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7. Abstract

This Safety Evaluation for Packaging (SEP) provides analysis and evaluations considered necessary to approve a one-time transfer of the 101-SY Hydrogen Mitigation Mixer Pump (HMMP). This SEP will demonstrate that the transfer of the HMMP in a new shipping container will provide an equivalent degree of safety as would be provided by packages meeting U.S. Department of Transportation (DOT)/U.S. Nuclear Regulatory Commission (NRC) requirements. This fulfills onsite transportation requirements implemented by WHC-CM-2-14.

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EXECUTIVE SUMMARY

This Safety Evaluation for Packaging (SEP) evaluates and documents the ability of the 101-SY Hydrogen Mitigation Mixer Pump (HMMP) Package to meet the radioactive material packaging requirements of WHC-CM-2-14, *Hazardous Material Packaging and Shipping.*[*] This packaging is used for the onsite transfer of the radioactively contaminated HMMP from the SY Tank Farm to designated storage or disposal areas. Onsite transfer is the transport of hazardous materials on controlled routes confined to established limited areas and to portions of federally owned roadways to which public access is prohibited during transfer.

The HMMP Package is used only for the transfer of the HMMP. The HMMP Package consists of two cylindrical carbon steel standard wall pipes with bolted flanged ends which provide two containment barriers for the contaminated pump. An annulus space between the pipes is provided to add lead or steel shot as required for shielding purposes. The package is loaded onto a truck-trailer combination and transferred to the designated storage or disposal site.

Part A of this SEP provides a description of the packaging, payload, and transfer operations. It also sets forth operational requirements for package transfer. Part B of this document contains the package evaluations: shielding, structural, tiedown, thermal, containment, risk, dose consequence, pressure, and hydrogen generation.

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[*] WHC-CM-2-14, *Hazardous Material Packaging and Shipping*, Westinghouse Hanford Company, Richland, Washington.

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LIST OF TERMS

ASME	American Society for Mechanical Engineers
ASTM	American Society for Testing and Materials
CWC	Central Waste Complex
DOT	U.S. Department of Transportation
ECN	Engineering Change Notice
EDE	effective dose equivalent
HEPA	high-efficiency particulate air (filter)
HMMP	Hydrogen Mitigation Mixer Pump
LST	lowest service temperature
NBS	Nominal Breaking Strength
NDT	Nil Ductility Testing
NRC	U.S. Nuclear Regulatory Commission
PDC	Packaging Design Criteria
QA	Quality Assurance
RL	U.S. Department of Energy, Richland Operations Office
SARP	Safety Analysis Report for Packaging
SEP	Safety Evaluation for Packaging
WHC	Westinghouse Hanford Company

PART A - PACKAGE DESCRIPTION AND OPERATIONS

1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

Radioactive waste material in storage tank 241-SY-101 (101-SY) causes higher-than-normal hydrogen gas buildup in the tank waste. Rollover of the radioactive waste contents occurs periodically during venting of the hydrogen gas. A modified test pump 60 ft long, 19,247 lb in weight, and powered by a 150 horsepower electric motor was installed in 101-SY to evaluate whether the agitation of the tank contents would lead to gradual release of hydrogen and, thereby, avoid safety concerns with periodic release of large quantities of hydrogen. This pump is referred as the Hydrogen Mitigation Mixer Pump (HMMP).

After completion of the testing program for hydrogen mitigation, this pump will be removed from 101-SY. As it is pulled out of 101-SY, the radioactively contaminated pump will undergo a high pressure water spray operation and then will be enclosed inside a portable flexible bag assembly. The pump will then be inserted into a shipping container which provides two containment barriers for the contaminated pump. Approximately 13 ft of the upper section of the pump will be cut off and the shipping container will then be sealed. This loaded shipping container is referred to as the HMMP Package. The packaging and contents will be transferred from the Tank Farms to the Central Waste Complex (CWC) for interim storage and then to T Plant for evaluation and processing for final disposition.

