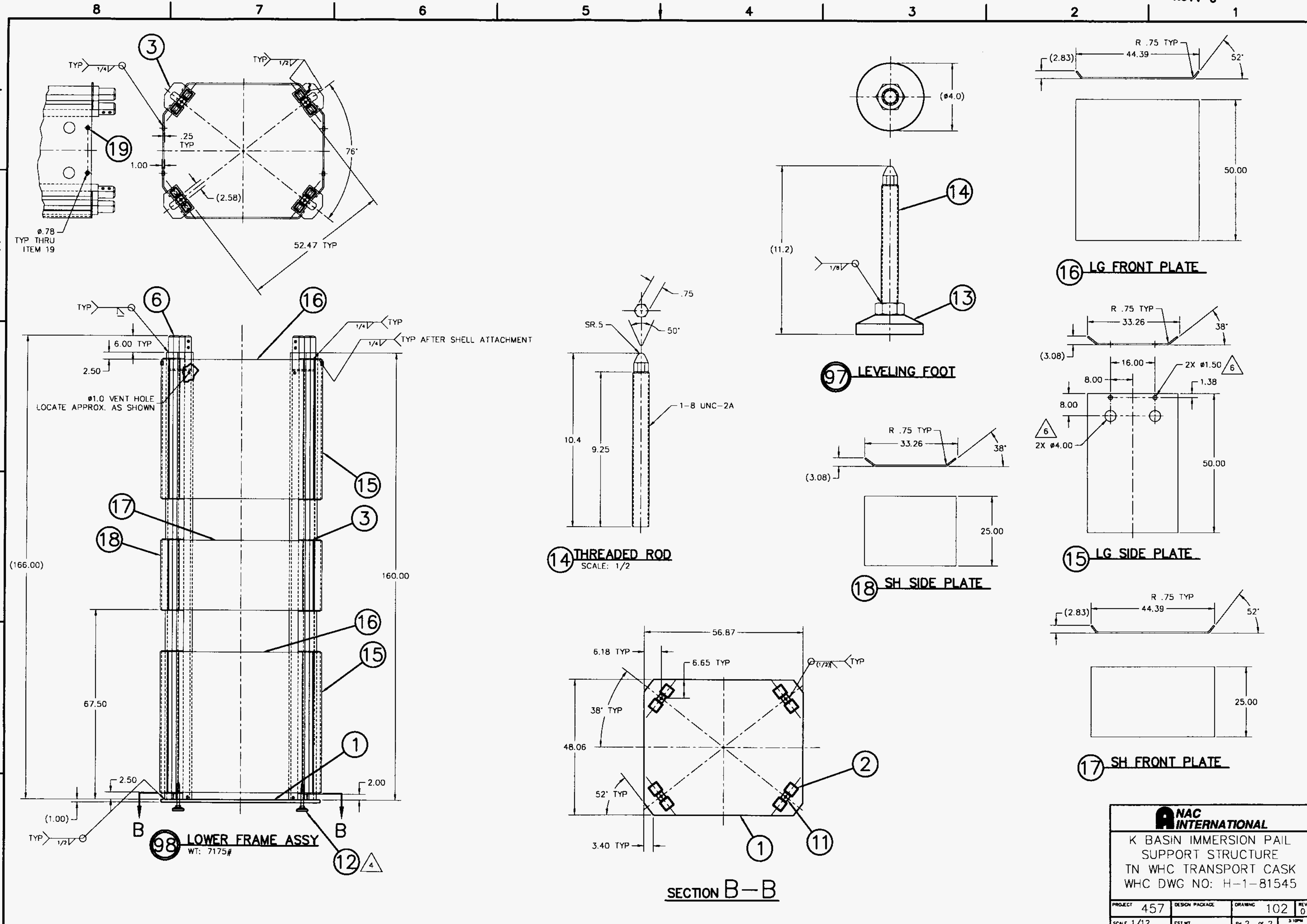
97 ASSY	98 ASSY	99 ASSY	ITEM	NAME	MATERIAL	SPEC	DRAWING No.	DESCRIPTION
	4	4	19	BUSHING	CARBON STEEL	ASTM A36		1 1/2 DIA BAR
	2		18	SH SIDE PLATE	CARBON STEEL	ASTM A36		1/2 PLATE
	2		17	SH FRONT PLATE	CARBON STEEL	ASTM A36		1/2 PLATE
	4		16	LG FRONT PLATE	CARBON STEEL	ASTM A36		1/2 PLATE
	4		15	LG SIDE PLATE	CARBON STEEL	ASTM A36		1/2 PLATE
1			14	THREADED ROD	STEEL	COML		1-8 UNC-2A
1			13	SWIVEL PAD	STEEL	COML		McMASTER-CARR #6103K76
	4		12	LEVELING FOOT			457-102-97	
	4		11	BOSS	CARBON STEEL	ASTM A36		2 SQ BAR
		4	10	TOP PLATE	CARBON STEEL	ASTM A36		1/2 PLATE
		2	9	SH SIDE PLATE	CARBON STEEL	ASTM A36		1/2 PLATE
		1	8	SH FRONT PLATE	CARBON STEEL	ASTM A36		1/2 PLATE
		2	7	LG FRONT PLATE	CARBON STEEL	ASTM A36		1/2 PLATE
	8		6	CONNECTOR	CARBON STEEL	AISI 1020		3 SQ BAR
		8	5	LEG	CARBON STEEL	ASTM A500, GR B		4 X 4 X 1/2 WALL TUBE
		4	4	LG SIDE PLATE	CARBON STEEL	ASTM A36		1/2 PLATE
	24	24	3	CORNER PLATE	CARBON STEEL	ASTM A36		3/8 PLATE
	8		2	LEG	CARBON STEEL	ASTM A500, GR B		4 X 4 X 1/2 WALL TUBE
	1		1	BASE PLATE	CARBON STEEL	ASTM A36		1 PLATE

QUANTITY

NAC INTERNATIONAL

K BASIN IMMERSION PAIL SUPPORT STRUCTURE TN WHC TRANSPORT CASK, WHC DWG NO: H-1-81545

PROJECT 457 | DESIGN PACKAGE | DRAWING 102 | REV 0
SCALE 1/12 | EST WT. | SH 1 OF 2
TYPE OF DRAWING: ENGINEERING
NEXT ASSEMBLY 457-110



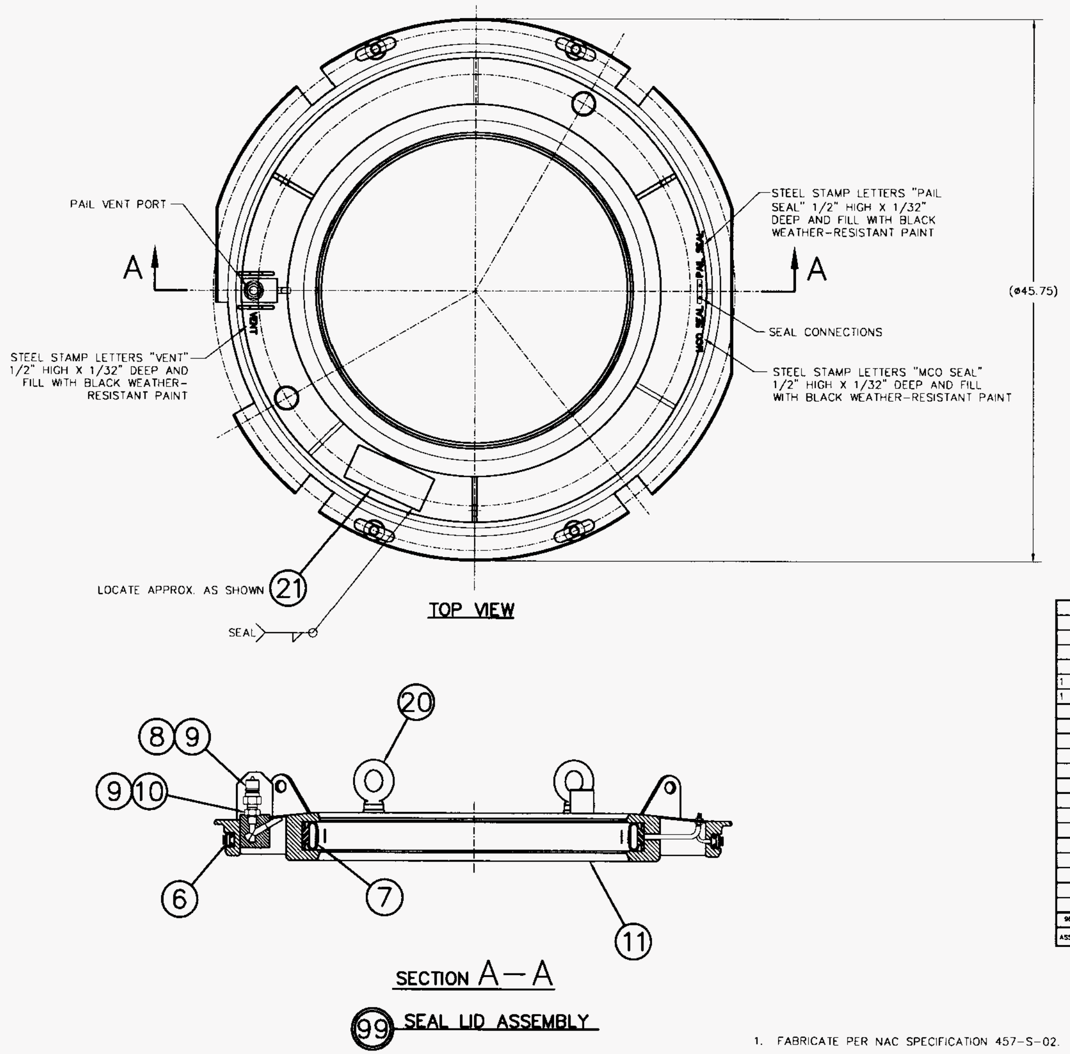
NAC INTERNATIONAL

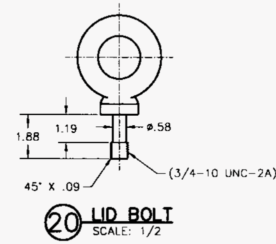
K BASIN IMMERSION PAIL SUPPORT STRUCTURE
TN WHC TRANSPORT CASK
WHC DWG NO: H-1-81545

PROJECT	DESIGN PACKAGE	DRAWING	REV
457		102	0
SCALE 1/12	EST.WT.	SH 2 OF 2	

No.	REVISION	BY	APPROVED BY	DATE
0	INITIAL ISSUE			

GEORGIA REGISTERED No. 15796 PROFESSIONAL ENGINEER NORMAN M. MEINERT





PROJECT INFORMATION
WHC SPECIFICATION NO.: WHC-S-0396
ITEM 7
WHC P.O. NO.: MJK-SPX-452727
TRANSNUCLEAR, INC. PROJECT NO.: 3035

96 ASSY	97 ASSY	98 ASSY	99 ASSY	ITEM	NAME	MATERIAL	SPEC	DRAWING No.	DESCRIPTION
			1	21	NAMEPLATE			457-111-35	
		4		20	LID BOLT	ST. STL.	COML		McMASTER-CARR #8891T84
		4		19	BOSS	304 ST. STL.	ASTM A276		1 3/4 DIA BAR
		2		18	VENT GUARD	304 ST. STL.	ASTM A240		1/4 PLATE
		2		17	GUIDE PIN POCKET			457-103-96	
1				16	POCKET END PLATE	304 ST. STL.	ASTM A240		11 GUAGE SHEET
1				15	POCKET TUBE	304 ST. STL.	ASTM A269		2" OD W/.12 WALL TUBE
		3		14	GUSSET	304 ST. STL.	ASTM A240		3/8 PLATE
		1		13	TOP PLATE	304 ST. STL.	ASTM A240		1/8 PLATE
		1		12	VENT WELDMENT			457-103-97	
			1	11	LID WELDMENT			457-103-98	
			1	10	ADAPTER	304 ST. STL.	ASTM A276		1 1/4 HEX BAR
			2	9	O-RING	EPDM	COML		PARKER #3-908E515-80
			1	8	QUICK DISCONNECT	ST. STL.	COML		HANSEN #LL3-K-8
			1	7	MCO SEAL	SILICONE	COML		CEFIL'AIR #736 W/ REC M8
			1	6	PAIL SEAL	SILICONE	COML		CEFIL'AIR #921 W/ REC M6
	1			5	VENT TUBE	304 ST. STL.	ASTM A240		1/2 DIA X .035 WALL TUBE
	1			4	BOSS	304 ST. STL.	ASTM A276		2 X 2 1/2 BAR
		3		3	LIFTING LUG	304 ST. STL.	ASTM A240		3/8 PLATE
		1		2	OUTER RING	304 ST. STL.	ASTM A182		FORGING
		1		1	CENTER RING	304 ST. STL.	ASTM A182		FORGING

QUANTITY

NOTES:

1. FABRICATE PER NAC SPECIFICATION 457-S-02.

TOLERANCES UNLESS OTHERWISE SPECIFIED

3 PLACE DEC	TOL.	2 PLACE DEC	TOL.
UNDER 3	±.003	UNDER 6	±.02
3-12	±.005	6-18	±.03
OVER 12	±.010	OVER 18	±.06
1 PLACE DEC.	±.1	FILLETS .015 TO .030	
FINISH (√)-AA-125 MICRO IN		ANGLES ±.5°	
THREADS-UNIFIED (2A-2B)			
RADIUS CORNERS .015-.030			

SYM. GEOMETRY: FLATNESS, STRAIGHTNESS, ANGULARITY, PERPENDICULARITY, PARALLELISM, CONCENTRICITY, TRUE POSITION

TYPE OF DRAWING: ENGINEERING

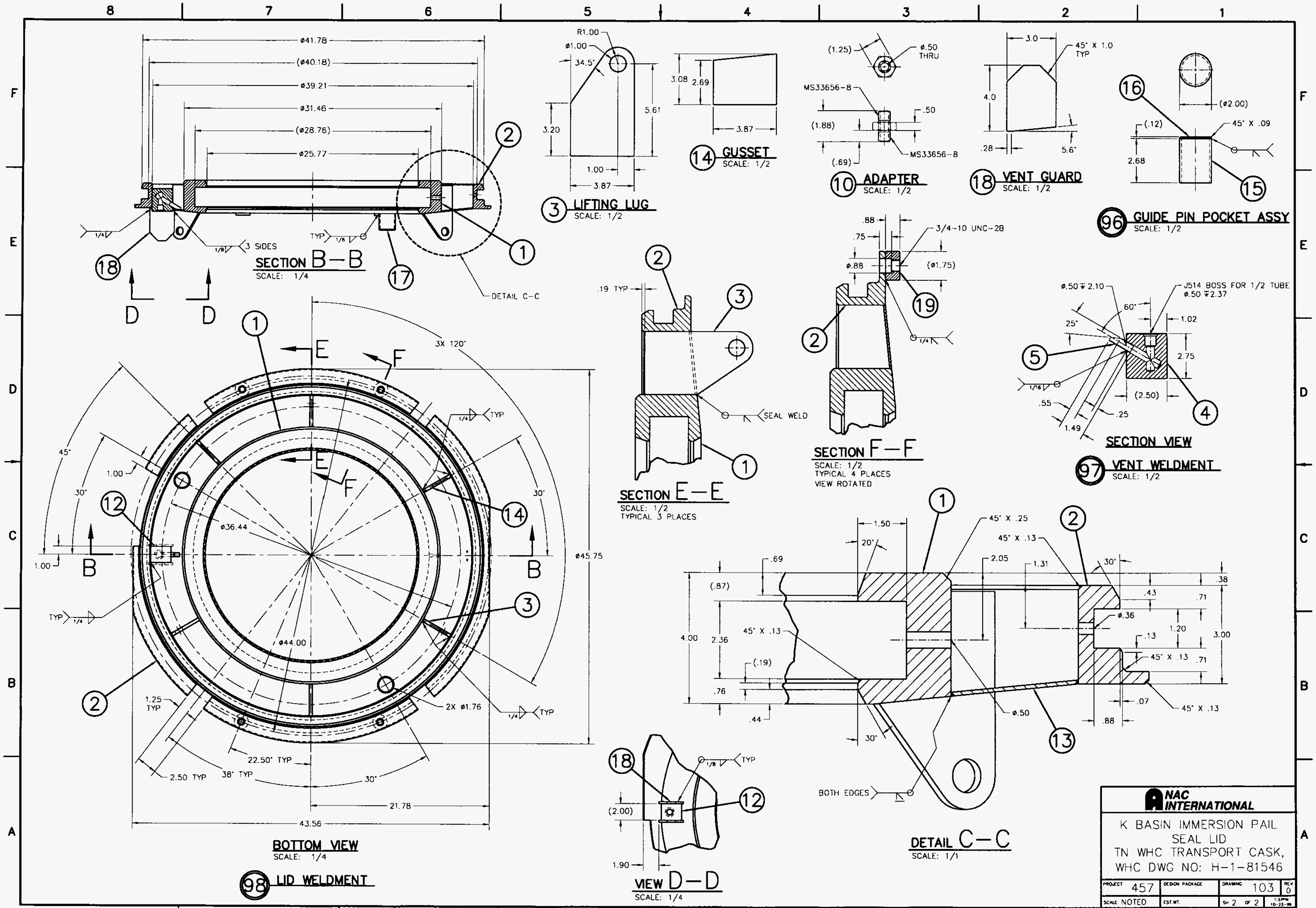
GROUP: DRAWN, CHECK, DESIGN AND ANALYSIS, LICENSING, PROJECT, QUALITY, V.P. ENGINEERING — NAME / DATE (signed)