A Packaging Design Criteria (PDC), WHC-SD-TP-PDC-019 (WHC 1994), was developed to provide design criteria for both the onsite transfer and storage of the removed equipment. Data presented in the PDC indicates that the equipment (pump) is a Type B quantity of waste and should be classified as **mixed low-level waste** for purposes of packaging design and transfer evaluations.

Classification as mixed waste requires that the equipment must be transferred from the Tank Farms to a licensed mixed waste storage facility within 90 days. This classification requires that the packaging must be designed and evaluated to meet special storage acceptance requirements at the CWC. Special package requirements for storage at the CWC include two containment barriers, 20 year service life, and 100 mrem/h or less radiation dose rate at the surface of the package.

1.2 PURPOSE AND SCOPE

This Safety Evaluation for Packaging (SEP) provides safety analyses and evaluations considered necessary to support a safe one-time onsite waste transfer of the HMMP Package. The scope will include the transfer of the HMMP Package from the Tank Farms to the CWC for interim storage and then to T Plant for processing and disposition.

This SEP demonstrates that the short-term onsite transfer of the HMMP Package meets the onsite transportation criteria. This fulfills the onsite transportation safety requirements implemented in WHC-CM-2-14, *Hazardous Material Packaging and Shipping.*

2.0 PACKAGING SYSTEMS

2.1 GENERAL INFORMATION

This section provides a description of the packaging system that will be used to transfer and store the HMMP described in Part A, Section 1.0 of this SEP. Information presented in this section will be evaluated in Part B of the SEP to assure that the proposed packaging system meets identified criteria and requirements.

The packaging consists of two cylindrical carbon steel standard wall pipes with bolted flanged ends which provide two containment barriers for the contaminated pump. The HMMP Package is designed to withstand normal transfer conditions and accident tests described in Part B of this SEP. The design lifetime is 20 years in the environment of the CWC. The HMMP Package will only be transferred in the horizontal position and will include adequate lifting attachments and tiedown down devices. Internal shielding, if required, will be added in the form of lead or steel shot in an annular space between two containment barriers to limit dose rates at the surface of the HMMP Package to acceptable values during transfer and interim storage. If additional shielding is required to reduce dose rates, external shielding will be installed on the outside of the HMMP Package.

This SEP will approve transfer of the HMMP Package within one year from date of issue unless otherwise designated by issue of an Engineering Change Notice (ECN).

2.2 CONFIGURATION AND DIMENSIONS

The main packaging assembly consists of a long section of standard wall pipe with closures on each end. The piping section is 64 in. outside diameter x 0.5 in. wall thickness. The closure on one end of the packaging is a 2 in. thick plate welded inside the end of the 64 in. diameter pipe. The inner closure on the opposite end of the assembly is a top hat assembly bolted to a 2 in. thick ring flange attached to the end of the 64 in. diameter pipe. The removable inner closure plate is attached to the ring flange with twenty-eight 1 in. diameter bolts, nuts, and lock washers. A ⅛ in. thick gasket seals the bolted inner plate to the ring flange. The removable outer closure plate is attached to the ring flange with thirty-two 1 in. diameter bolts, nuts, and lock washers. A ⅛ in. thick gasket seals the bolted outer plate to the ring flange. Double containment of the end closures is provided by a 2 in. thick plate welded to the end of the 64 in. pipe at the welded closure end of the packaging and by another top hat assembly installed around the outside of the bolted inner closure end.

Stiffening rings are installed at intervals along the length of the HMMP Package to support/protect the package during lifting and normal transfer and/or potential accident conditions. An outer layer of plate is installed between the stiffening rings to form a 2 in. wide annulus for installation of shielding material along the full length of the package. The outer plate is 5/16 in. thick along the container length, except from column line 8 through 15 which uses ½ in. thick plate. The shielding annulus also provides double containment of the waste contents along the sidewalls of the package for storage.

The overall length of the HMMP Package is nominally 52 ft.

2.3 MATERIALS OF CONSTRUCTION

Material requirements for the HMMP Package are described in the parts list on Westinghouse Hanford Company (WHC) design Drawing H-2-83734, Sheet 1 (Part A, Section 9.2). In general, all structural components are carbon steel. Specifically, the standard wall ½ in. diameter piping material and closure end plates are American Society for Testing and Materials (ASTM) A671 carbon steel. The outer 5/16 in. diameter plate material is ASTM A516 carbon steel. End closure bolts and nuts are alloy steel American Society of Mechanical Engineers (ASME) SA307. Gasket material for sealing the bolted end closure connections is made of reinforced flexible graphite.

2.4 FABRICATION METHODS

Specific fabrication methods for construction and assembly of the package are described in the "General Notes" of packaging design Drawing H-2-83734, Sheet 1 (Part A, Section 9.2).

2.5 WEIGHTS

The calculated maximum gross weight of the HMMP Package with external shielding (lead shot) and contents (HMMP) is approximately 138,800 lb. The weight of the HMMP Package without shielding and with contents (HMMP) is approximately 72,930 lb. The maximum weight of the package is based on installing shielding material in the full length of the shielding annulus.

2.6 CONTAINMENT BOUNDARY

The packaging enclosure (pipe and end plates) is the single containment required during transfer of the HMMP Package and is the primary containment barrier during interim storage of the package. The primary containment boundary is sealed on one end with a welded plate and is sealed on the opposite end with a bolted top hat assembly and gasket. A secondary containment boundary is provided on the HMMP Package by installing additional plates on each end of the main enclosure, by installing the shielding annulus the full length of the package, and by sealing with a bolted top hat assembly and gasket. One pipe fitting is provided on the outside of the package for venting and will be sealed during transfer of the package.

2.7 CAVITY SIZE

The cavity size of the HMMP Package is 63 in. diameter by 52 ft long.

2.8 HEAT DISSIPATION

Maximum heat dissipation from waste contents for the HMMP Package is 0.88 W. The heat is transferred passively to the environment.

2.9 SHIELDING

Shielding will be added on the outside surface of the HMMP Package, if required, to limit dose rate at the surface of the package to 100 mrem/h or less. Shielding will consist of lead shot or steel shot, or other approved material, poured through openings provided on the outside wall of the "shielding annulus." If other shielding is required in addition to the lead shot or steel shot, layers of solid lead shielding will be installed around the outside of the package as necessary to limit the dose rate to acceptable values.

If dose rates are slightly above 100 mrem/h after sealing of the package, use of solid lead shielding on the outside of the package only may be considered.

2.10 LIFTING DEVICES

Lifting attachments are installed on each end of the packaging and are suitable for raising and lowering a fully loaded package in the horizontal position. The lifting attachments are designed for use with a special lifting beam assembly (Drawing H-2-83744 in Part A, Section 9.5).

2.11 TIEDOWN DEVICES

Two special attachments are installed on the bottom end and midpoint of the packaging to secure the package to a strongback/tilt mechanism unit on the transport trailer. Stiffening rings are installed at intervals along the length of the packaging and are provided with holes that are used to attach tiedowns to the transport trailer.

3.0 PACKAGE CONTENTS

3.1 GENERAL DESCRIPTION

Contents of the HMMP Package are considered to be the HMMP placed in a portable flexible bag assembly. The following data relates to the HMMP scheduled for removal from 101-SY and placed in the specific package for transfer:

1. The test pump is located in 101-SY. The physical description and reference drawings are as follows:

Maximum length:	60 ft*
Maximum diameter:	53 in.
Estimated weight:	19,427 lb
Reference drawings:	H-2-89945 through H-2-89967

3.2 RADIONUCLIDE ACTIVITY

Radionuclide activity in terms of curie content is evaluated in Part B, Section 2.1 and indicates that the HMMP Package must be transported as a Type B quantity of waste. Specifically the total curies of waste material attached to the HMMP is 561 Ci and is 280 times the effective A_2 value of the mixture of radionuclides.

3.3 FISSILE CONTENT

Fissile content (in grams) of the estimated amount of waste material attached to the HMMP is evaluated in Part B, Section 2.2. The evaluation indicated that the quantity of fissile material attached to the pump is 1.8 g. The HMMP is thus considered as "fissile excepted" since the total fissile content is less than 15 g.