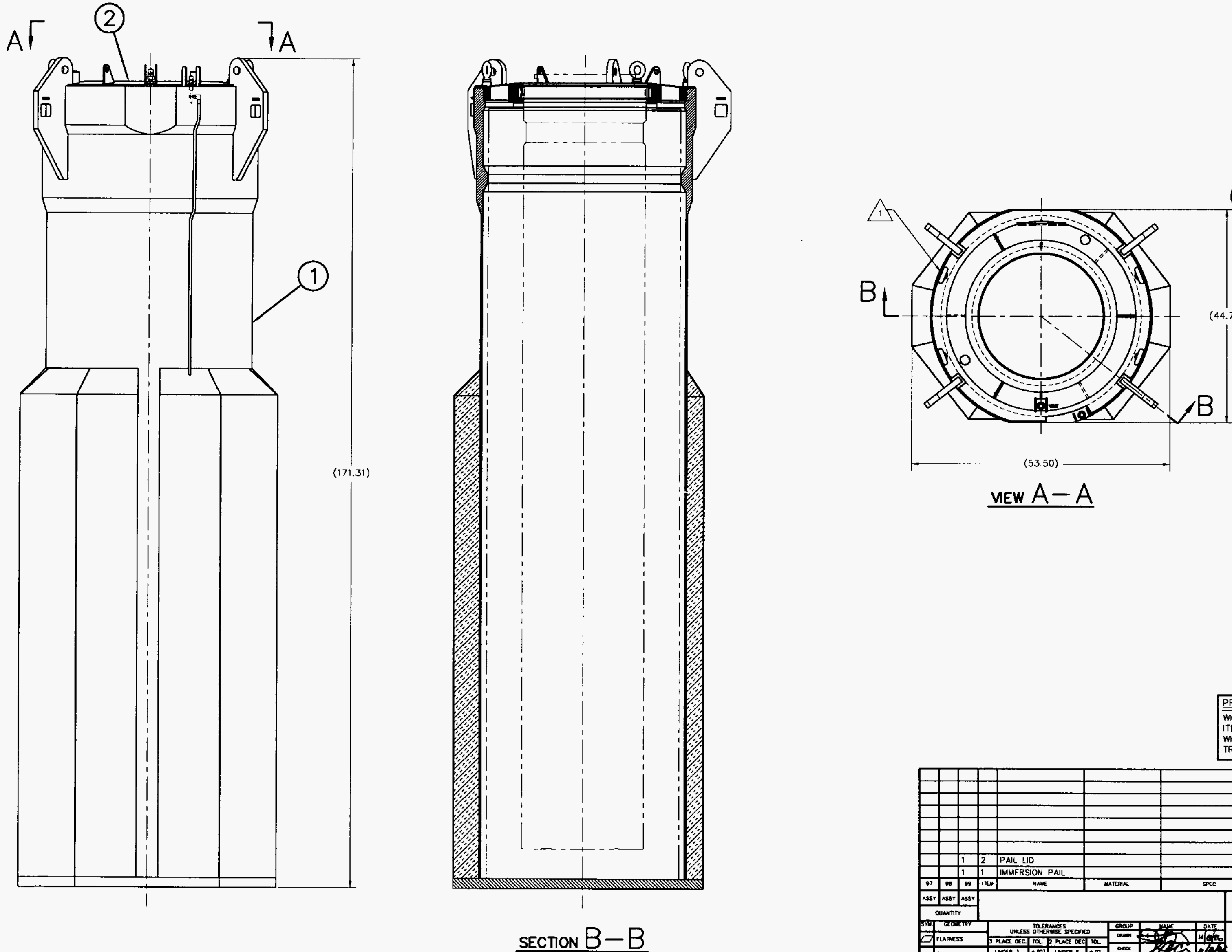
NEXT ASSEMBLY: 457-104

NAC INTERNATIONAL

K BASIN IMMERSION PAIL SEAL LID
TN WHC TRANSPORT CASK,
WHC DWG NO: H-1-81546

PROJECT	DESIGN PACKAGE	DRAWING	REV
457		103	0
SCALE 1/4	EST WT. 600#	SH 1 OF 2	


SECTION B-B
SCALE: 1/4
DETAIL C-C
LIFTING LUG
SCALE: 1/2
GUSSET
SCALE: 1/2
ADAPTER
SCALE: 1/2
VENT GUARD
SCALE: 1/2
GUIDE PIN POCKET ASSY
SCALE: 1/2
SECTION E-E
SCALE: 1/2
TYPICAL 3 PLACES
SECTION F-F
SCALE: 1/2
TYPICAL 4 PLACES
VIEW ROTATED
SECTION VIEW
VENT WELDMENT
SCALE: 1/2
BOTTOM VIEW
SCALE: 1/4
LID WELDMENT
VIEW D-D
SCALE: 1/4
DETAIL C-C
SCALE: 1/1
SEAL WELD
BOTH EDGES
MS33656-8
3/4-10 UNC-2B
J514 BOSS FOR 1/2 TUBE
NAC INTERNATIONAL
K BASIN IMMERSION PAIL
SEAL LID
TN WHC TRANSPORT CASK,
WHC DWG NO: H-1-81546
PROJECT 457
DRAWING 103
REV 0
SCALE NOTED
SH 2 OF 2



1 HAND-TIGHT ENGAGEMENT ON LID BOLTS.

No.	REVISION	BY	APPROVED BY	DATE
0	INITIAL ISSUE			

GEORGIA REGISTERED No. 15706 PROFESSIONAL ENGINEER NORMAN M. MEINERT

PROJECT INFORMATION
WHC SPECIFICATION NO.: WHC-S-0396
ITEM 7
WHC P.O. NO.: MJK-SPX-452727
TRANSNUCLEAR, INC. PROJECT NO.: 3035

97	98	99	ITEM	NAME	MATERIAL	SPEC	DRAWING No.	DESCRIPTION
		1	2	PAIL LID			457-103-99	
		1	1	IMMERSION PAIL			457-101-99	
ASSY	ASSY	ASSY						
QUANTITY								

NAC INTERNATIONAL

K BASIN IMMERSION PAIL ASSEMBLY, TN WHC TRANSPORT CASK, WHC DWG NO: H-1-81547

TOLERANCES UNLESS OTHERWISE SPECIFIED: 3 PLACE DEC. TOL.: UNDER 3 ±.003; 3-12 ±.005; OVER 12 ±.010. 2 PLACE DEC. TOL.: UNDER 6 ±.02; 6-18 ±.03; OVER 18 ±.06. 1 PLACE DEC. ±.1. FILLETS .015 TO .030. ANGLES ±.5°. RADIUS CORNERS .015-.030.

TYPE OF DRAWING: ENGINEERING

NEXT ASSEMBLY: 457-108

PROJECT 457 | DRAWING 104 | REV 0 | SCALE 1/8 | EST. WT. 6300# | SH 1 OF 1

No.	REVISION	BY	APPROVED BY	DATE
0	INITIAL ISSUE			

GEORGIA REGISTERED No. 15706 PROFESSIONAL ENGINEER NORMAN M. MEINERT

87 ASSY	88 ASSY	89 ASSY	90 ASSY	91 ASSY	92 ASSY	93 ASSY	94 ASSY	95 ASSY	96 ASSY	97 ASSY	98 ASSY	99 ASSY	ITEM	NAME	MATERIAL	SPEC	DRAWING No.	DESCRIPTION
										2			105	SPLIT RING	ST.STL.	COM'L		McMASTER-CARR #90905A659
										1			104	SAFETY SIGN			457-111-38	
1													103	ACTUATION PIN	STEEL	COM'L		1/2 DIA X 3.5 LG
1													102	BOSS	CARBON STEEL	AISI 1020		1 1/2 SQ BAR
1													101	GUSSET	CARBON STEEL	ASTM A36		1/2 PLATE
1													100	GUSSET	CARBON STEEL	ASTM A36		1/2 PLATE
2													99	CAM SIDE	CARBON STEEL	ASTM A36		1/2 PLATE
	1												98	ACTUATION PIN	STEEL	COM'L		1/2 DIA X 3.5 LG
	2												97	BRACE	CARBON STEEL	ASTM A36		1/2 PLATE
	1												96	ROD	CARBON STEEL	COM'L		1 1/2 SCH. 40 PIPE
	2												95	LOCK PIN	CARBON STEEL	AISI 1020		1/2 DIA BAR
		2											94	PIVOT PLATE	CARBON STEEL	ASTM A36		1/2 PLATE
		1											93	SHORT CROSS	CARBON STEEL	ASTM A36		1/2 PLATE
		1											92	CROSS	CARBON STEEL	ASTM A36		1/2 PLATE
		1											91	MAIN SUPPORT	CARBON STEEL	ASTM A36		1/2 PLATE
											2		90	NYLOK NUT	STEEL	COM'L		1/2-13UNC
											4		89	HEX NUT	STEEL	COM'L		1/2-13UNC
											4		88	HEX HD BOLT	STEEL	COM'L		1/2-13UNC-2A X 4.0 LG
											4		87	HEX HD BOLT	STEEL	COM'L		3/8-16UNC-2A X 1.5 LG
											2		86	SUPPORT RETAINER	CARBON STEEL	ASTM A36		1/2 PLATE
											2		85	ACTUATION CAM			457-105-87	
											2		84	PIN ROD WELDMENT			457-105-88	
											2		83	SUPPORT WELDMENT			457-105-89	
										2			82	HORIZONTAL SUPPORT	MALLEABLE IRON	COM'L		1 1/2 SCH. 40 PIPE
										2			81	90° SIDE OUTLET TEE	MALLEABLE IRON	COM'L		McMASTER-CARR #4936T33
										8	8		80	AJUSTABLE TEE	MALLEABLE IRON	COM'L		McMASTER-CARR #4936T56
			1										79	FLANGE TUBE BODY	CARBON STEEL	ASTM A513, TYPE 5		2 3/8 X 3/16 WALL TUBE
			1										78	FLANGE BASE PLATE	CARBON STEEL	ASTM A36		3/8 PLATE
													77					
										2			76	HORIZONTAL SUPPORT	CARBON STEEL	COM'L		1 1/2 SCH. 40 PIPE
					1			1					75	PULLEY ASSEMBLY			457-105-91	
											2		74	WINCH MOUNT			457-105-92	
										4	4		73	COLLAR	MALLEABLE IRON	COM'L		MCMASTER-CARR #4936T136
										1			72	STAIRWAY SPACER	6061-T6 AL	ASTM B209/B211		PLATE/BAR
										1			71	STAIRWAY	ALUM.	COM'L		MCMASTER-CARR #7946T85
												2	70	DROP-DOWN PLANK			457-105-94	
							8						69	PLANK PIVOT PLATE	6061-T6 AL	ASTM B209		3/8 PLATE
												4	68	QUICK DISCONNECT SNAP	CARBON STEEL	COM'L		McMASTER-CARR #7935T4
												4	67	CHAIN BARRIER	CARBON STEEL	COM'L		McMASTER-CARR #98335A069
													66					

91 ASSY	91 ASSY	92 ASSY	93 ASSY	94 ASSY	95 ASSY	96 ASSY	97 ASSY	98 ASSY	99 ASSY	ITEM	NAME	MATERIAL	SPEC	DRAWING No.	DESCRIPTION
										65					
									4	64	PIVOT PIN	CARBON STEEL	ASTM A36		ROUND BAR
									1	63	STATIONARY PLANK			457-105-94	
									16	62	RETAINER BOLT	CARBON STEEL	COM'L		1/4-20 X 5/8 LG HEX HD BOLT
									8	61	PLANK RETAINER	6061-T6 AL	ASTM B209		1/4 X 3/4 FLAT BAR
									2	60	STATIONARY PLANK			457-105-95	
									2	59	REMOVEABLE BARRIER			457-105-96	
									1	58	RIGHT PLATFORM			457-105-97	
									1	57	LEFT PLATFORM			457-105-98	
		1								56	WINCH		COM'L		McMASTER-CARR #3196T44
		1								55	BASE	CARBON STEEL	ASTM A36		1/2 PLATE
		2								54	GUSSET	CARBON STEEL	ASTM A36		1/2 PLATE
		1								53	BACKING PLATE	CARBON STEEL	ASTM A36		3/8 PLATE
		2								52	HORIZONTAL SUPPORT	CARBON STEEL	COM'L		1 1/2 SCH. 40 PIPE
		2								51	VERTICAL SUPPORT	CARBON STEEL	COM'L		1 1/2 SCH. 40 PIPE
			2							50	TOE-BOARD	2024-T531 AL	ASTM B211		4 X 1/4 FLAT BAR
			1							49	HOOK EYE	6061-T6 AL	ASTM B209		1/4 PLATE
			1							48	GUSSET	6061-T6 AL	ASTM B209		1/4 PLATE
			1							47	CHANNEL	6061-T6 AL	ASTM B308		4 X .180 ALUM. CHANNEL
			2							46	PIVOT PLATE	6061-T6 AL	ASTM B209		1/2 PLATE
			2							45	CHANNEL	6061-T6 AL	ASTM B308		4 X .180 ALUM. CHANNEL
			2							44	LOCK PLATE	6061-T6 AL	ASTM B211		RECT. BAR/PLATE
			2							43	CHANNEL	6061-T6 AL	ASTM B308		4 X .180 ALUM. CHANNEL
			4							42	SPACER PLATE	6061-T6 AL	ASTM B209		1/2 PLATE
			1							41	TREAD PLATE	6061-T6 AL	ASTM B632		3/8 DIAMOND TREAD PLATE
			3							40	CHANNEL	6061-T6 AL	ASTM B308		4 X .180 ALUM. CHANNEL
			2							39	CHANNEL	6061-T6 AL	ASTM B308		4 X .180 ALUM. CHANNEL
	1								4	38	PIN	CARBON STEEL	COM'L		1/8 X 1 COTTER PIN
	1									37	SHAFT	CARBON STEEL	ASTM A36		ROUND BAR
	2									36	SPACER	CARBON STEEL	COM'L		1/2 TYPE A WIDE FLAT WASHER
	1									35	SHEAVE	POWDERED METAL	COM'L		CROSSBY #916147
	2									34	SIDE PLATE	CARBON STEEL	ASTM A36		RECT. BAR/PLATE
	1									33	BASE PLATE	CARBON STEEL	ASTM A36		RECT. BAR/PLATE
					8					32	LOCK PLATE	6061-T6	ASTM B209		1/2 PLATE
				2	2					31	TOE-BOARD	2024-T531 AL	ASTM B211		4 X 1/4 FLAT BAR
				1	1					30	TOE-BOARD	2024-T531 AL	ASTM B211		4 X 1/4 FLAT BAR
				1	1					29	TOE-BOARD	2024-T531 AL	ASTM B211		4 X 1/4 FLAT BAR
				1	1					28	TREAD PLATE	6061-T6 AL	ASTM B632		3/8 DIAMOND TREAD PLATE
				4	4					27	CHANNEL	6061-T6 AL	ASTM B308		4 X .180 ALUM. CHANNEL
				4	4					26	PLANK HOOK	6061-T6 AL	ASTM B209		1/2 PLATE
			6	4	4					25	END CAP	6061-T6 AL	ASTM B209		1/4 PLATE
				2	2					24	CHANNEL	6061-T6 AL	ASTM B308		4 X .180 ALUM. CHANNEL
						2	4	2		23	PLUG	MALLEABLE IRON	COM'L		McMASTER-CARR #4936T139
							4	4		22	90° ELBOW	MALLEABLE IRON	COM'L		McMASTER-CARR #4936T19
							2	3		21	TWO SOCKET CROSS	MALLEABLE IRON	COM'L		McMASTER-CARR #4936T39
						1				20	HORIZONTAL SUPPORT	CARBON STEEL	COM'L		1 1/2 SCH. 40 PIPE
							2	2		19	HORIZONTAL SUPPORT	CARBON STEEL	COM'L		1 1/2 SCH. 40 PIPE
						2	5	5		18	VERTICAL SUPPORT	CARBON STEEL	COM'L		1 1/2 SCH. 40 PIPE
						4	22	26		17	JOINING TEE	MALLEABLE IRON	COM'L		McMASTER-CARR # 4936T36
							4	4		16	SIDE OUTLET ELBOW	MALLEABLE IRON	COM'L		McMASTER-CARR #4936T29
							8	8		15	NUT	CARBON STEEL	COM'L		5/16-18 HEX NUT
							8	8		14	WASHER	CARBON STEEL	COM'L		5/16 FLAT WASHER
							8	8		13	BOLT	CARBON STEEL	COM'L		5/16-18 X 2 1/4 HEX HD BOLT
							8	8		12	SPACER	CARBON STEEL	COM'L		ROUND BAR
							8	8		11	FEMALE SOCKET	MALLEABLE IRON	COM'L		McMASTER-CARR #4936T113
							8	8		10	MALE SOCKET	MALLEABLE IRON	COM'L		McMASTER-CARR #4936T117
							4	4		9	STRUT	CARBON STEEL	COM'L		1 1/2 SCH. 40 PIPE
							2	2		8	STRUT	CARBON STEEL	COM'L		1 1/2 SCH. 40 PIPE
							2	2		7	STRUT	CARBON STEEL	COM'L		1 1/2 SCH. 40 PIPE
								12		6	TEE	MALLEABLE IRON	COM'L		McMASTER-CARR #4936T13
							6	8		5	HORIZONTAL SUPPORT	CARBON STEEL	COM'L		1 1/2 SCH. 40 PIPE
							4	4		4	HORIZONTAL SUPPORT	CARBON STEEL	COM'L		1 1/2 SCH. 40 PIPE
							4			3	VERTICAL SUPPORT	CARBON STEEL	COM'L		1 1/2 SCH. 40 PIPE
							4	8		2	VERTICAL SUPPORT	CARBON STEEL	COM'L		1 1/2 SCH. 40 PIPE
							8	8		1	FLOOR FLANGE			457-105-90	

QUANTITY

PROJECT INFORMATION
WHC SPECIFICATION NO.: WHC-S-0396
ITEM 7
WHC P.O. NO.: MJK-SPX-452727
TRANSNUCLEAR, INC. PROJECT NO.: 3035

NOTES:

2 DIMENSION/SIZE AS REQUIRED TO POSITION STAIRWAY TO CORRECT ELEVATION.

1 MOUNT STAIRWAY, ITEM 39, CENTERED ABOUT PLATFORM. CUT PERSONNEL BARRIER, ITEM 3, AS REQUIRED. INSERT PLUG, ITEM 37, IN CUT ENDS.

SYM	GEOMETRY
	FLATNESS
	STRAIGHTNESS
	ANGULARITY
	PERPENDICULARITY
	PARALLELISM
	CONCENTRICITY
	TRUE POSITION

TOLERANCES UNLESS OTHERWISE SPECIFIED

3 PLACE DEC.	TOL.	2 PLACE DEC.	TOL.
UNDER 3	±.003	UNDER 6	±.02
3-12	±.005	6-18	±.03
OVER 12	±.010	OVER 18	±.06
1 PLACE DEC.	±.1	FILLETS .015 TO .030	
FINISH (√)-AA-125 MICRO IN		ANGLES ±.5°	
THREADS-UNIFIED CL2A-2B			

RADIUS CORNERS .015-.030

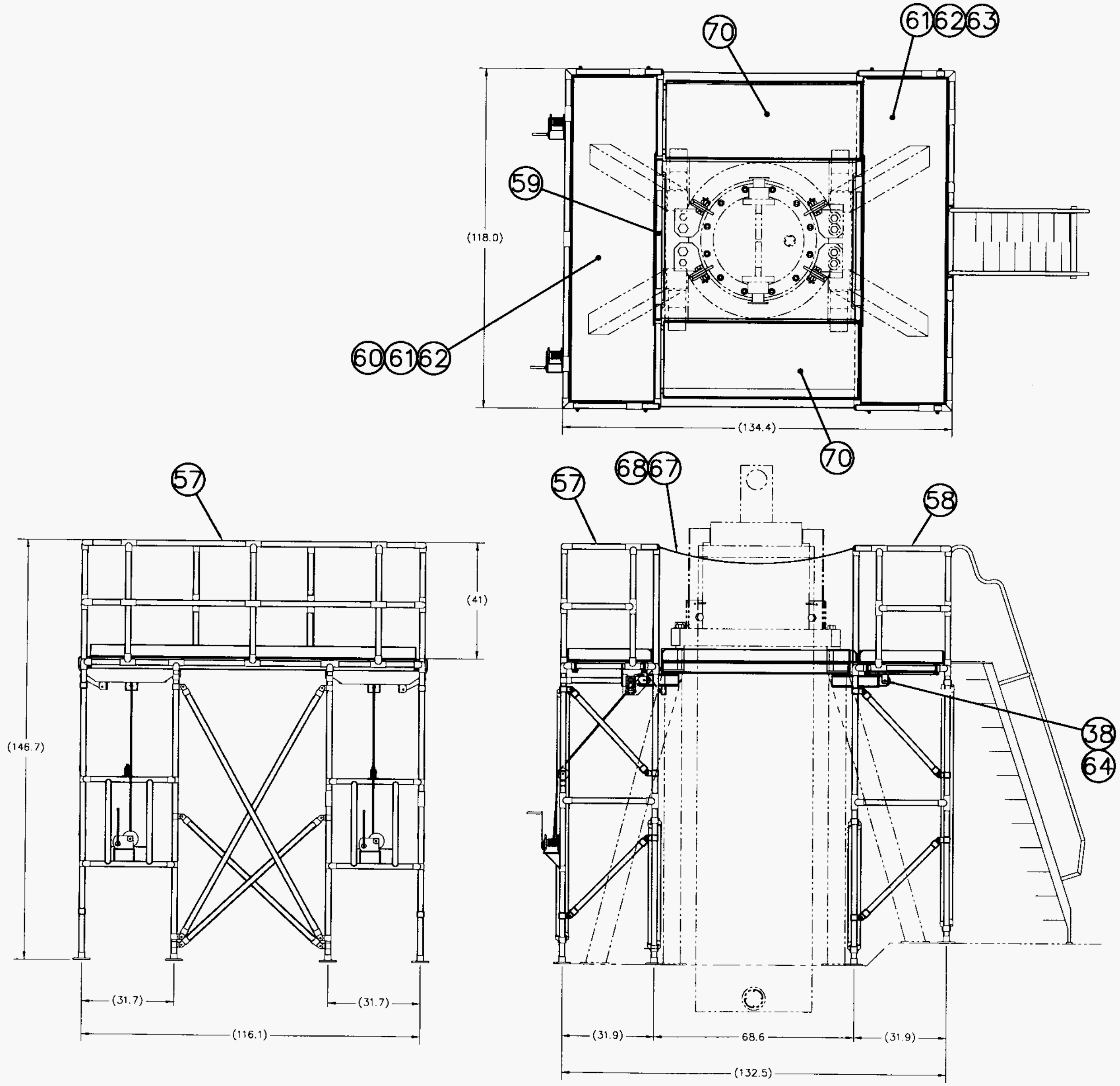
TYPE OF DRAWING: ENGINEERING

GROUP	NAME	DATE
DRAWN		
CHECK		
DESIGN AND ANALYSIS		12-2-96
LICENSING	N/A	
PROJECTS		12-2-96
QUALITY		
V.P. ENGINEERING		
NEXT ASSEMBLY		

NAC INTERNATIONAL

K BASIN TRANSPORT TRAILER WORK PLATFORM TN WHC TRANSPORT CASK WHC DWG H-1-81548

PROJECT 457	DESIGN PACKAGE	DRAWING 105	REV 0
SCALE NA	EST. WT. 1207#	SH 1 OF 7	3:32PM 12-2-96

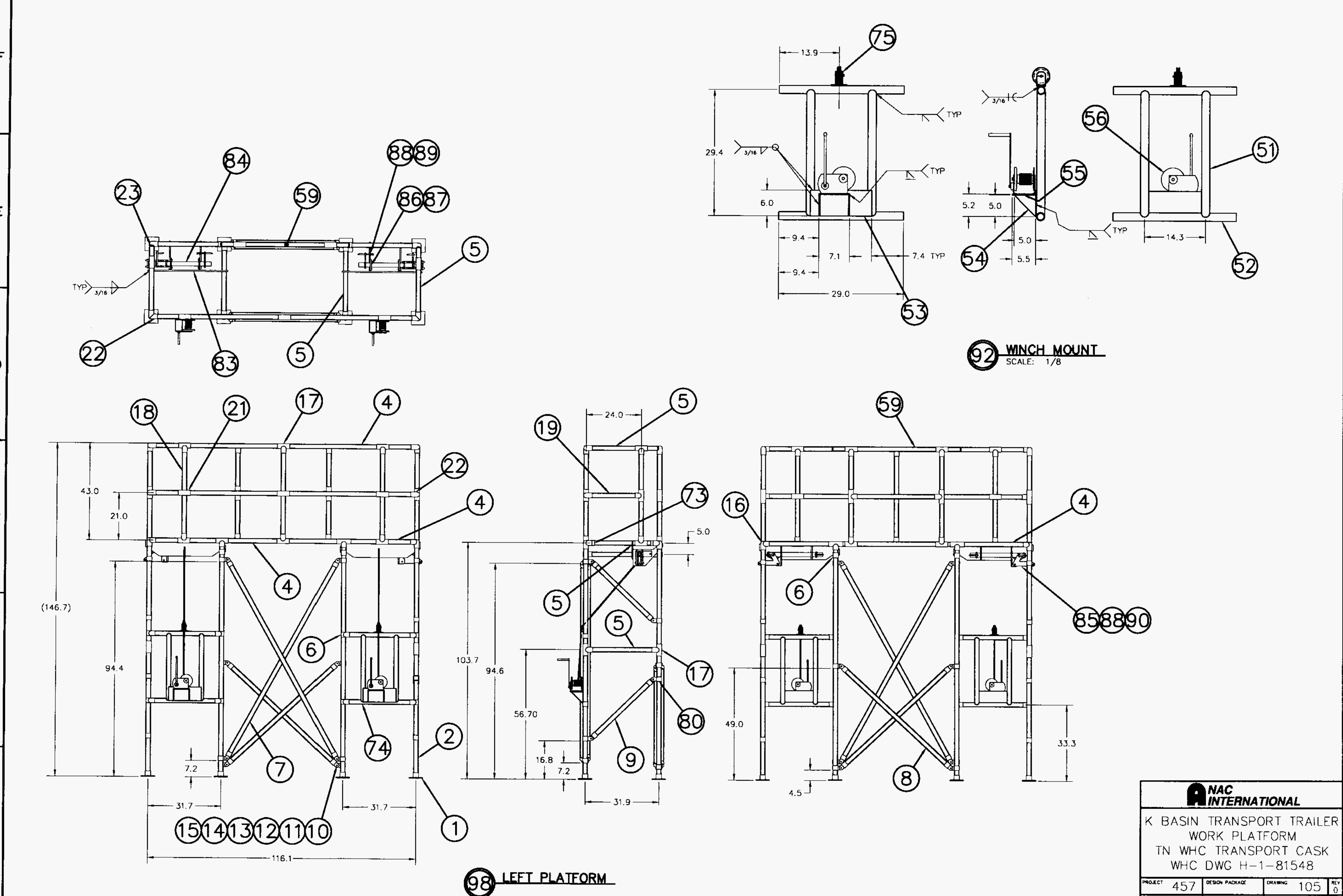


99 WORK PLATFORM ASSEMBLY

NAC INTERNATIONAL

K BASIN TRANSPORT TRAILER
WORK PLATFORM
TN WHC TRANSPORT CASK
WHC DWG H-1-81548

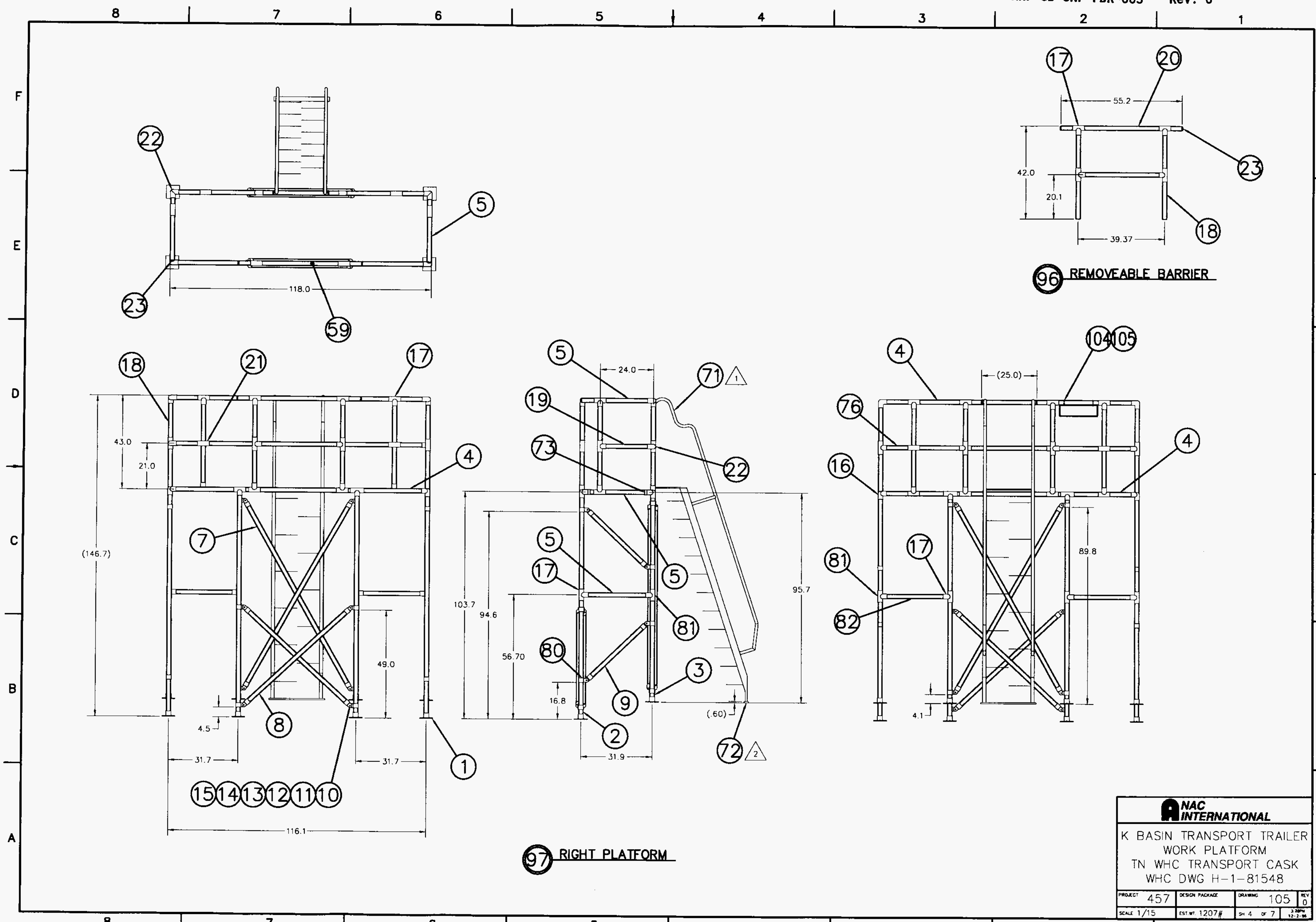
PROJECT	DESIGN PACKAGE	DRAWING	REV
457		105	0
SCALE 1/15	EST.WT. 1207#	SH 2 OF 7	



NAC INTERNATIONAL

K BASIN TRANSPORT TRAILER
WORK PLATFORM
TN WHC TRANSPORT CASK
WHC DWG H-1-81548

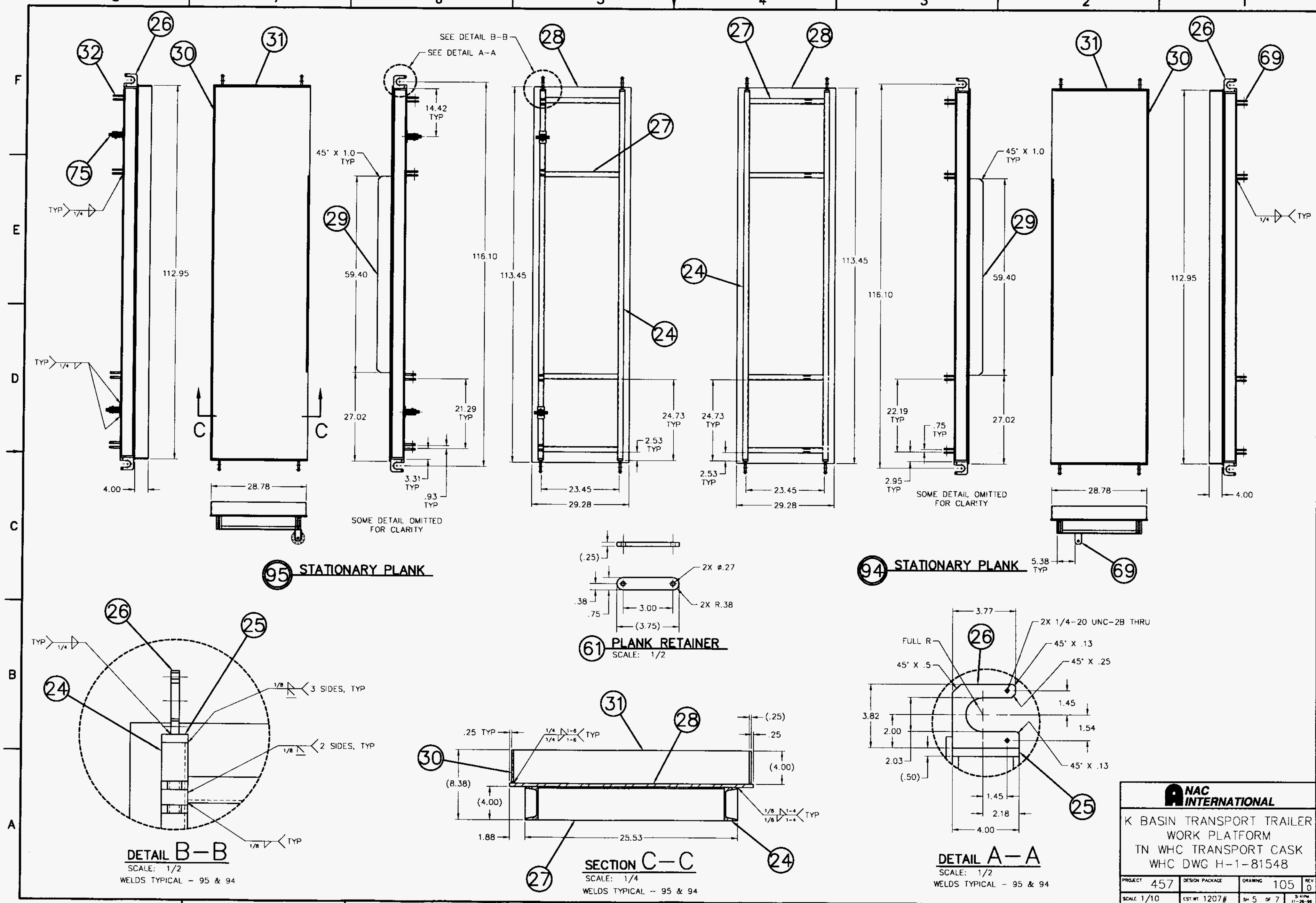
PROJECT	DESIGN PACKAGE	DRAWING	REV
457		105	0
SCALE 1/15	EST.WT. 1207#	SH 3 OF 7	