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*Approximately 13 ft of the upper section of the hydrogen mitigation mixer pump will be cut off after insertion into the shipping container.

4.0 TRANSPORTATION SYSTEM

4.1 TRANSPORTER

The transporter system consists of a truck/trailer assembly suitable for transfer of the HMMP Package system including the shipping container, strongback, and tilting mechanism (maximum 100 tons - Sketch in Part A, Section 9.4). The strongback (Drawing H-2-82736 in Part A, Section 9.3) is used to interface the shipping container with the tilting mechanism. Suitable attachments are provided on the vehicle for securing the HMMP Package to the trailer bed.

4.2 TIEDOWN SYSTEM

Design of a tiedown system is provided to safely secure the HMMP Package on the transport vehicle during transfer to the storage and processing/repackaging facilities. A sketch of the tiedown system in shown in Part B, Section 6.5.

4.3 SPECIAL TRANSFER REQUIREMENTS

1. The speed of the transport vehicle during waste package transfer shall not exceed 35 mph on straight sections of the highway and 15 mph for curved sections of the highway. The maximum speed may be reduced (as directed) due to adverse weather or road conditions.

2. The transporter is considered for "Exclusive Use" only. The transporter is restricted from use for any other purpose while assigned to the 101-SY pump removal project.

3. Escorts shall be provided at the front and rear of the transport vehicle during package transfer to warn and/or control oncoming traffic and to observe the package.

4. The vent opening shall be sealed prior to transfer of the package according to Drawing H-2-83750 (Part A, Section 9.2).

5. The package shall be loaded, secured, and unloaded in the horizontal position.

6. The transport vehicle shall stop at all railroad crossings that have warning lights or crossing gates prior to crossing.

7. The HMMP Package shall be secured to the transport vehicle using the tiedown system described in Part B, Section 6.5.

8. The HMMP Package shall not be transferred at ambient temperatures less than 0 °F and shall not be transferred during extreme fog conditions. If ice or adverse snow conditions exist, the road shall be cleared and sanded prior to transfer.

9. The dose rate on the surface of the package and at 2 m from the vehicle shall be limited to 200 mrem/h and 10 mrem/h, respectively, for transfer of the package. For storage of the package, the dose rate on the surface of the package shall be limited to 100 mrem/h. The dose rate at the vehicle driver location shall not exceed 2 mrem/h during transfers of the package.

5.0 ACCEPTANCE OF PACKAGING FOR USE

The following requirements shall be verified and/or inspections shall be performed prior to use of the HMMP Package according to WHC-CM-4-2, *Quality Assurance Manual*, and Part A, Section 7.0:

1. Verify that all non-destructive testing and inspections have been completed as specified by the design drawings and information included in this SEP.

2. Inspect the package to assure that it is in good physical condition without any visual deficiencies.

3. Inspection shall include the verification of a Quality Assurance (QA) acceptance tag.

4. Verify that bolts do not have headmarks matching those on the "Suspect Fastener Headmark List."

5. Verify gasket material and geometry are in accordance with drawing requirements.

6. Verify visible painted surfaces do not have scratches or gouges exposing bare metal.

7. Verify that there are no gouges, dents, or scratches on flange sealing surfaces that would prevent sealing.

6.0 OPERATING REQUIREMENTS

6.1 GENERAL

Specific operating procedures shall be developed and approved by designated Transportation and Packaging personnel to verify transportation requirements are provided prior to transfer of the package.

All applicable instructions and procedures for onsite transfer of the package shall be in compliance with WHC-CM-2-14. The approved SEP shall be considered the controlling document for transfer of the package except where other applicable WHC requirements are more restrictive. Operating procedures shall include instructions to assure that the package is being used in accordance with the SEP.

Operating procedures, in general, shall cover the mounting of the empty shipping container onto the tilt mechanism on the trailer, loading of the contents into the package, loading of the package on the transport vehicle, transporting the package, and unloading the package at transfer destination(s). Bolt tightening specifications, or reference to the specifications, for all flanged connections shall also be included in the operating procedures.