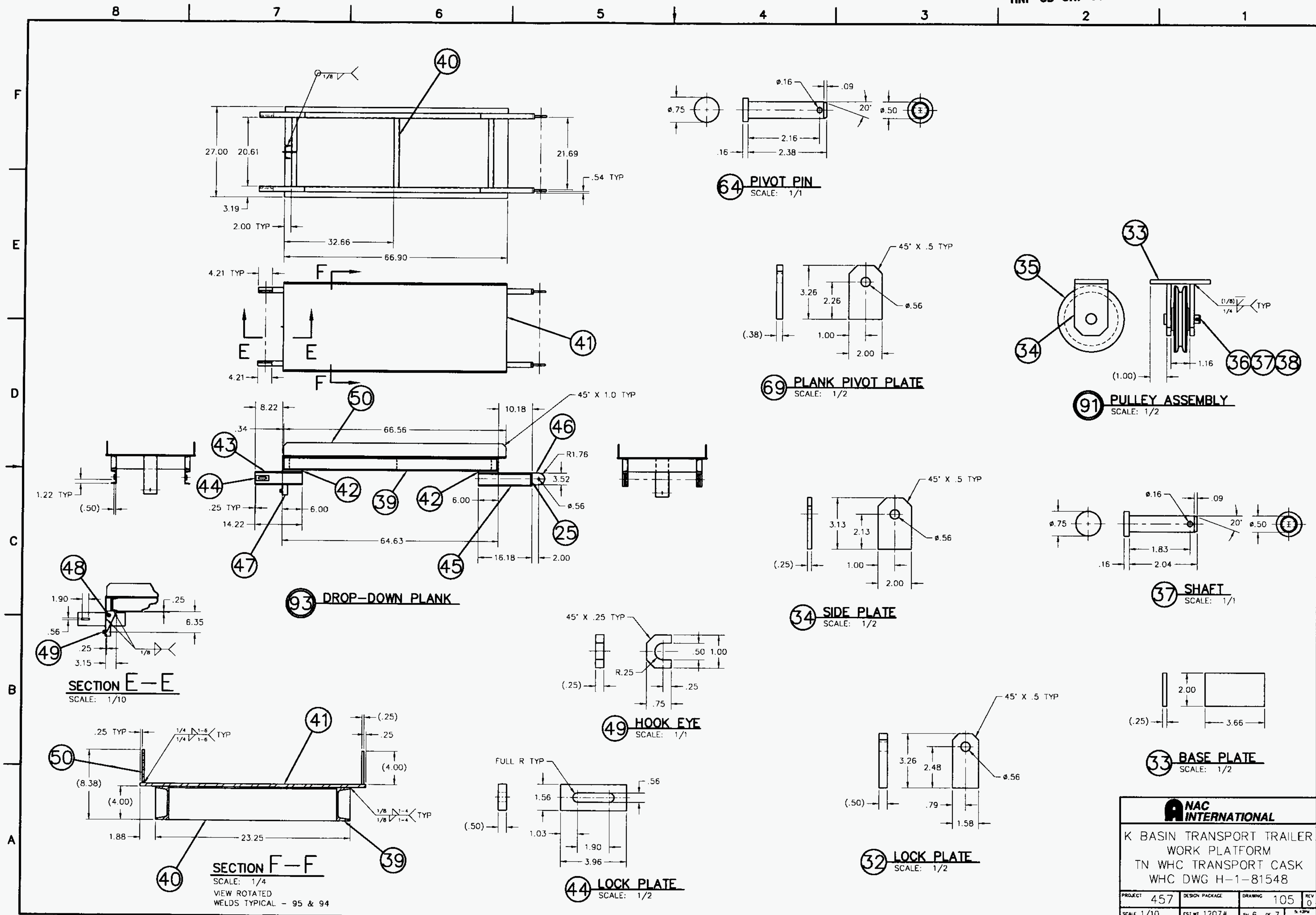
NAC INTERNATIONAL

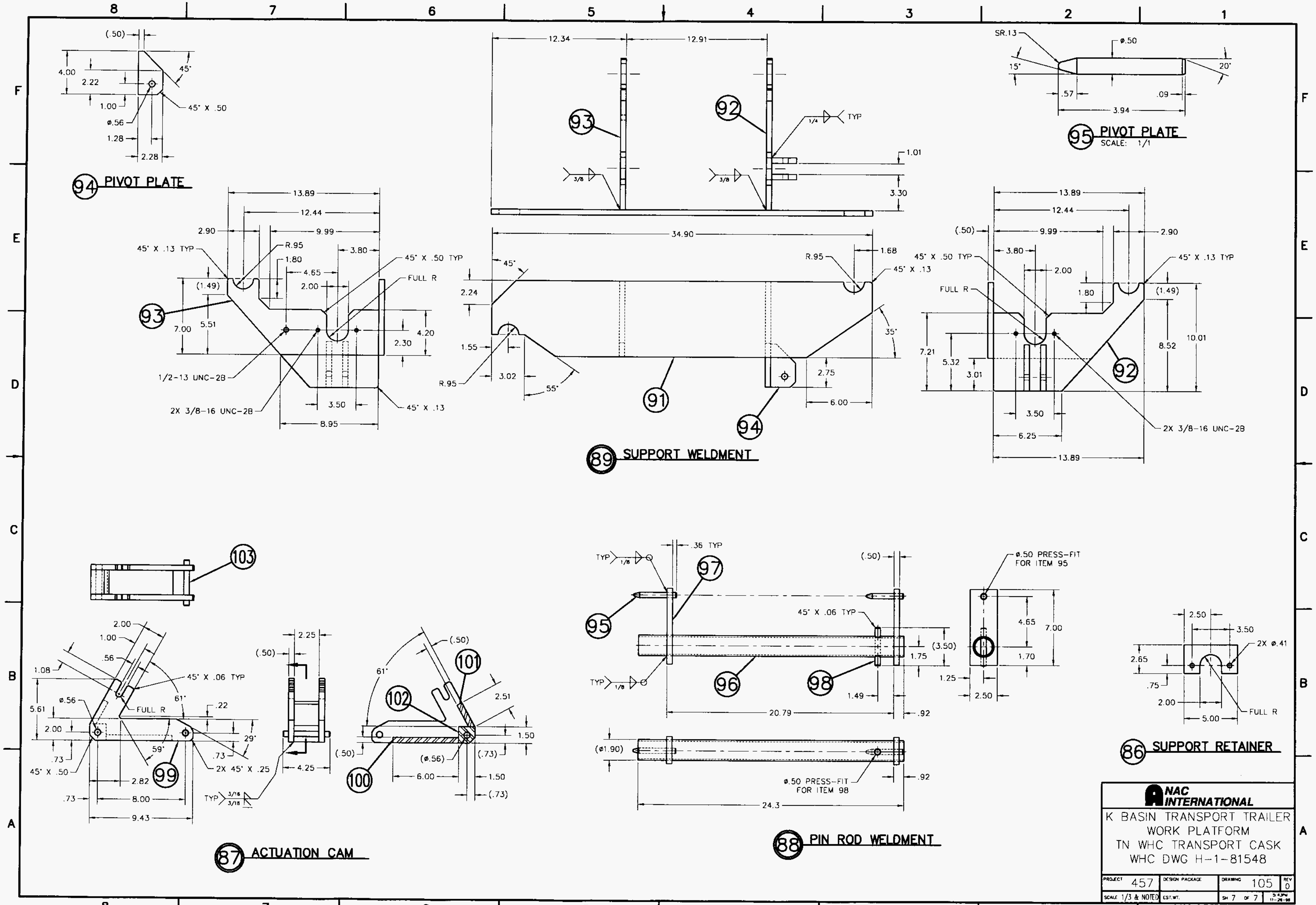
K BASIN TRANSPORT TRAILER
WORK PLATFORM
TN WHC TRANSPORT CASK
WHC DWG H-1-81548

PROJECT	DESIGN PACKAGE	DRAWING	REV
457		105	0
SCALE 1/15	EST WT 1207#	SH 4 OF 7	3:38PM 12-2-96

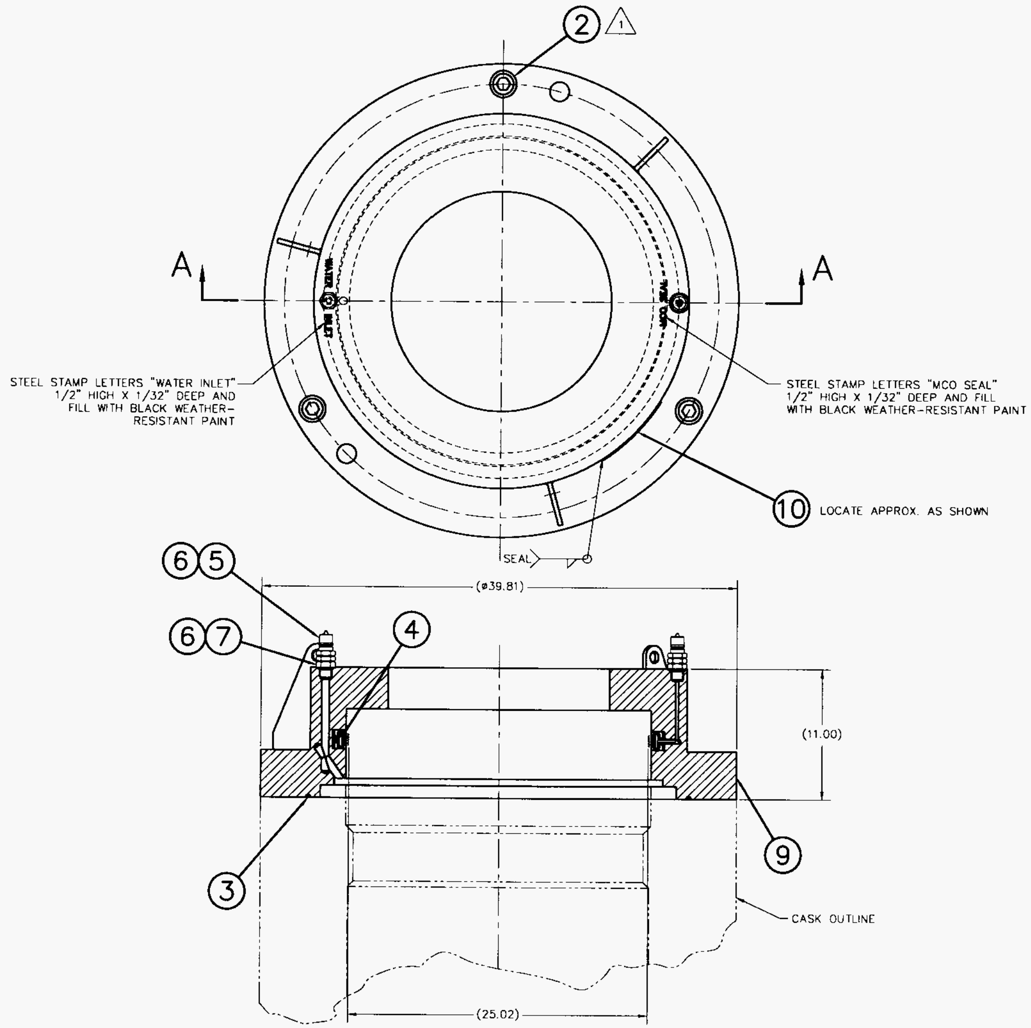


95 STATIONARY PLANK
94 STATIONARY PLANK
61 PLANK RETAINER
SCALE: 1/2
SOME DETAIL OMITTED FOR CLARITY
SEE DETAIL B-B
SEE DETAIL A-A
DETAIL B-B
SCALE: 1/2
WELDS TYPICAL - 95 & 94
SECTION C-C
SCALE: 1/4
WELDS TYPICAL - 95 & 94
DETAIL A-A
SCALE: 1/2
WELDS TYPICAL - 95 & 94
2X 1/4-20 UNC-2B THRU
FULL R
3 SIDES, TYP
2 SIDES, TYP
NAC INTERNATIONAL
K BASIN TRANSPORT TRAILER
WORK PLATFORM
TN WHC TRANSPORT CASK
WHC DWG H-1-81548
PROJECT 457
DRAWING 105
REV 0
SCALE 1/10
EST WT 1207#
SH 5 OF 7


93 DROP-DOWN PLANK
SECTION E-E
SCALE: 1/10
SECTION F-F
SCALE: 1/4
VIEW ROTATED
WELDS TYPICAL - 95 & 94
44 LOCK PLATE
SCALE: 1/2
49 HOOK EYE
SCALE: 1/1
64 PIVOT PIN
SCALE: 1/1
69 PLANK PIVOT PLATE
SCALE: 1/2
34 SIDE PLATE
SCALE: 1/2
32 LOCK PLATE
SCALE: 1/2
91 PULLEY ASSEMBLY
SCALE: 1/2
37 SHAFT
SCALE: 1/1
33 BASE PLATE
SCALE: 1/2
45° X 1.0 TYP
45° X .5 TYP
45° X .25 TYP
FULL R TYP
NAC INTERNATIONAL
K BASIN TRANSPORT TRAILER
WORK PLATFORM
TN WHC TRANSPORT CASK
WHC DWG H-1-81548
PROJECT 457
DESIGN PACKAGE
DRAWING 105
REV 0
SCALE 1/10
EST.WT. 1207#
SH 6 OF 7


94 PIVOT PLATE
95 PIVOT PLATE
SCALE: 1/1
89 SUPPORT WELDMENT
103
87 ACTUATION CAM
88 PIN ROD WELDMENT
86 SUPPORT RETAINER
NAC INTERNATIONAL
K BASIN TRANSPORT TRAILER
WORK PLATFORM
TN WHC TRANSPORT CASK
WHC DWG H-1-81548
PROJECT 457
DRAWING 105
REV 0
SCALE 1/3 & NOTED
SH 7 OF 7

No	REVISION	BY	APPROVED BY	DATE
0	INITIAL ISSUE			



SECTION A—A

99 LID ASSEMBLY

GEORGIA REGISTERED No. 15706 PROFESSIONAL ENGINEER NORMAN M. MEINERT

PROJECT INFORMATION
WHC SPECIFICATION NO.: WHC-S-0396
ITEM 7
WHC P.O. NO.: MJK-SPX-452727
TRANSNUCLEAR, INC. PROJECT NO.: 3035

97 ASSY	98 ASSY	99 ASSY	ITEM	NAME	MATERIAL	SPEC	DRAWING No.	DESCRIPTION
		1	10	NAMEPLATE			457-111-37	
		1	9	LID WELDMENT			457-106-98	
	3		8	LIFTING LUG	304 ST.STL.	ASTM A240		3/8 PLATE
		2	7	ADAPTER	304 ST.STL.	ASTM A276		1 3/8 HEX BAR
		4	6	O-RING	EPDM	COML		PARKER #3-912E515-75
		2	5	QUICK DISCONNECT	ST.STL.	COML		HANSEN #LL6-KP-12
		1	4	MCO SEAL	SILICONE	COML		CEFIL'AIR #704 W/ RJO 6
		1	3	LID SEAL	BUTYL	COML		PARKER .275 CSECT DIA X 31.31 I.D.
		3	2	LID BOLT	304 ST.STL.	ASTM A276		BAR
	1		1	LID BODY	304 ST.STL.	ASTM A182		FORGING

QUANTITY

SYM.	GEOMETRY
▱	FLATNESS
—	STRAIGHTNESS
∠	ANGULARITY
⊥	PERPENDICULARITY
//	PARALLELISM
◎	CONCENTRICITY
⊕	TRUE POSITION

TOLERANCES UNLESS OTHERWISE SPECIFIED

3 PLACE DEC.	TOL.	2 PLACE DEC.	TOL.
UNDER 3	±.003	UNDER 6	±.02
3-12	±.005	6-18	±.03
OVER 12	±.010	OVER 18	±.06
1 PLACE DEC.	±.1	FILLETS .015 TO .030	
FINISH (√)-AA-125 MICRO IN		ANGLES ±.5°	
THREADS-UNIFIED CL2A-2B			
RADIUS CORNERS .015-.030			

TYPE OF DRAWING: ENGINEERING

GROUP	NAME	DATE
DRAWN	[signature]	[illegible]
CHECK	[signature]	12/2/96
DESIGN AND ANALYSIS	[signature]	12-2-96
LICENSING	N/A	
PROJECTS	[signature]	12-2-96
QUALITY	[signature]	12-2-96
V.P. ENGINEERING	[signature]	12/2/96
NEXT ASSEMBLY		

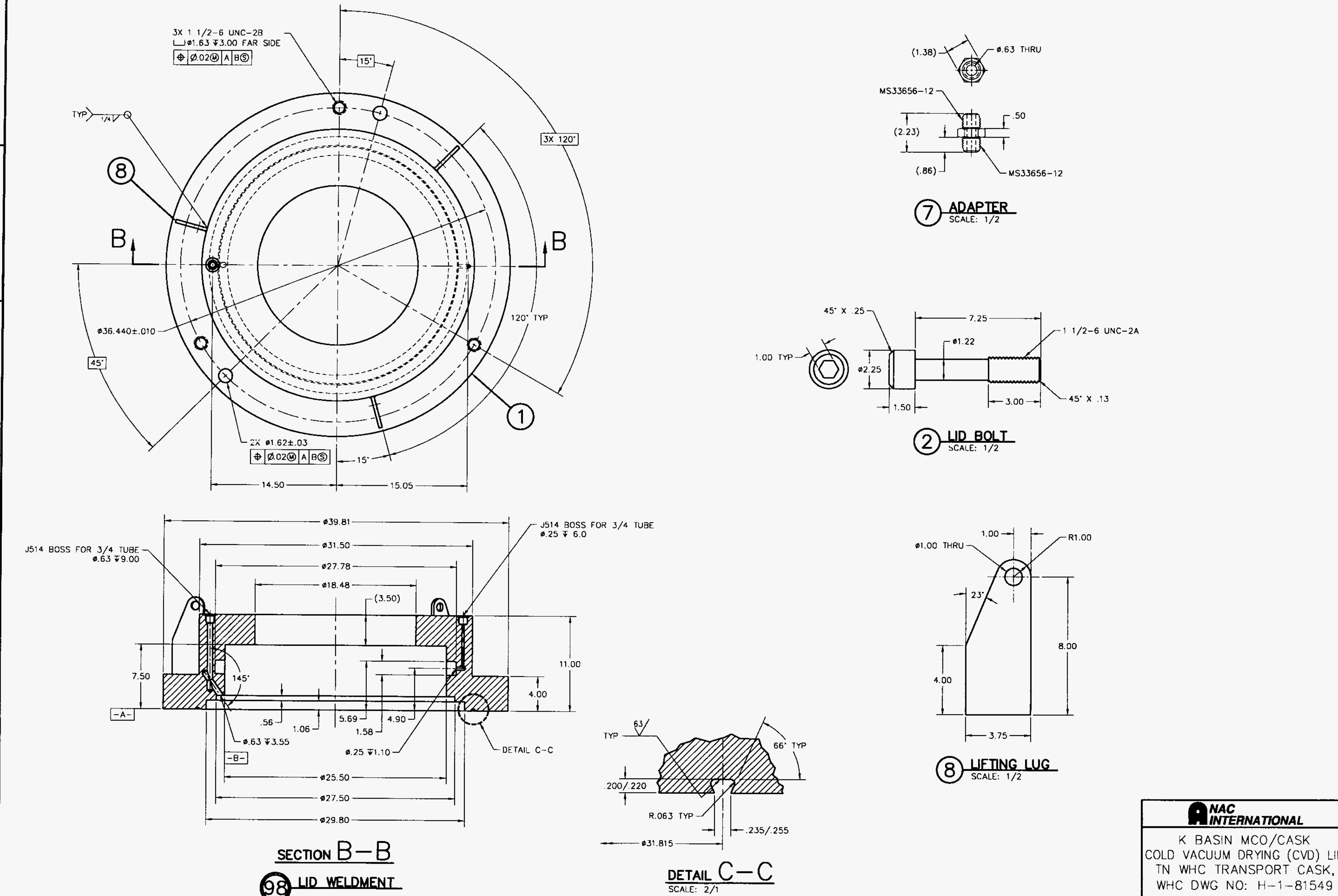
NAC INTERNATIONAL

K BASIN MCO/CASK
COLD VACUUM DRYING (CVD) LID
TN WHC TRANSPORT CASK,
WHC DWG NO: H-1-81549

PROJECT 457	DESIGN PACKAGE	DRAWING 106	REV 0
SCALE 1/4	EST.WT. 1535#	SH 1 OF 2	3:11 PM 12-2-96

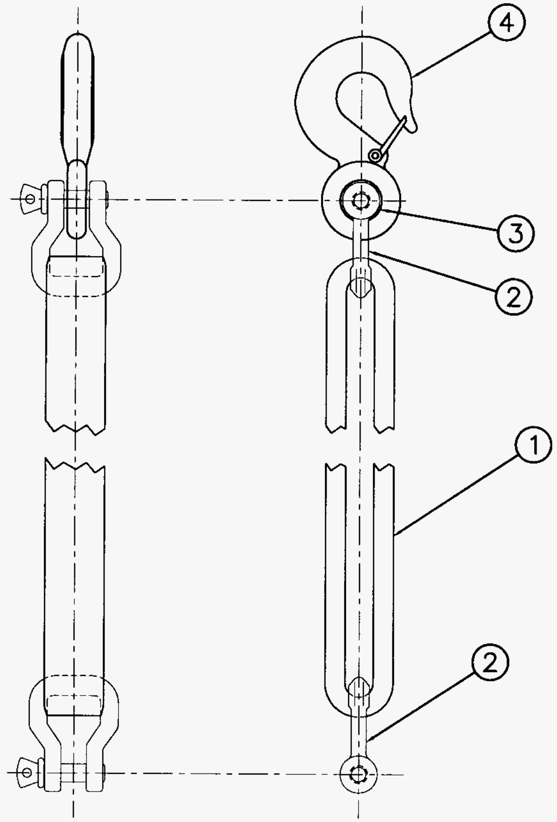
NOTES:

1. TIGHTEN ITEM 2, LID BOLT, TO 65±5 FT-LB.



NAC INTERNATIONAL			
K BASIN MCO/CASK COLD VACUUM DRYING (CVD) LID TN WHC TRANSPORT CASK, WHC DWG NO: H-1-81549			
PROJECT 457	DESIGN PACKAGE	DRAWING 106	REV 0
SCALE 1/4	EST.WT.	SH 2 OF 2	

No.	REVISION	BY	APPROVED BY	DATE
0	INITIAL ISSUE			



(99) LIFT SLING
WT: 100#

GEORGIA REGISTERED PROFESSIONAL ENGINEER No. 15706 NORMAN M. MEINERT

PROJECT INFORMATION
WHC SPECIFICATION NO.: WHC-S-0396
ITEM 7
WHC P.O. NO.: MJK-SPX-452727
TRANSNUCLEAR, INC. PROJECT NO.: 3035

97 ASSY	98 ASSY	99 ASSY	ITEM	NAME	MATERIAL	SPEC	DRAWING No.	DESCRIPTION
		1	4	EYE HOOK	ALLOY STEEL	COML		CROSBY #S-320-AN-1022465
		1	3	SPOOL	ALLOY STEEL	COML		CROSBY #S-255-1020939
		2	2	SHACKLE	ALLOY STEEL	COML		CROSBY #S-253-1020611
		1	1	LIFT SLING	WRAPPED KEVLAR	COML		BAIRSTOW #TPXC400016

QUANTITY

SYM.	GEOMETRY
▱	FLATNESS
—	STRAIGHTNESS
∠	ANGULARITY
⊥	PERPENDICULARITY
//	PARALLELISM
◎	CONCENTRICITY
⊕	TRUE POSITION

TOLERANCES UNLESS OTHERWISE SPECIFIED

3 PLACE DEC.	TOL.	2 PLACE DEC.	TOL.
UNDER 3	±.003	UNDER 6	±.02
3-12	±.005	6-18	±.03
OVER 12	±.010	OVER 18	±.06
1 PLACE DEC.	±.1	FILLETS .015 TO .030	
FINISH (√)-AA-125 MICRO IN.		ANGLES ±.5°	
THREADS-UNIFIED CL2A-2B			

RADIUS CORNERS .015-.030

TYPE OF DRAWING: ENGINEERING

GROUP	NAME	DATE
DRAWN	[signature]	[illegible]
CHECK	[signature]	11/8/96
DESIGN AND ANALYSIS	[signature]	[illegible]
LICENSING	N/A	
PROJECTS	[signature]	[illegible]
QUALITY	[signature]	[illegible]
V.P. ENGINEERING	[signature]	[illegible]

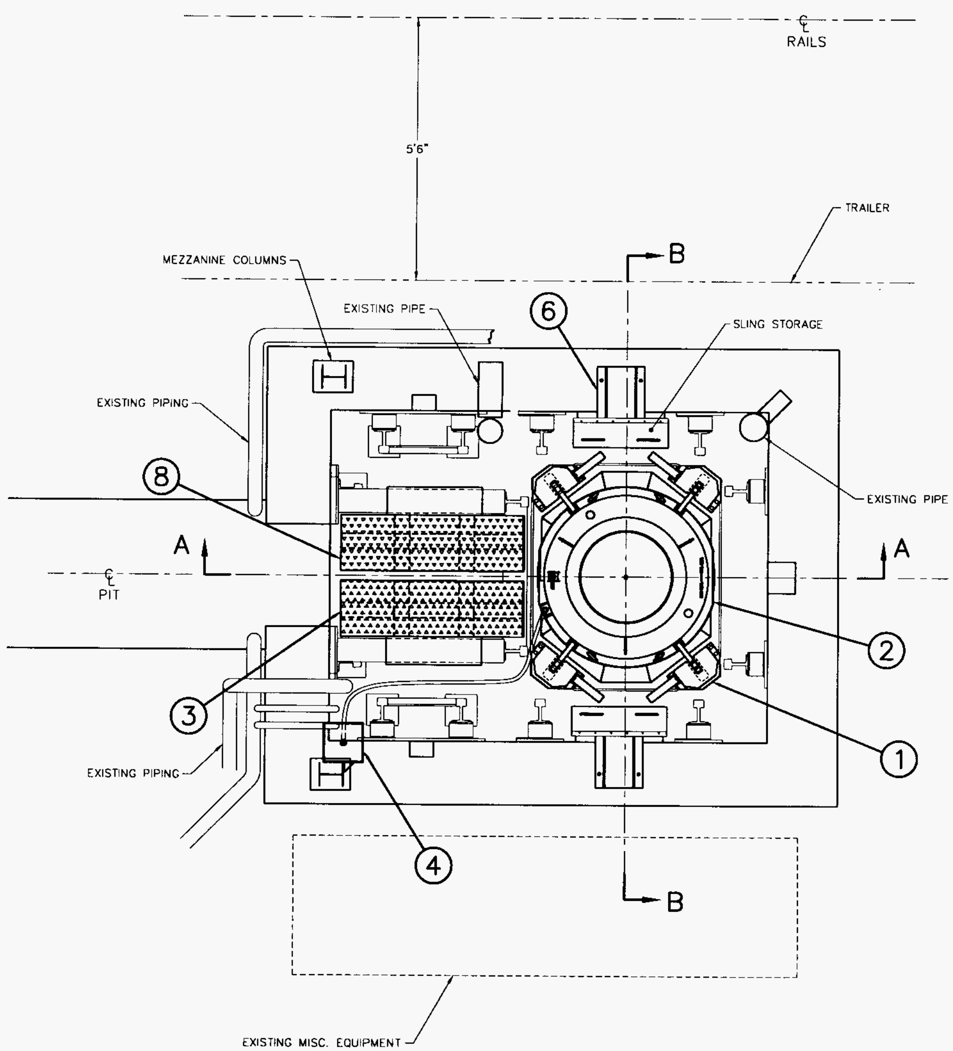
NEXT ASSEMBLY 457-108

NAC INTERNATIONAL

K BASIN IMMERSION PAIL ANCILLARY EQUIPMENT, TN WHC TRANSPORT CASK WHC DWG NO: H-1-81550

PROJECT 457 | DESIGN PACKAGE | DRAWING 107 | REV 0
SCALE 1/4 | EST. WT. | SH 1 OF 1 | 9:55AM 11-8-96

No.	REVISION	BY	APPROVED BY	DATE
0	INITIAL ISSUE			



PROJECT INFORMATION
WHC SPECIFICATION NO.: WHC-S-0396
ITEM 7
WHC P.O. NO.: MJK-SPX-452727
TRANSNUCLEAR, INC. PROJECT NO.: 3035

97 ASSY	98 ASSY	99 ASSY	ITEM	NAME	MATERIAL	SPEC	DRAWING No.	DESCRIPTION
		1	8	WORK PLATFORM			457-111-99	
		1	7	LIFT BEAM			457-112-99	
		2	6	SLING STORAGE			457-111-97	
		4	5	PAIL LIFT SLING			457-107-99	
		1	4	PAIL RESERVOIR			457-111-98	
		1	3	WORK PLATFORM			457-111-95	
		1	2	IMMERSION PAIL ASSY			457-104-99	
		1	1	STRUCTURAL SUPPORT			457-110-99	

QUANTITY

NAC INTERNATIONAL

K BASIN IMMERSION PAIL INTERFACE CONTROL DRAWING TN WHC TRANSPORT CASK, WHC DWG NO: H-1-81551

SYM	GEOMETRY
	FLATNESS
	STRAIGHTNESS
∠	ANGULARITY
⊥	PERPENDICULARITY
//	PARALLELISM
◎	CONCENTRICITY
⊕	TRUE POSITION

TOLERANCES UNLESS OTHERWISE SPECIFIED

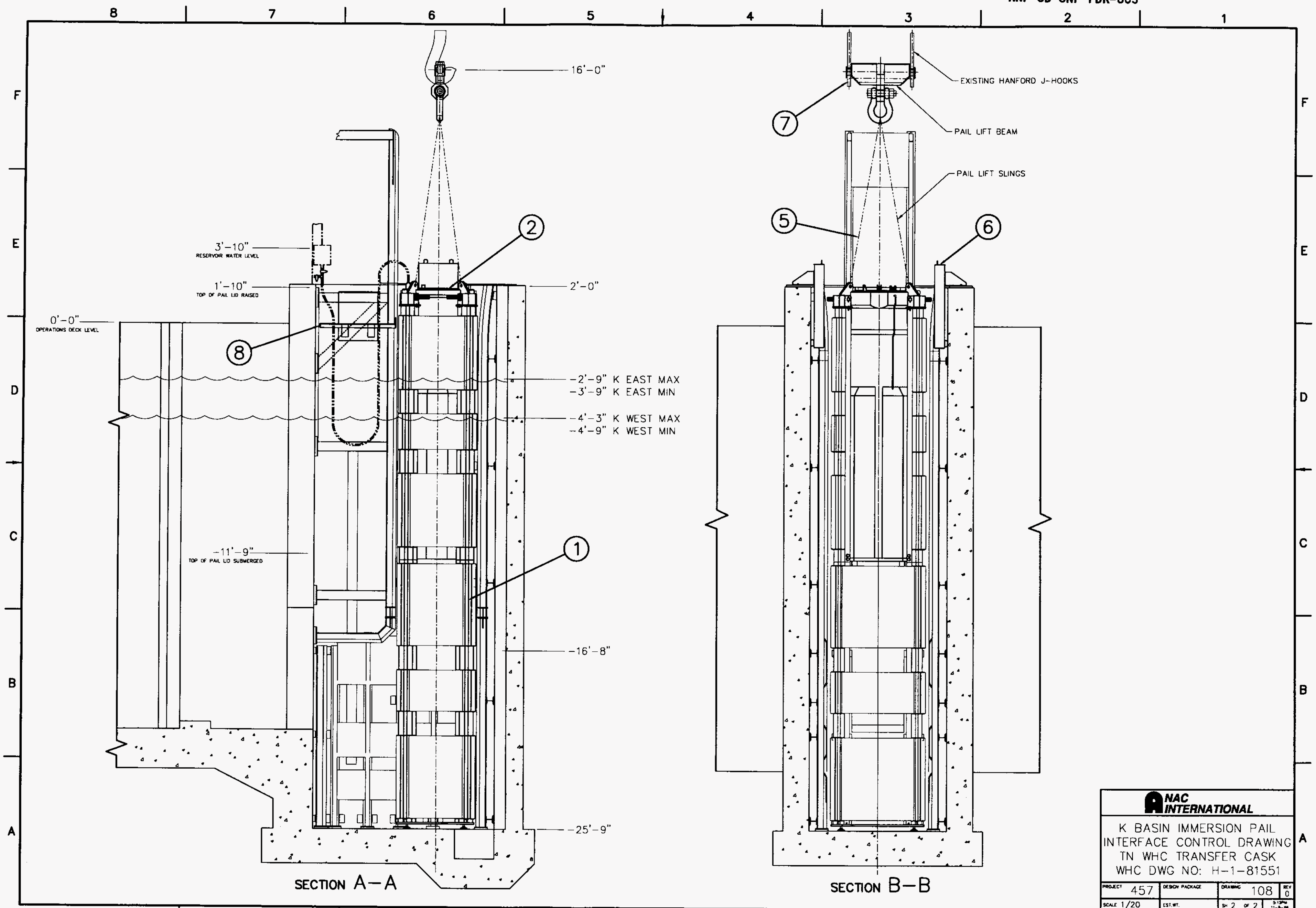
3 PLACE DEC.	TOL.	2 PLACE DEC.	TOL.
UNDER 3	±.003	UNDER 6	±.02
3-12	±.005	6-18	±.03
OVER 12	±.010	OVER 18	±.06
1 PLACE DEC. ±.1		FILLETS .015 TO .030	
FINISH (√)-AA-125 MICRO IN		ANGLES ±.5°	
THREADS-UNIFIED (2)A-2B			
RADIUS CORNERS .015-.030			

TYPE OF DRAWING: ENGINEERING

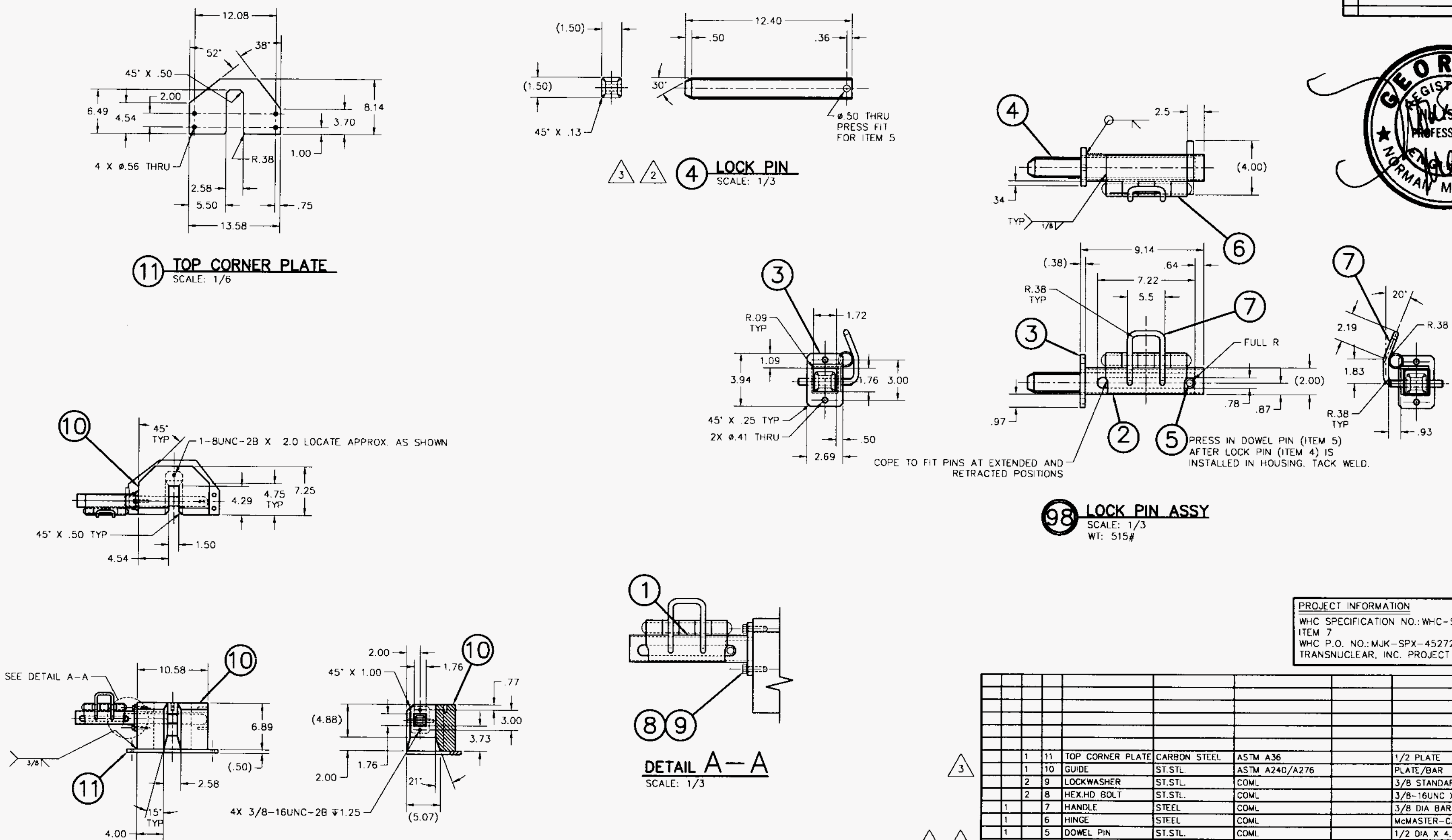
GROUP	NAME	DATE
DRAWN	[signature]	4/9/96
CHECK	[signature]	11/6/96
DESIGN AND ANALYSIS	JGB	11-6-96
LICENSING	N/A	
PROJECTS	[signature]	11-26-96
QUALITY	[signature]	11/26/96
V.P. ENGINEERING	[signature]	11/27/96
NEXT ASSEMBLY		

PROJECT 457 | DESIGN PACKAGE | DRAWING 108 | REV 0
SCALE 1/12 | EST. WT. | SH 1 OF 2

GEORGIA REGISTERED No. 16706 PROFESSIONAL ENGINEER NORMAN M. MEINERT


16'-0"
EXISTING HANFORD J-HOOKS
PAIL LIFT BEAM
PAIL LIFT SLINGS
3'-10"
RESERVOIR WATER LEVEL
1'-10"
TOP OF PAIL LID RAISED
2'-0"
0'-0"
OPERATIONS DECK LEVEL
-2'-9" K EAST MAX
-3'-9" K EAST MIN
-4'-3" K WEST MAX
-4'-9" K WEST MIN
-11'-9"
TOP OF PAIL LID SUBMERGED
-16'-8"
-25'-9"
1
2
5
6
7
8
SECTION A-A
SECTION B-B
NAC INTERNATIONAL
K BASIN IMMERSION PAIL
INTERFACE CONTROL DRAWING
TN WHC TRANSFER CASK
WHC DWG NO: H-1-81551
PROJECT 457
DESIGN PACKAGE
DRAWING 108
REV 0
SCALE 1/20
EST.WT.
SH 2 OF 2

No.	REVISION	BY	APPROVED BY	DATE
0	INITIAL ISSUE			



PROJECT INFORMATION
WHC SPECIFICATION NO.: WHC-S-0396
ITEM 7
WHC P.O. NO.: MJK-SPX-452727
TRANSNUCLEAR, INC. PROJECT NO.: 3035

NOTES:

1. FABRICATE PER NAC SPECIFICATION 457-S-02.

△2 HEAT TREAT TO CONDITION H1150.

△3 SAFETY RELATED LOAD PATH COMPONENT.

4. REMOVE ALL OIL AND GREASE FROM CARBON STEEL SURFACES PER SSPC-S-1. ABRASIVE BLAST PER SSPC-SP 10. MASK STAINLESS AND PRIME WITH ONE COAT AMERCOAT NUMBER 64 PRIMER AND FINISH WITH TWO COATS WHITE AMERCOAT NUMBER 66 SEAL GLOSS TOPCOAT.