6.2 INSTALLATION OF PACKAGE CONTENTS

The HMMP (Part A, Section 2.2) will undergo several operations before placement into the shipping container. The pump, as it is removed from the tank, will undergo a high pressure water spray operation and then will be enclosed inside a portable flexible bag assembly prior to insertion into the shipping container. Approximately 13 ft of the upper section of the pump will be cut off after removal. Basic steps for removing the pump and placing into the shipping container are as follows:

1. The shipping container shall be located in the special strongback and tilt assembly on the truck-trailer and raised into the vertical position in accordance with DOE-RL-92-36, *Hanford Site Hoisting and Rigging Manual* (RL 1993) and the vendor's operating manual.

2. The pump shall be attached (hooked) to a portable flexible bag assembly installed on a spray wash assembly in accordance with DOE-RL-92-36, *Hanford Site Hoisting and Rigging Manual* (RL 1993) and the appropriate work plan.

3. During removal from the tank by the crane and during insertion into the portable flexible bag assembly, the pump shall be sprayed with 3000 psi, 160 °F water.

4. The pump shall be fully raised into the portable flexible bag assembly in accordance with DOE-RL-92-36, *Hanford Site Hoisting and Rigging Manual* (RL 1993). The bottom section of the bag shall be remotely closed in accordance with the appropriate work plan. It shall be confirmed that approved absorbent material has been placed in the flexible bag and/or the shipping container to absorb at least twice the amount of expected free liquids that may be present in the waste contents.

5. Using the crane, the pump inside the flexible bag shall be moved at a minimum possible elevation, then lifted approximately 75 ft, transferred over to the tilt assembly, and inserted into the shipping container in accordance with DOE-RL-92-36, *Hanford Site Hoising and Rigging Manual* (RL 1993) and the appropriate work plan.

6. The shipping container shall be lowered toward the horizontal position in accordance with DOE-RL-92-36, *Hanford Site Hoisting and Rigging Manual* (RL 1993) and the appropriate work plan.

7. In accordance with the appropriate work plan, the loaded shipping container in the tilt assembly shall be moved to the designated area and the upper section of the pump (approximately 13 ft) shall be cut off. The pump shall then be stabilized inside the shipping container.

8. The two top closure plates on the shipping container shall be installed with care not to damage the gasket material. The bolts on the closure plates shall be tightened using the tightening sequence and torquing requirements provided in Drawing H-2-83750 (Part A, Section 9.2) and in the field procedures.

9. The shipping container shall be lowered completely to the horizontal position.

10. The radiation dose rate at any contact surface of the shipping container shall be verified not exceed 100 mrem/h. If this dose rate is exceeded significantly, lead shot or steel shot shall be added to the shipping container annulus and additional solid lead shielding may be installed on the external surfaces to reduce the dose rate to acceptable limits prior to transfer of the package. If dose rates are slightly above 100 mrem/h after sealing of the package, use of solid lead shielding on the outside of the package <u>only</u> may be considered. The surface contamination levels of the shipping container shall be verified to not exceed the limits of the following table (*WHC Radiological Control Manual*, WHC-CM-1-6):

Nuclide (note 1)	Removable (dpm/100 cm^2) (note 2)	Total (Fixed + Removable) (dpm/100 cm^2) (note 3)
U-natural, ^{235}U, ^{238}U, and associated decay products.	220 alpha	5,000 alpha
Transuranics, ^{226}Ra, ^{228}Ra, ^{230}Th, ^{228}Th, ^{231}Pa, ^{227}Ac, ^{125}I, ^{129}I	20	500
Th-nat, ^{232}Th, ^{90}Sr, ^{223}Ra, ^{224}Ra, ^{232}U, ^{126}I, ^{131}I, ^{133}I	200	1,000
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except ^{90}Sr and others noted above. Includes mixed fission products containing ^{90}Sr.	1,000 beta/gamma	5,000 beta/gamma

Table notes:

1. The values in this table apply to radioactive contamination deposited on, but not incorporated into the interior of the contaminated item. Where contamination by both alpha-and beta/gamma-emitting nuclides exists, the limits established for the alpha-and beta/gamma-emitting nuclides apply independently.
2. The amount of removable radioactive material per 100 cm^2 of surface area should be determined by swiping the area with dry filter or soft absorbent paper, while applying moderate pressure, and then assessing the amount of radioactive material on the swipe with an appropriate instrument of known efficiency. For objects with a surface area less than 100 cm^2, the entire surface should be swiped, and the activity per unit area should be based on the actual surface area. Except for transuranic elements, ^{228}Ra, ^{227}Ac, ^{228}Th, ^{230}Th, ^{231}Pa, and alpha emitters, it is not necessary to use swiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual contamination levels are below the values for removable contamination.
3. The levels may be averaged over 1 m^2 provided the maximum activity in any area of 100 cm^2 is less than three times the values in the Table.

10. Install the package tiedowns on the special tilt/trailer per instructions in Part B, Section 6.5. Fully inspect the package to confirm that all transportation requirements are met and release the package for transport.

6.3 UNLOADING THE PACKAGE

1. Verify that the dose rate at the surface of the package does not exceed 100 mrem/h and that surface contamination does not exceed the limits specified in Part A, Section 6.2 (10). Inspect the package and determine that it is acceptable for storage and/or processing of the contents at the designated facility.

2. Determine the actual center of gravity of the package and total gross weight based on the package, waste contents, and shielding installed in or on the package. Information is provided in the tiedown analysis in Part B, Section 6.5 for specific scenarios for addition of shielding which estimate approximate centers of gravity. Prepare a plan to safely lift the package in the horizontal position. Hoisting and rigging operations shall approve this plan.

3. Remove the tiedowns and prepare the package for rigging.

4. Provide a suitable crane, rigging, and lifting beam (Drawing H-2-83744, Part A, Section 9.5) to safely lift the specified load and transfer the package horizontally to the storage or process facility in accordance with DOE-RL-92-36, *Hanford Site Hoisting and Rigging Manual* (RL 1993) and the appropriate work plan.

7.0 QUALITY ASSURANCE

7.1 INTRODUCTION

The QA requirements for packaging and transport systems described in this SEP are based on a short term transfer campaign of specific package contents. In addition, it is not the intent of this SEP to approve reuse of the packaging after removal of the specific contents (equipment) described in this SEP. Under these conditions, an extensive QA program that would normally be provided in a SARP (for long-term use of packaging) is not considered necessary for this short-term transfer campaign. However, a QA plan or specific set of instructions are considered necessary to assure that the packaging and transport systems are acceptable for their intended use.

Verifications shall be made to assure that the following requirements were included in the QA plan or set of instructions and that these instructions were followed to control the design, and fabrication of the packaging:

1. Design, material procurement, construction, testing, and verification activities for the packaging are in accordance with, or equivalent to WHC-CM-4-2 for the assigned safety class.

2. Approval requirements associated with the analysis, design, and fabrication of the packaging and components are in accordance with WHC-CM-3-5, *Document Control and Records Management Manual*, and are properly documented.

3. The assigned Safety Class 3 of the packaging and Safety Class 3 of the packaging components (WHC 1994) are in accordance with requirements of *Management Requirements and Procedures* (MRP) 5.46, WHC-CM-1-3.

4. All required inspections and testing of the packaging are properly documented.

8.0 MAINTENANCE

Preventive maintenance shall be performed on the packaging during the 20 year design lifetime as required to prevent deterioration of the packaging. Preventive maintenance shall consist of inspection, repair and/or replacement of parts, and repainting.

9.0 APPENDICES

9.1 REFERENCES

RL, 1993, *Hanford Site Hoisting and Rigging Manual*, DOE-RL-92-36, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

WHC, 1994, *Packaging Design Criteria for Transfer and Disposal of Hydrogen Mitigation Mixer Pump*, WHC-SD-TP-PDC-019, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-1-3, *Management Requirements and Procedures*, Westinghouse Hanford Company, Richland, Washington.