	97 ASSY	98 ASSY	99 ASSY	ITEM	NAME	MATERIAL	SPEC	DRAWING No.	DESCRIPTION
△3			1	11	TOP CORNER PLATE	CARBON STEEL	ASTM A36		1/2 PLATE
			1	10	GUIDE	ST.STL.	ASTM A240/A276		PLATE/BAR
			2	9	LOCKWASHER	ST.STL.	COML		3/8 STANDARD
			2	8	HEX.HD BOLT	ST.STL.	COML		3/8-16UNC X 1 1/4 LG
		1		7	HANDLE	STEEL	COML		3/8 DIA BAR
		1		6	HINGE	STEEL	COML		McMASTER-CARR #16175A48
		1		5	DOWEL PIN	ST.STL.	COML		1/2 DIA X 4.0 LG
△3 △2		1		4	LOCK PIN	17-4PH ST.STL.	ASTM A564		1 1/2 SQ BAR
		1		3	FLANGE	CARBON STEEL	ASTM A36		3/8 PLATE
		1		2	HOUSING	CARBON STEEL	ASTM A500		2 X 2 X .120 WALL TUBE
			1	1	LOCK PIN ASSY			457-109-98	

QUANTITY

SYM.	GEOMETRY
⏥	FLATNESS
—	STRAIGHTNESS
∠	ANGULARITY
⊥	PERPENDICULARITY
//	PARALLELISM
◎	CONCENTRICITY
⌖	TRUE POSITION

TOLERANCES UNLESS OTHERWISE SPECIFIED

3 PLACE DEC.	TOL.	2 PLACE DEC.	TOL.
UNDER 3	±.003	UNDER 6	±.02
3-12	±.005	6-18	±.03
OVER 12	±.010	OVER 18	±.06
1 PLACE DEC.	±.1	FILLETS .015 TO .030	
FINISH (√)-AA-125 MICRO IN		ANGLES ±.5°	
THREADS-UNIFIED CL2A-2B			
RADIUS CORNERS .015-.030			

TYPE OF DRAWING: ENGINEERING

GROUP	NAME	DATE
DRAWN	[signature]	[illegible]
CHECK	[signature]	[illegible]
DESIGN AND ANALYSIS	[signature]	11-26-96
LICENSING	N/A	
PROJECTS	[signature]	11-21-96
QUALITY	[signature]	11/27/96
V.P. ENGINEERING	[signature]	11/27/96

NEXT ASSEMBLY 457-110

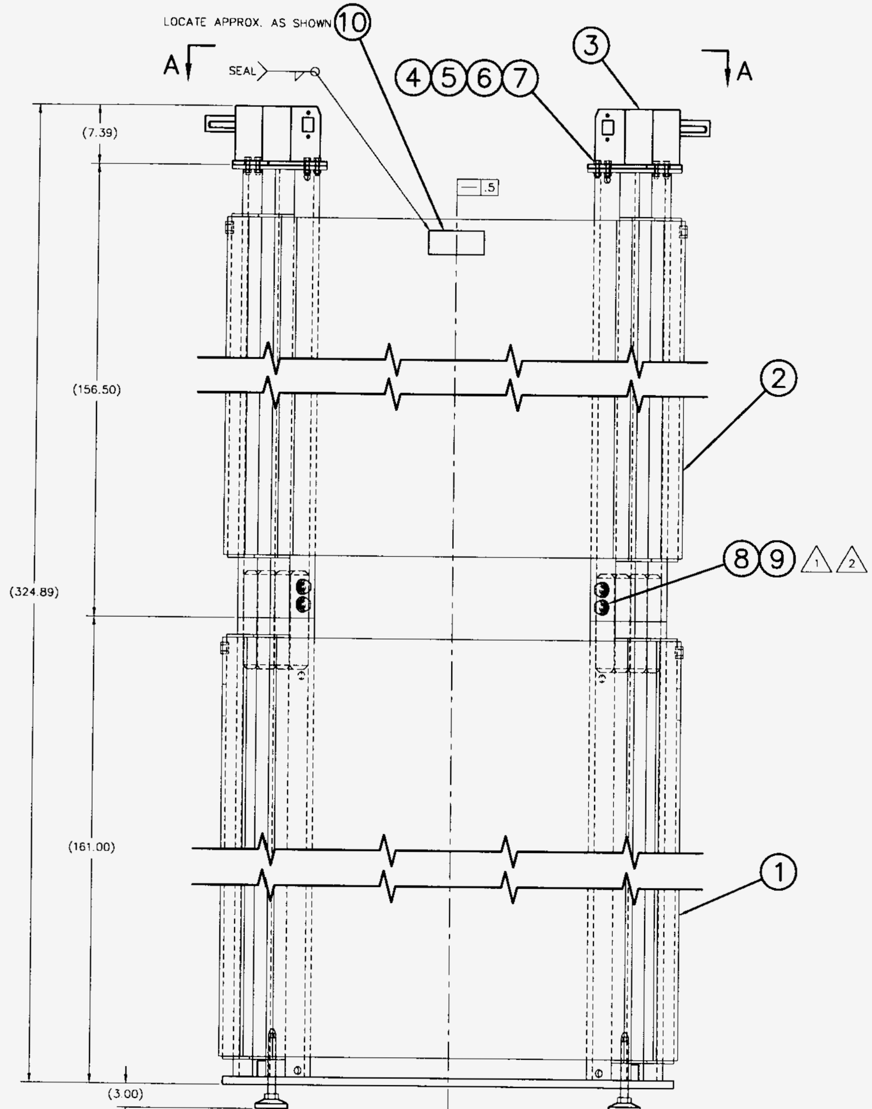
NAC INTERNATIONAL

K BASIN IMMERSION PAIL LOCK PIN GUIDE ASSEMBLY TN WHC TRANSPORT CASK, WHC DWG NO: H-1-81552

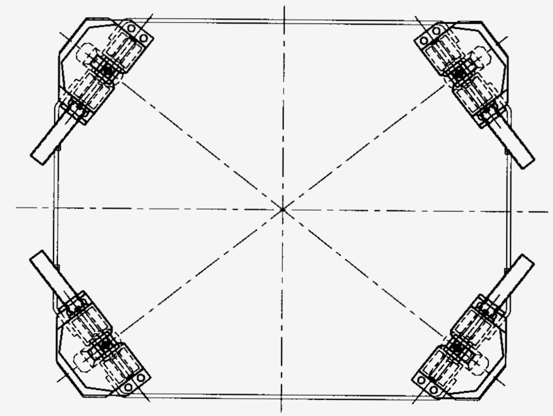
PROJECT 457 | DESIGN PACKAGE | DRAWING 109 | REV 0
SCALE NOTED | EST.WT. | SH 1 OF 1 | 12:20PM 11-25-96

GEORGIA REGISTERED PROFESSIONAL ENGINEER No. 15706 NORMAN M. MEINERT

No.	REVISION	BY	APPROVED BY	DATE
0	INITIAL ISSUE			



99 SUPPORT STRUCTURE ASSEMBLY
SCALE: 1/6



VIEW A–A
SCALE: 1/6

NOTES:

1. APPLY BOSTIC NEVER-SEEZ PURE NICKEL LUBRICANT TO FULL THREAD LENGTH.
2. TORQUE TO 35±5 FT-LBS.

GEORGIA REGISTERED No. 15706 PROFESSIONAL ENGINEER NORMAN M. MEINERT

PROJECT INFORMATION
WHC SPECIFICATION NO.: WHC-S-0396
ITEM 7
WHC P.O. NO.: MJK-SPX-452727
TRANSNUCLEAR, INC. PROJECT NO.: 3035

97 ASSY	98 ASSY	99 ASSY	ITEM	NAME	MATERIAL	SPEC	DRAWING No.	DESCRIPTION
		1	10	NAMEPLATE			457-111-34	
		16	9	WASHER	ST.STL.	COML		1 STANDARD
		16	8	HEX HEAD BOLT	ST.STL.	COML		1-8UNC X 2 LG
		16	7	LOCKWASHER	ST.STL.	COML		1/2 STANDARD
		16	6	WASHER	ST.STL.	COML		1/2 STANDARD
		16	5	HEX HEAD NUT	ST.STL.	COML		1/2-13UNC
		16	4	HEX HEAD BOLT	ST.STL.	COML		1/2-13UNC X 1 3/4 LG
		4	3	LOCK PIN ASSY			457-109-99	
		1	2	UPPER FRAME ASSY			457-102-99	
		1	1	LOWER FRAME ASSY			457-102-98	

QUANTITY

SYM.	GEOMETRY
	FLATNESS
	STRAIGHTNESS
	ANGULARITY
	PERPENDICULARITY
	PARALLELISM
	CONCENTRICITY
	TRUE POSITION

TOLERANCES UNLESS OTHERWISE SPECIFIED

3 PLACE DEC.	TOL.	2 PLACE DEC.	TOL.
UNDER 3	±.003	UNDER 6	±.02
3-12	±.005	6-18	±.03
OVER 12	±.010	OVER 18	±.06
1 PLACE DEC.	±.1	FILLETS .015 TO .030	
FINISH (✓)-AA-125 MICRO IN		ANGLES ±.5°	
THREADS-UNIFIED CL2A-2B			

RADIUS CORNERS .015-.030
TYPE OF DRAWING: ENGINEERING

GROUP	NAME	DATE
DRAWN	[signature]	[illegible]
CHECK	[signature]	[illegible]
DESIGN AND ANALYSIS	[signature]	12-2-96
LICENSING	N/A	
PROJECTS	[signature]	12-2-96
QUALITY	[signature]	12-2-96
V.P. ENGINEERING	[signature]	12-2-96

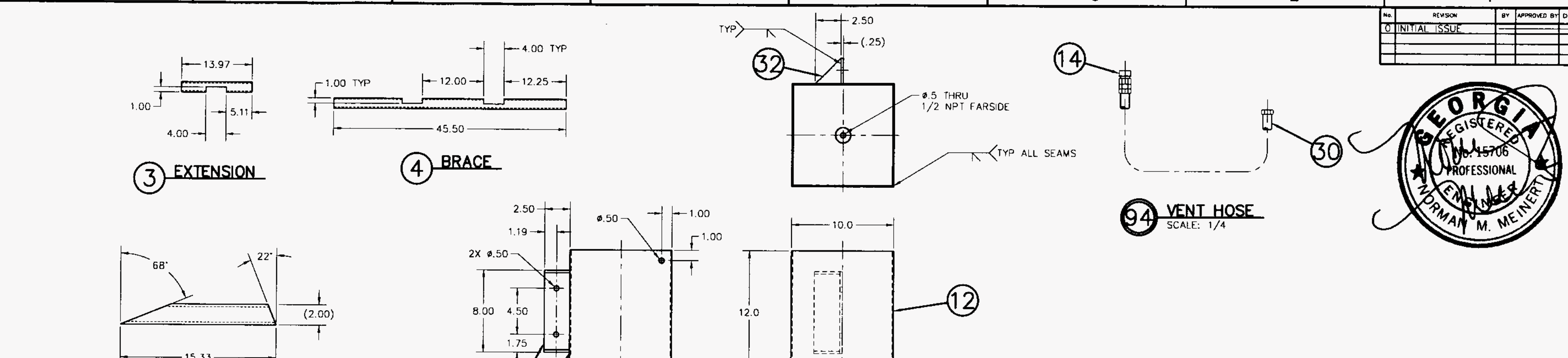
NEXT ASSEMBLY 457-108

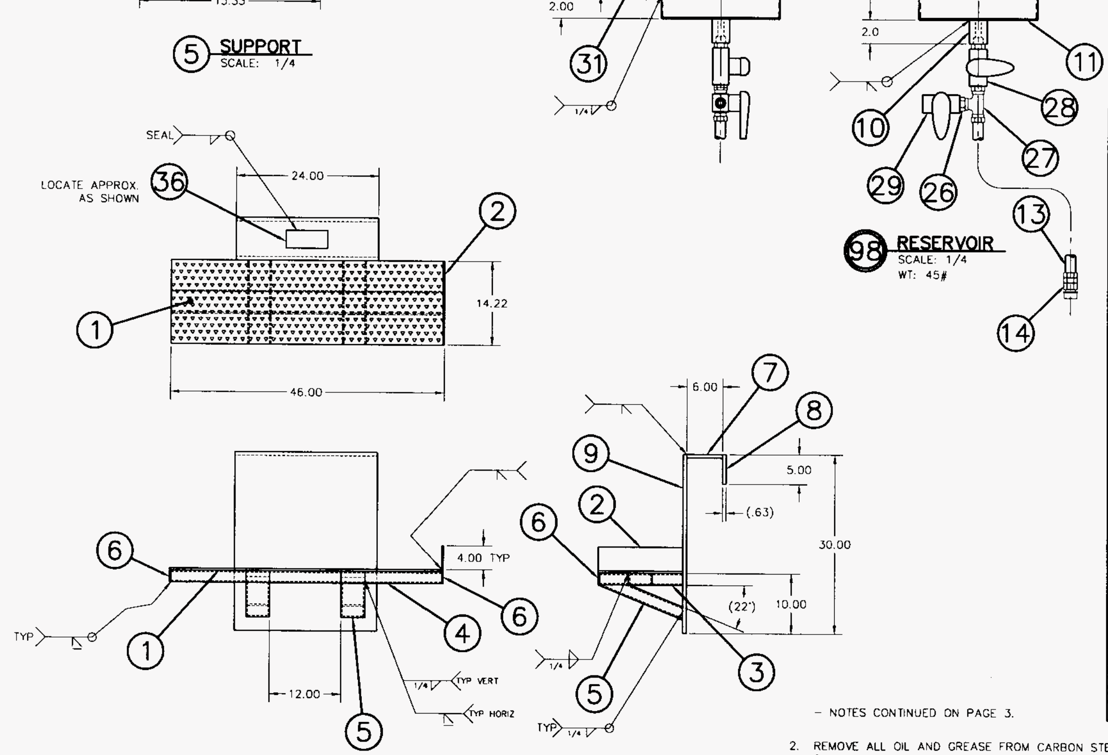
NAC INTERNATIONAL

K BASIN IMMERSION PAIL SUPPORT STRUCTURE ASSY TN WHC TRANSPORT CASK, WHC DWG NO: H-1-81553

PROJECT	DESIGN PACKAGE	DRAWING	REV
457		110	0
SCALE 1/6	EST. WT	SH 1 OF 1	3:43PM 12-2-96

No.	REVISION	BY	APPROVED BY	DATE
0	INITIAL ISSUE			





99 WORK PLATFORM
WT: 325#

95 WORK PLATFORM
MIRROR IMAGE OF -99

PROJECT INFORMATION
WHC SPECIFICATION NO.: WHC-S-0396
ITEM 7
WHC P.O. NO.: MJK-SPX-452727
TRANSNUCLEAR, INC. PROJECT NO.: 3035

94 ASSY	95 ASSY	96 ASSY	97 ASSY	98 ASSY	99 ASSY	ITEM	NAME	MATERIAL	SPEC	DRAWING No.	DESCRIPTION
						39	IMM.PAIL NAMEPL.	304 ST.STL.	ASTM A240		12 GA SHEET
						38	TRAILER PLAT. SIGN	304 ST.STL.	ASTM A240		12 GA SHEET
						37	CVD LID NAMEPL	304 ST.STL.	ASTM A240		12 GA SHEET
	1				1	36	WORK PLAT. NAMEPL	304 ST.STL.	ASTM A240		12 GA SHEET
						35	IMM.PAIL LID NAMEPL	304 ST.STL.	ASTM A240		12 GA SHEET
						34	SUPT.STRUC.NAMEPL	304 ST.STL.	ASTM A240		12 GA SHEET
						33	LIFT BEAM NAMEPL	304 ST.STL.	ASTM A240		12 GA SHEET
				2		32	GUSSET	304 ST.STL.	ASTM A240		1/4 PLATE
				1		31	BRACKET	304 ST.STL.	ASTM A240		1/4 PLATE
1						30	HOSE	NEOPRENE	COML		1/2 ID X 36 FT., 1/2 NPT MALE ENDS
				1		29	2-WAY VALVE	316 ST.STL.	COML		WHITEY #SS-45F8-RD
				1		28	2-WAY VALVE	316 ST.STL.	COML		WHITEY #SS-45F8
				1		27	PIPE TEE	304 ST.STL.	COML		McMASTER-CARR #4464K51
				3		26	PIPE NIPPLE	304 ST.STL.	COML		McMASTER-CARR #4830K172
			2			25	SLING BOX LID HANDLE	ST.STL.	ASTM A276		3/8 DIA BAR
			1			24	SLING BOX SPACER	ST.STL.	ASTM A554		2 X 4 X .18 WALL RECT. TUBE
			1			23	SLING BOX HINGE	ST.STL.	COML		McMASTER-CARR #1582A519
			2			22	SLING BOX FRONT/BACK	ST.STL.	ASTM A240		7 GAUGE SHEET
			2			21	SLING BOX SIDE	ST.STL.	ASTM A240		7 GAUGE SHEET
			1			20	SLING BOX TOP	ST.STL.	ASTM A240		7 GAUGE SHEET
			1			19	SLING BOX BOTTOM	ST.STL.	ASTM A240		7 GAUGE SHEET
			1			18	SLING BOX MOUNT ASSY.			457-111-96	
		1				17	SLING BOX MOUNT PLATE	ST.STL.	ASTM A240		3/8 PLATE
		2				16	SLING BOX MOUNT GUSSET	ST.STL.	ASTM A240		3/8 PLATE
		1				15	SLING BOX MOUNT BASE	ST.STL.	ASTM A240		1/2 PLATE
1				1		14	COUPLING	ST.STL.	COML		HANSEN #LL3-H21
				1		13	HOSE	NEOPRENE	COML		1/2 ID X 25 FT., 1/2 NPT MALE ENDS
				4		12	WALL	304 ST.STL.	ASTM A240		1/4 PLATE
				1		11	BASE	304 ST.STL.	ASTM A240		1/4 PLATE
				1		10	NIPPLE	304 ST.STL.	ASTM A276		1 1/2 DIA BAR
	1				1	9	PLATE	CARBON STEEL	ASTM A36		5/8 PLATE
	1				1	8	PLATE	CARBON STEEL	ASTM A36		5/8 PLATE
	1				1	7	CAP	CARBON STEEL	ASTM A36		5/8 PLATE
	4				4	6	CAP	CARBON STEEL	ASTM A36		1/4 PLATE
	2				2	5	BRACE	CARBON STEEL	ASTM A500 GRADE B		2 X 4 X 1/4 WALL TUBE
	1				1	4	BRACE	CARBON STEEL	ASTM A500 GRADE B		2 X 4 X 1/4 WALL TUBE
	2				2	3	EXTENSION	CARBON STEEL	ASTM A500 GRADE B		2 X 4 X 1/4 WALL TUBE
	1				1	2	TOE KICK	CARBON STEEL	ASTM A36		1/4 PLATE
	1				1	1	DECKING	CARBON STEEL	COML		3/8 DIAMOND PLATE

QUANTITY

- NOTES CONTINUED ON PAGE 3.

2. REMOVE ALL OIL AND GREASE FROM CARBON STEEL SURFACES PER SSPC-S-1. ABRASIVE BLAST PER SSPC-SP 10. PRIME WITH ONE COAT AMERCOAT NUMBER 64 PRIMER AND FINISH WITH TWO COATS WHITE AMERCOAT NUMBER 66 SEAL GLOSS TOPCOAT.

1. FABRICATE PER NAC SPECIFICATION 457-S-02.

NOTES:

SYM.	GEOMETRY
	FLATNESS
	STRAIGHTNESS
	ANGULARITY
	PERPENDICULARITY
	PARALLELISM
	CONCENTRICITY
	TRUE POSITION

TOLERANCES UNLESS OTHERWISE SPECIFIED

3 PLACE DEC.	TOL.	2 PLACE DEC.	TOL.
UNDER 3	±.003	UNDER 6	±.02
3-12	±.005	6-18	±.03
OVER 12	±.010	OVER 18	±.06
1 PLACE DEC.	±.1	FILLETS .015 TO .030	
FINISH (√)-A-125 MICRO IN		ANGLES ±.5°	
THREADS-UNIFIED CLASS 2B			
RADIUS CORNERS .015-.030			

TYPE OF DRAWING: ENGINEERING

NEXT ASSEMBLY: 457-108

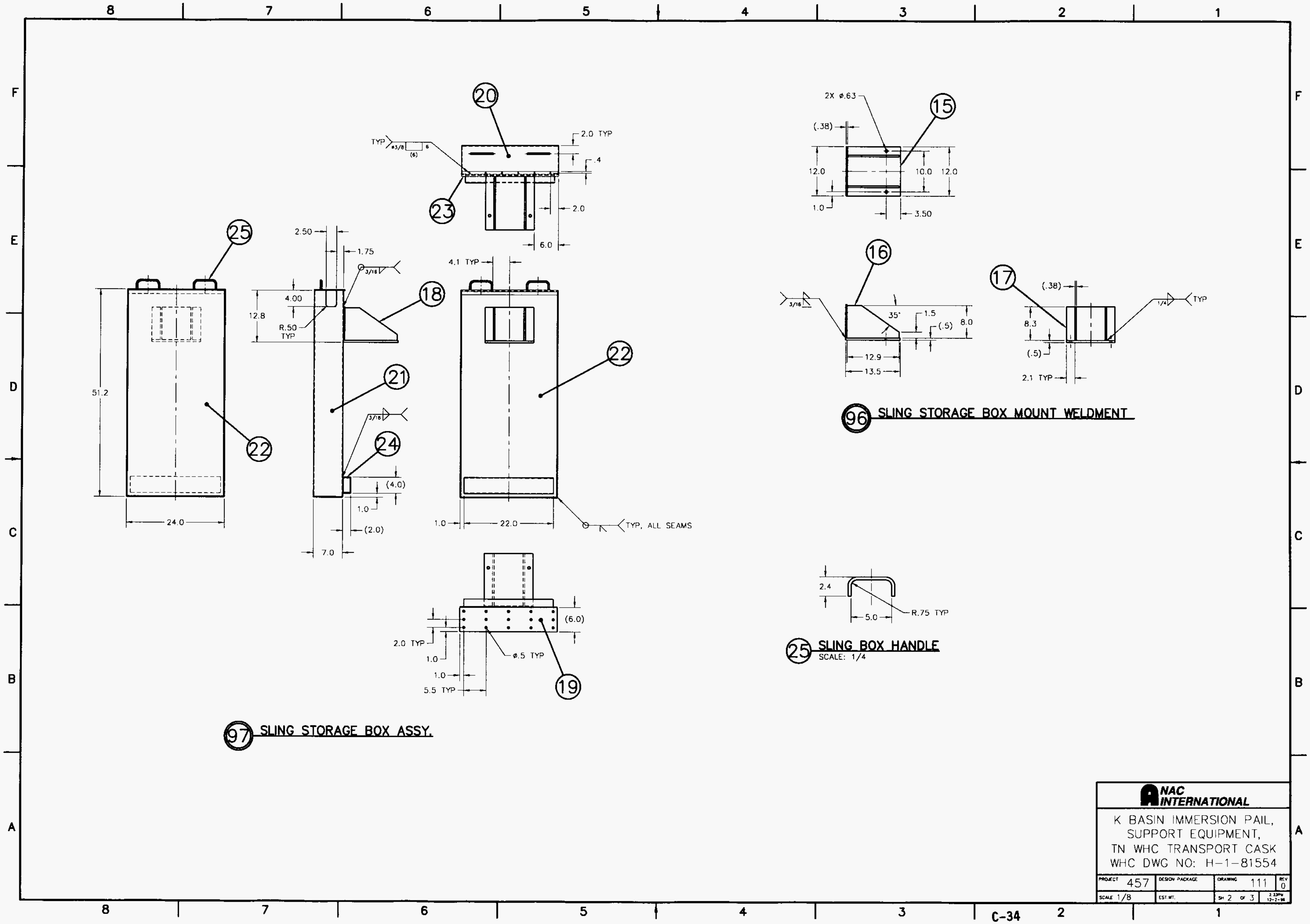
GROUP / NAME / DATE: DRAWN, CHECK, DESIGN AND ANALYSIS, LICENSING, PROJECTS, QUALITY, V.P. ENGINEERING (signed and dated)

NAC INTERNATIONAL

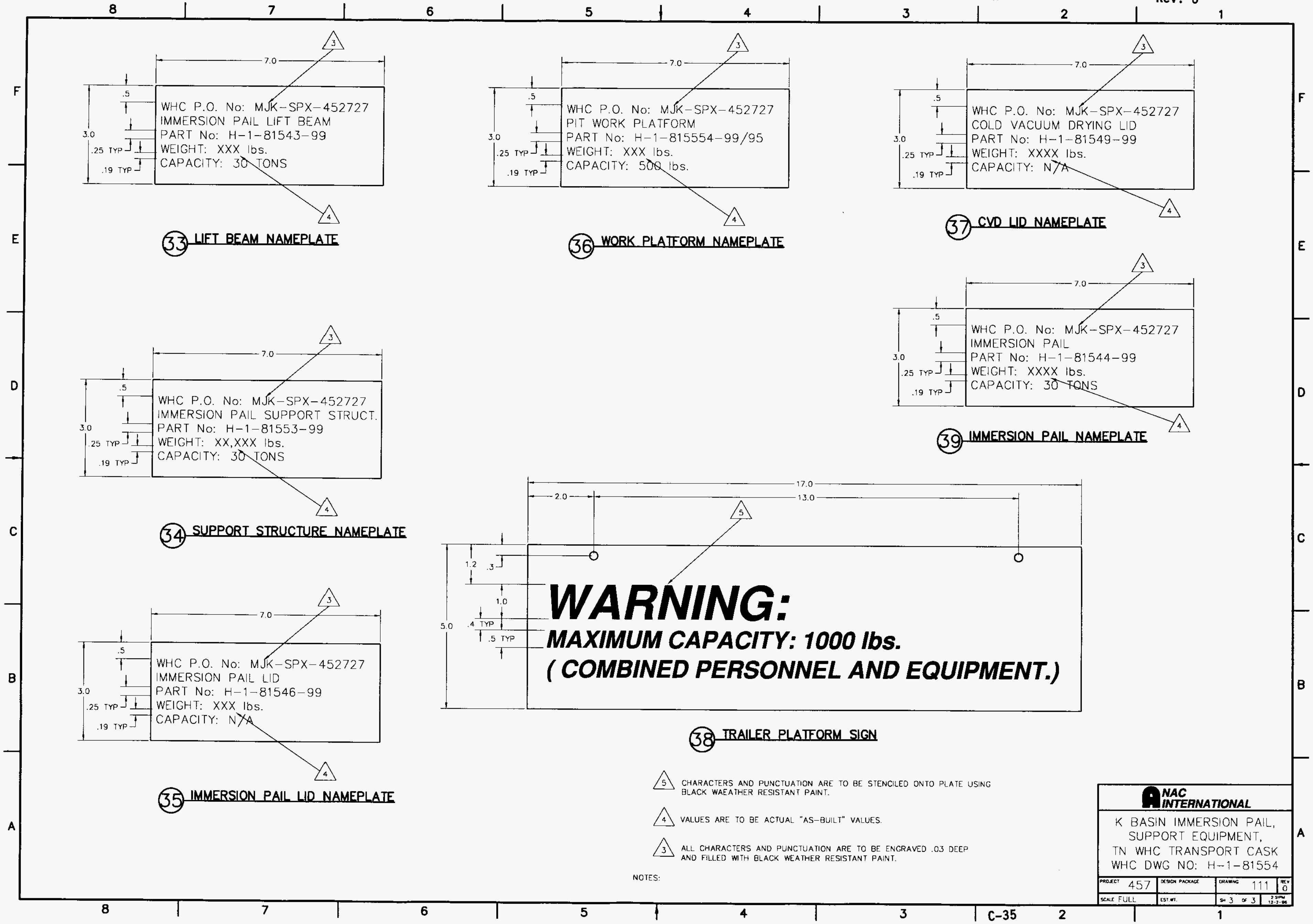
K BASIN IMMERSION PAIL, SUPPORT EQUIPMENT, TN WHC TRANSPORT CASK WHC DWG NO: H-1-81554

PROJECT 457 | DESIGN PACKAGE | DRAWING 111 | REV 0

SCALE 1/8 | EST.WT. | SH 1 OF 3

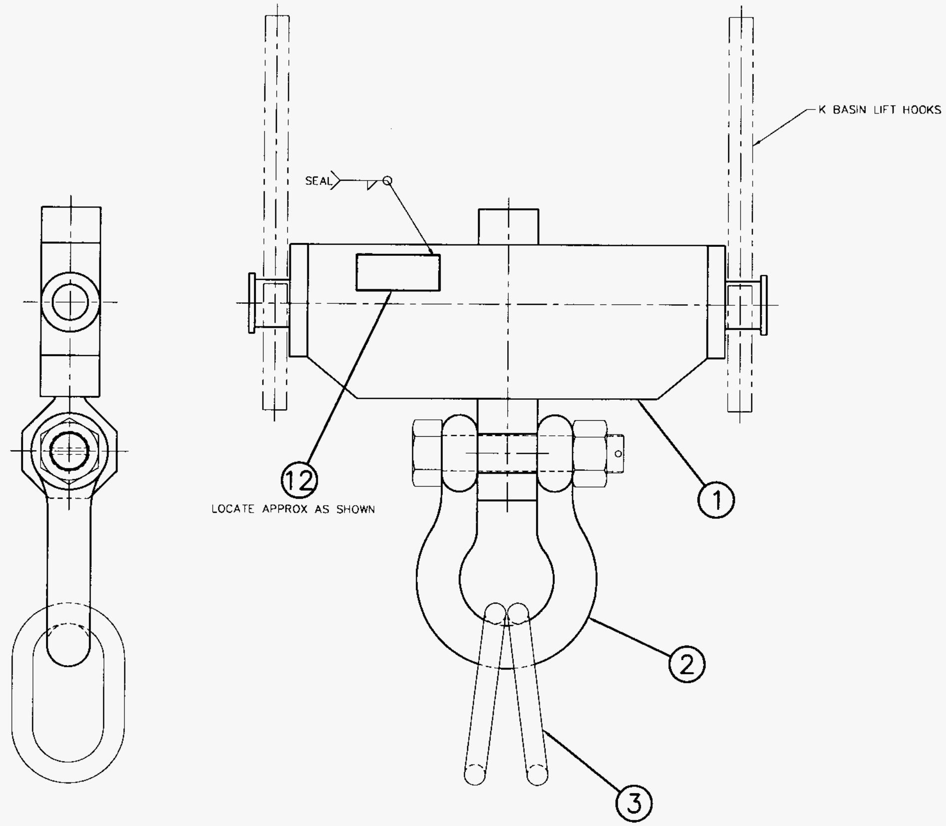


97 SLING STORAGE BOX ASSY.
96 SLING STORAGE BOX MOUNT WELDMENT
25 SLING BOX HANDLE
SCALE: 1/4
TYP, ALL SEAMS
2X ø.63
R.75 TYP
R.50 TYP
ø.5 TYP
NAC INTERNATIONAL
K BASIN IMMERSION PAIL, SUPPORT EQUIPMENT, TN WHC TRANSPORT CASK
WHC DWG NO: H-1-81554
PROJECT 457
DRAWING 111
REV 0
SCALE 1/8
SH 2 OF 3


WHC P.O. No: MJK-SPX-452727
IMMERSION PAIL LIFT BEAM
PART No: H-1-81543-99
WEIGHT: XXX lbs.
CAPACITY: 30 TONS
33 LIFT BEAM NAMEPLATE
WHC P.O. No: MJK-SPX-452727
PIT WORK PLATFORM
PART No: H-1-815554-99/95
WEIGHT: XXX lbs.
CAPACITY: 500 lbs.
36 WORK PLATFORM NAMEPLATE
WHC P.O. No: MJK-SPX-452727
COLD VACUUM DRYING LID
PART No: H-1-81549-99
WEIGHT: XXXX lbs.
CAPACITY: N/A
37 CVD LID NAMEPLATE
WHC P.O. No: MJK-SPX-452727
IMMERSION PAIL
PART No: H-1-81544-99
WEIGHT: XXXX lbs.
CAPACITY: 30 TONS
39 IMMERSION PAIL NAMEPLATE
WHC P.O. No: MJK-SPX-452727
IMMERSION PAIL SUPPORT STRUCT.
PART No: H-1-81553-99
WEIGHT: XX,XXX lbs.
CAPACITY: 30 TONS
34 SUPPORT STRUCTURE NAMEPLATE
WHC P.O. No: MJK-SPX-452727
IMMERSION PAIL LID
PART No: H-1-81546-99
WEIGHT: XXX lbs.
CAPACITY: N/A
35 IMMERSION PAIL LID NAMEPLATE
WARNING:
MAXIMUM CAPACITY: 1000 lbs.
(COMBINED PERSONNEL AND EQUIPMENT.)
38 TRAILER PLATFORM SIGN
7.0
.5
3.0
.25 TYP
.19 TYP
17.0
2.0
13.0
1.2
.3
1.0
.4 TYP
.5 TYP
5.0
5 CHARACTERS AND PUNCTUATION ARE TO BE STENCILED ONTO PLATE USING BLACK WAEATHER RESISTANT PAINT.
4 VALUES ARE TO BE ACTUAL "AS-BUILT" VALUES.
3 ALL CHARACTERS AND PUNCTUATION ARE TO BE ENGRAVED .03 DEEP AND FILLED WITH BLACK WEATHER RESISTANT PAINT.
NOTES:
NAC INTERNATIONAL
K BASIN IMMERSION PAIL,
SUPPORT EQUIPMENT,
TN WHC TRANSPORT CASK
WHC DWG NO: H-1-81554
PROJECT 457
DRAWING 111
REV 0
SCALE FULL
SH 3 OF 3

No.	REVISION	BY	APPROVED BY	DATE
0	INITIAL ISSUE			

GEORGIA REGISTERED No. 15706 PROFESSIONAL ENGINEER NORMAN M. MEINERT



99 LIFT BEAM ASSEMBLY

PROJECT INFORMATION
WHC SPECIFICATION NO.: WHC-S-0396
ITEM 7
WHC P.O. NO.: MJK-SPX-452727
TRANSNUCLEAR, INC. PROJECT NO.: 3035

3. THIS ASSEMBLY IS A SAFETY RELATED LOAD PATH COMPONENT.

2. REMOVE ALL OIL AND GREASE FROM SURFACES IN ACCORDANCE WITH SSPC-SP 1-82. ABRASIVE BLAST TO NEAR WHITE METAL FINISH PER SSPC-SP 10. APPLY ONE COAT OF AMERCOAT NUMBER 64 PRIMER AND FINISH WITH TWO COATS YELLOW (5607) AMERCOAT NUMBER 66 SEAL GLOSS TOPCOAT.

1. FABRICATE PER NAC SPECIFICATION 457-S-02.

NOTE:

97 ASSY	98 ASSY	99 ASSY	ITEM	NAME	MATERIAL	SPEC	DRAWING No.	DESCRIPTION
		1	12	LIFT BEAM NAMEPLATE			457-111-33	
	1		11	EYE PLATE	CARBON STEEL	ASTM A516, GR 55		5 PLATE
	2		10	TOP PLATE	CARBON STEEL	ASTM A516, GR 55		1/2 PLATE
	2		9	CORNER PLATE	CARBON STEEL	ASTM A516, GR 55		1/2 PLATE
	2		8	BOTTOM PLATE	CARBON STEEL	ASTM A516, GR 55		1 1/2 PLATE
	2		7	TRUNNION CAP	CARBON STEEL	ASTM A516, GR 55		1/2 PLATE
	2		6	TRUNNION	CARBON STEEL	ASTM A588, GR A		4 DIA ROUND BAR
	2		5	END PLATE	CARBON STEEL	ASTM A516, GR 55		1 1/2 PLATE
	2		4	SIDE PLATE	CARBON STEEL	ASTM A516, GR 55		1 1/4 PLATE
		2	3	MASTER LINK	ALLOY STEEL	COML		CROSBY #A-342-1014388
		1	2	SHACKLE	ALLOY STEEL	COML		CROSBY #G-2130-1019711
		1	1	LIFT BEAM WELDMENT			457-112-98	

QUANTITY

TOLERANCES UNLESS OTHERWISE SPECIFIED			
3 PLACE DEC.	TOL.	2 PLACE DEC.	TOL.
UNDER 3	±.003	UNDER 6	±.02
3-12	±.005	6-18	±.03
OVER 12	±.010	OVER 18	±.06
1 PLACE DEC.	±.1	FILLETS .015 TO .030	
FINISH (√)-AA-125 MICRO IN		ANGLES ±.5°	
THREADS-UNIFIED CL2A-2B			
RADIUS CORNERS .015-.030			

SYM. GEOMETRY: FLATNESS, STRAIGHTNESS, ANGULARITY, PERPENDICULARITY, PARALLELISM, CONCENTRICITY, TRUE POSITION

TYPE OF DRAWING: ENGINEERING

GROUP / NAME / DATE: DRAWN; CHECK; DESIGN AND ANALYSES; LICENSING N/A; PROJECTS; QUALITY; V.P. ENGINEERING 12/2/96

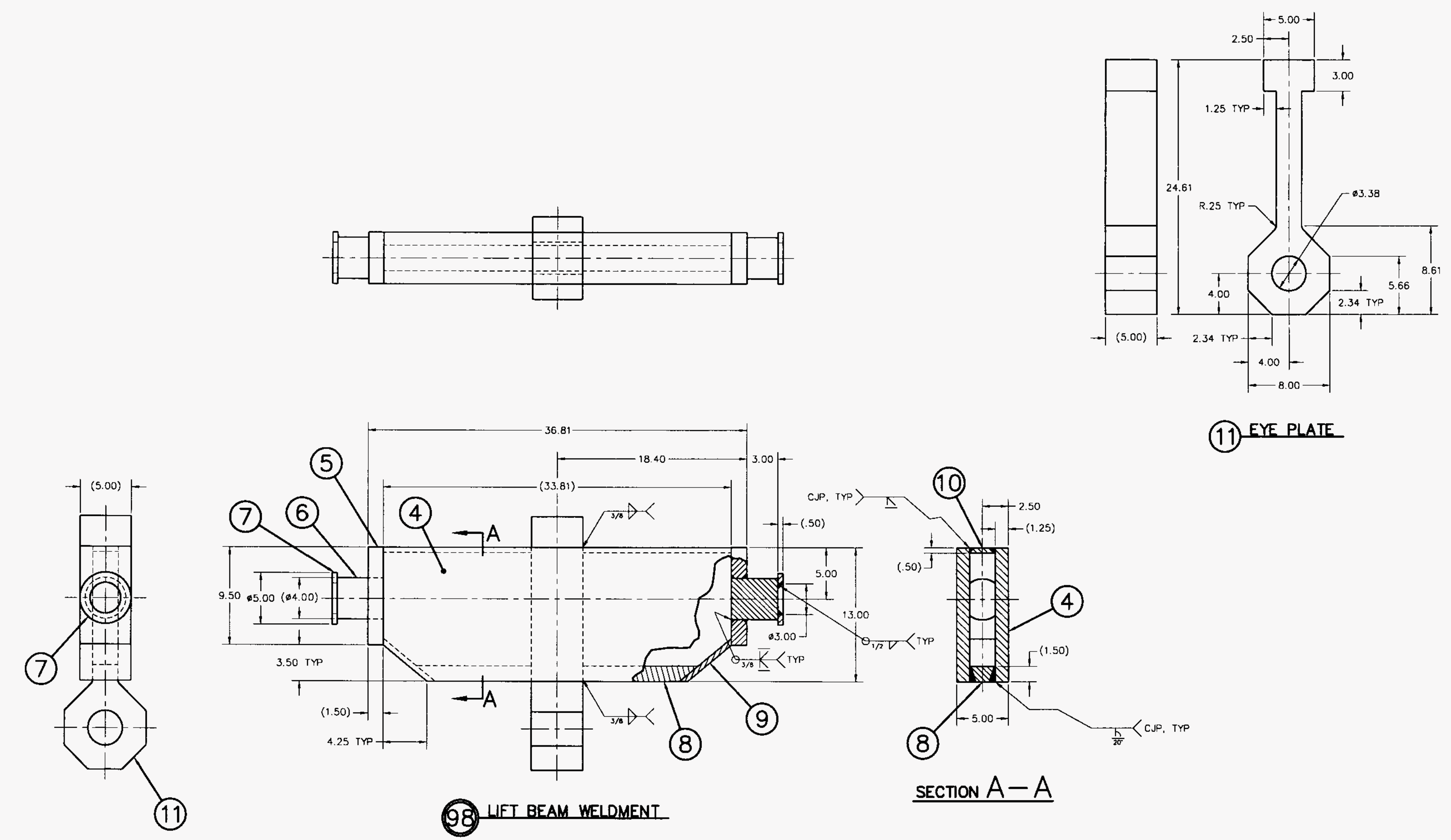
NEXT ASSEMBLY 457-108

NAC INTERNATIONAL

K BASIN IMMERSION PAIL, LIFT BEAM ASSEMBLY, TN WHC TRASPORT CASK WHC DWG NO: H-1-81543

PROJECT 457 | DESIGN PACKAGE | DRAWING 112 | REV 0

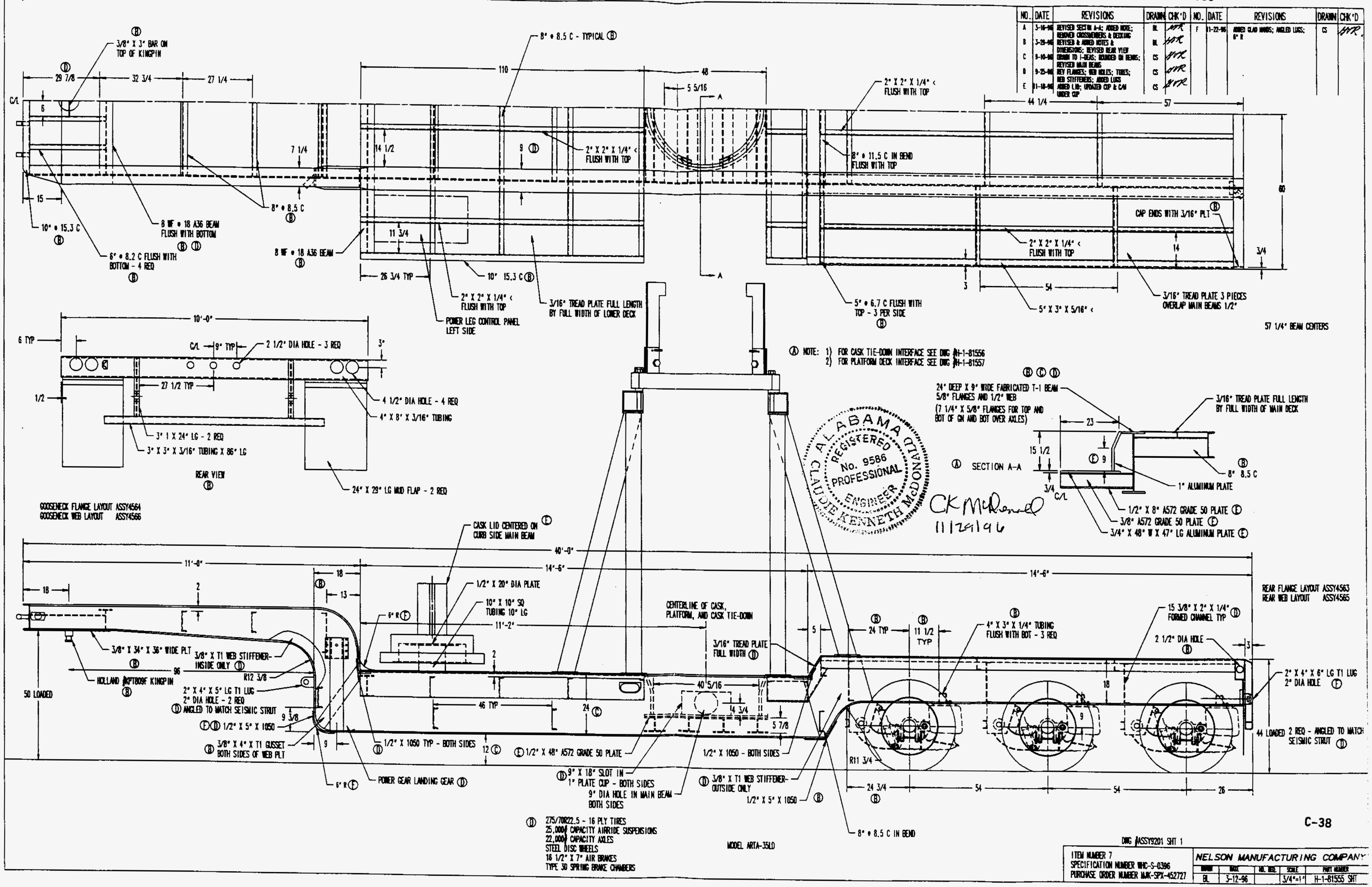
SCALE 1/4 | EST. WT. | SH 1 OF 2 | 2:43PM 12-2-96

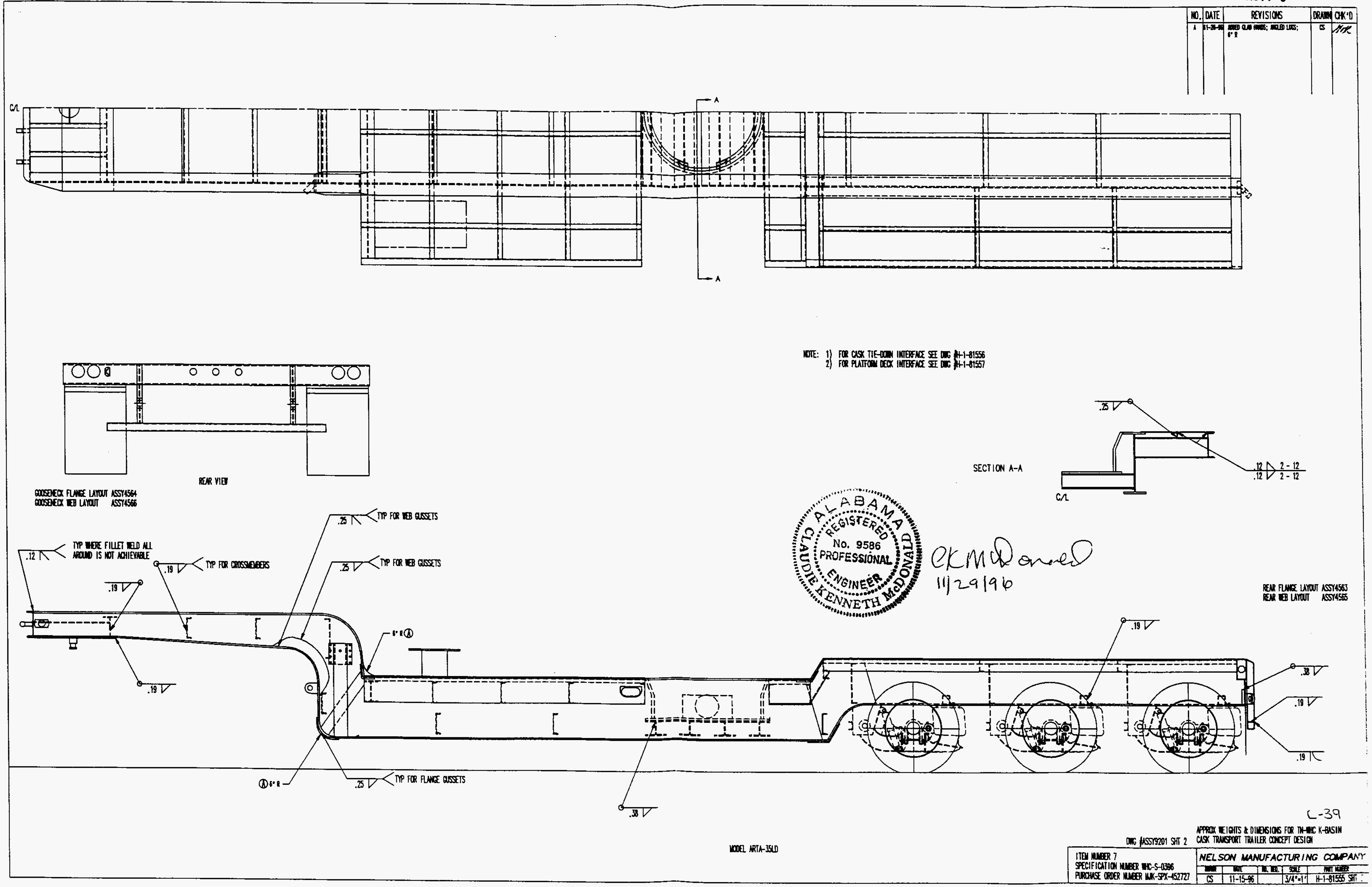


NAC INTERNATIONAL

K BASIN IMMERSION PAIL,
LIFT BEAM ASSEMBLY,
TN WHC TRANSPORT CASK
WHC DWG NO: H-1-81543

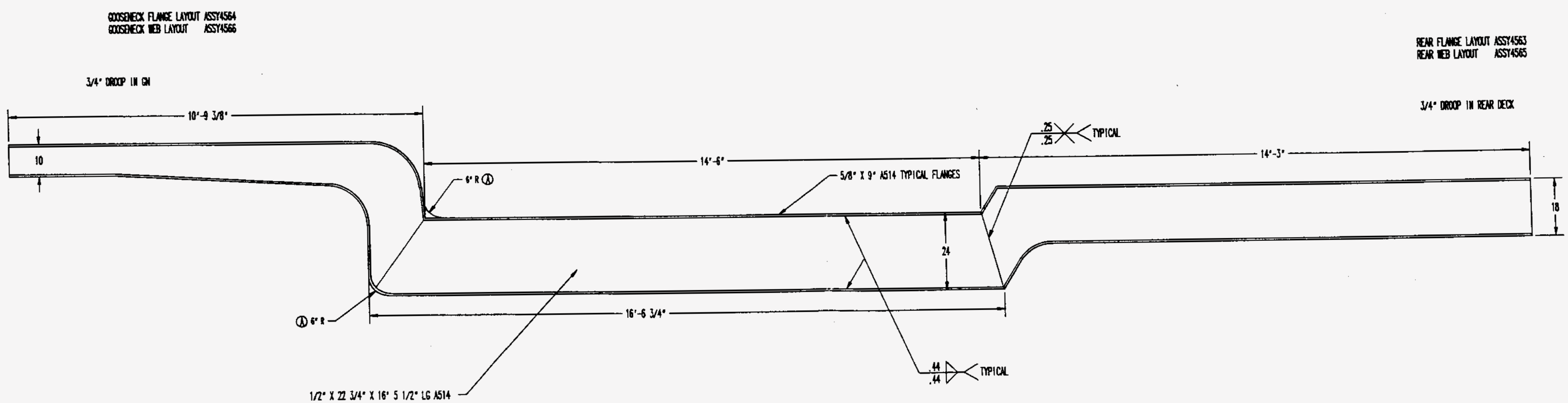
PROJECT	DESIGN PACKAGE	DRAWING	REV
457		112	0
SCALE 1/4	EST WT.	SH 2 OF 2	


REVISIONS
A 3-16-96 REVISED SECTION A-A; ADDED NOTE; REMOVED CROSSMEMBERS & DECKING
B 3-29-96 REVISED & ADDED NOTES & DIMENSIONS; REVISED REAR VIEW
C 9-10-96 CHANGED TO I-BEAMS; ROUNDED GN BENDS; REVISED MAIN BEAMS
D 9-25-96 REV FLANGES; WEB HOLES; TIRES; WEB STIFFENERS; ADDED LUGS
E 11-18-96 ADDED LID; UPDATED CUP & C/A UNDER CUP
F 11-22-96 ADDED CLAD HANDS; ANGLED LUGS; 6" R
3/8" X 3" BAR ON TOP OF KINGPIN
8" ● 8.5 C - TYPICAL
2" X 2" X 1/4" ∠ FLUSH WITH TOP
8" ● 11.5 C IN BEND FLUSH WITH TOP
CAP ENDS WITH 3/16" PLT
10" ● 15.3 C
8 WF ● 18 A36 BEAM FLUSH WITH BOTTOM
6" ● 8.2 C FLUSH WITH BOTTOM - 4 REQ
8" ● 8.5 C
8 WF ● 18 A36 BEAM
POWER LEG CONTROL PANEL LEFT SIDE
3/16" TREAD PLATE FULL LENGTH BY FULL WIDTH OF LOWER DECK
5" ● 6.7 C FLUSH WITH TOP - 3 PER SIDE
5" X 3" X 5/16" ∠
3/16" TREAD PLATE 3 PIECES OVERLAP MAIN BEAMS 1/2"
57 1/4" BEAM CENTERS
2 1/2" DIA HOLE - 3 REQ
4 1/2" DIA HOLE - 4 REQ
4" X 8" X 3/16" TUBING
3" 1 X 24" LG - 2 REQ
3" X 3" X 3/16" TUBING X 86" LG
REAR VIEW
24" X 29" LG MUD FLAP - 2 REQ
GOOSENECK FLANGE LAYOUT ASSY4564
GOOSENECK WEB LAYOUT ASSY4566
NOTE: 1) FOR CASK TIE-DOWN INTERFACE SEE DWG H-1-81556
2) FOR PLATFORM DECK INTERFACE SEE DWG H-1-81557
24" DEEP X 9" WIDE FABRICATED T-1 BEAM 5/8" FLANGES AND 1/2" WEB (7 1/4" X 5/8" FLANGES FOR TOP AND BOT OF GN AND BOT OVER AXLES)
3/16" TREAD PLATE FULL LENGTH BY FULL WIDTH OF MAIN DECK
SECTION A-A
1" ALUMINUM PLATE
8" 8.5 C
1/2" X 8" A572 GRADE 50 PLATE
3/8" A572 GRADE 50 PLATE
3/4" X 48" W X 47" LG ALUMINUM PLATE
ALABAMA REGISTERED No. 9586 PROFESSIONAL ENGINEER CLAUDE KENNETH McDONALD
CK McDonald 11/29/96
CASK LID CENTERED ON CURB SIDE MAIN BEAM
1/2" X 20" DIA PLATE
10" X 10" SQ TUBING 10" LG
CENTERLINE OF CASK, PLATFORM, AND CASK TIE-DOWN
3/16" TREAD PLATE FULL WIDTH
REAR FLANGE LAYOUT ASSY4563
REAR WEB LAYOUT ASSY4565
4" X 3" X 1/4" TUBING FLUSH WITH BOT - 3 REQ
15 3/8" X 2" X 1/4" FORMED CHANNEL TYP
2 1/2" DIA HOLE
2" X 4" X 6" LG T1 LUG 2" DIA HOLE
44 LOADED 2 REQ - ANGLED TO MATCH SEISMIC STRUT
3/8" X 34" X 36" WIDE PLT
3/8" X T1 WEB STIFFENER - INSIDE ONLY
HOLLAND KPT809F KINGPIN
50 LOADED
2" X 4" X 5" LG T1 LUG 2" DIA HOLE - 2 REQ ANGLED TO MATCH SEISMIC STRUT
1/2" X 5" X 1050
3/8" X 4" X T1 GUSSET BOTH SIDES OF WEB PLT
1/2" X 1050 TYP - BOTH SIDES
POWER GEAR LANDING GEAR
1/2" X 48" A572 GRADE 50 PLATE
9" X 18" SLOT IN 1" PLATE CUP - BOTH SIDES 9" DIA HOLE IN MAIN BEAM BOTH SIDES
1/2" X 1050 - BOTH SIDES
3/8" X T1 WEB STIFFENER - OUTSIDE ONLY
1/2" X 5" X 1050
8" ● 8.5 C IN BEND
275/70R22.5 - 16 PLY TIRES
25,000# CAPACITY AIRRIDE SUSPENSIONS
22,000# CAPACITY AXLES
STEEL DISC WHEELS
16 1/2" X 7" AIR BRAKES
TYPE 30 SPRING BRAKE CHAMBERS
MODEL ARTA-35LD
DWG ASSY9201 SHT 1
ITEM NUMBER 7
SPECIFICATION NUMBER WHC-S-0396
PURCHASE ORDER NUMBER MJK-SPX-452727
NELSON MANUFACTURING COMPANY
BL 3-12-96 3/4"=1' H-1-81555 SHT



NO. | DATE | REVISIONS | DRAWN | CHK'D
A | 11-26-96 | ADDED CLAD HANDS; ANGLED LUGS; 6" R | CS
C/L
A
A
NOTE: 1) FOR CASK TIE-DOWN INTERFACE SEE DWG #H-1-81556
2) FOR PLATFORM DECK INTERFACE SEE DWG #H-1-81557
REAR VIEW
GOOSENECK FLANGE LAYOUT ASSY4564
GOOSENECK WEB LAYOUT ASSY4566
SECTION A-A
C/L
.25
.12 2 - 12
.12 2 - 12
TYP FOR WEB GUSSETS
TYP WHERE FILLET WELD ALL AROUND IS NOT ACHIEVABLE
TYP FOR CROSSMEMBERS
TYP FOR FLANGE GUSSETS
.12
.19
.25
.38
6" R
REAR FLANGE LAYOUT ASSY4563
REAR WEB LAYOUT ASSY4565
ALABAMA REGISTERED No. 9586 PROFESSIONAL ENGINEER CLAUDIE KENNETH McDONALD
CKMcDonald
11/29/96
L-39
MODEL ARTA-35LD
DWG #ASSY9201 SHT 2
APPROX WEIGHTS & DIMENSIONS FOR TN-WHC K-BASIN CASK TRANSPORT TRAILER CONCEPT DESIGN
ITEM NUMBER 7
SPECIFICATION NUMBER WHC-S-0396
PURCHASE ORDER NUMBER MJK-SPX-452727
NELSON MANUFACTURING COMPANY
CS
11-15-96
3/4"=1'
H-1-81555 SHT

NO.	DATE	REVISIONS	DRAWN	CHK'D
A	11-26-96	ADDED 6" R	CS	JR.



ALABAMA REGISTERED No. 9586 PROFESSIONAL ENGINEER CLAUDIE KENNETH McDONALD

C K McDonald
11/29/96

C-40

MODEL ARTA-35LD

DWG #ASSY9201 SHT 3

APPROX WEIGHTS & DIMENSIONS FOR TN-WHC K-BASIN
CASK TRANSPORT TRAILER CONCEPT DESIGN

ITEM NUMBER 7
SPECIFICATION NUMBER WHC-S-0396
PURCHASE ORDER NUMBER MJK-SPX-452727

NELSON MANUFACTURING COMPANY

DRAWN	DATE	NO. REQ.	SCALE	PART NUMBER
CS	11-18-96		3/4"=1'	H-1-81555 SHT 3

DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	SNF Storage Projects	Date 2/5/97
Project Title/Work Order		EDT No. 620085
Spent Nuclear Fuel Project/Cask and Transporation System		ECN No. NA

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
K. E. Ard	X3-85				X
G. D. Bazinet	B4-55				X
S. A. Brisbin	R3-86				X
D. M. Chenault	R3-86				X
W. S. Edwards	G1-11				X
L. H. Goldmann	R3-86				X
C. R. Hoover	G1-50				X
J. J. Irwin	H0-34				X
A. T. Kee	R3-86				X
T. D. Merkling	X3-79				X
C. B. Loftis	S7-41				X
R. W. Rasmussen	R3-86				X
C. A. Thompson	R3-85				X
Central Files	A3-88	X			
project files	R3-11	X			

A-6000-135 (01/93) WEF067