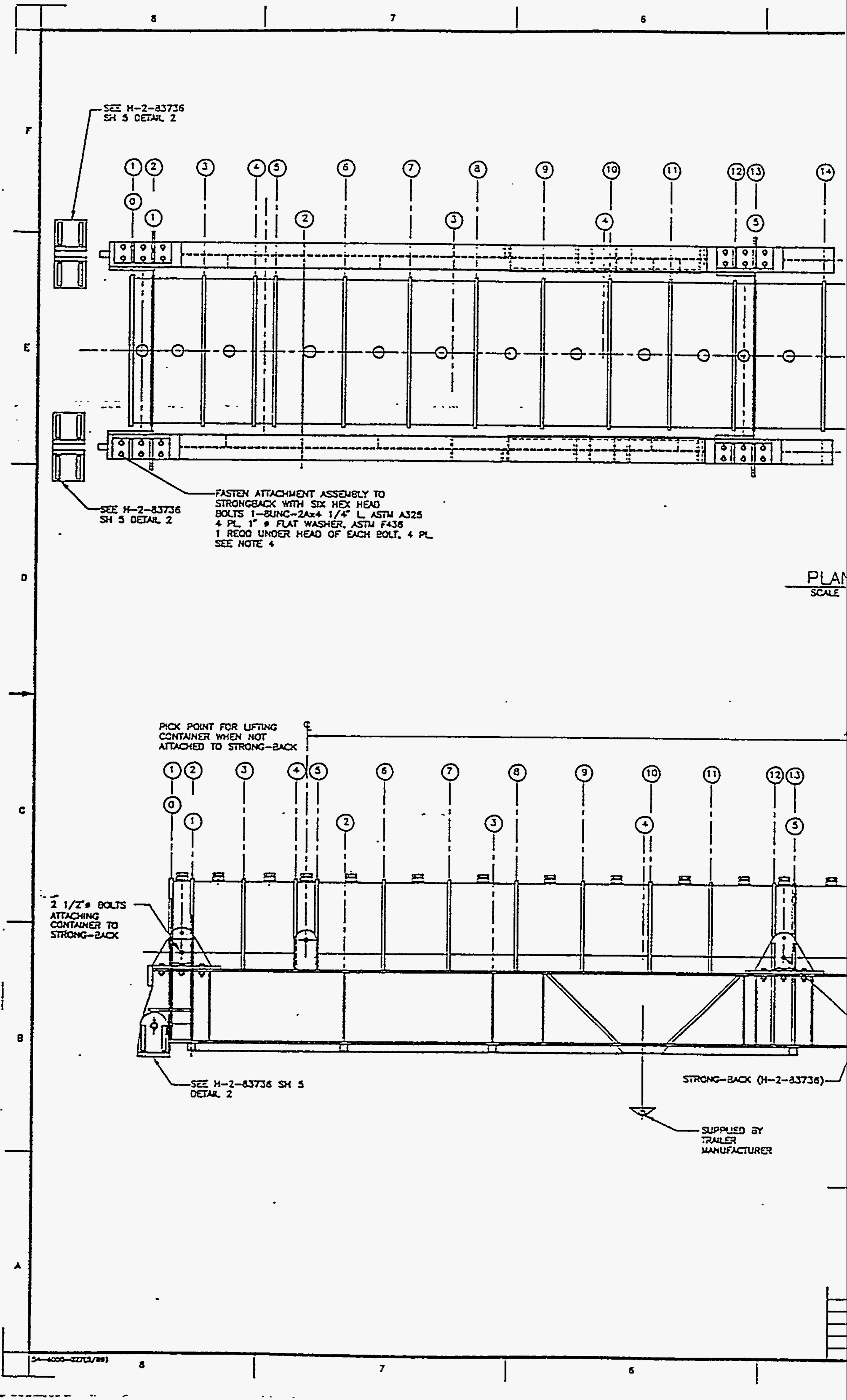
WHC-CM-1-6, *WHC Radiological Control Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-2-14, *Hazardous Material Packaging and Shipping*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-3-5, *Document Control and Records Management Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-4-2, *Quality Assurance Manual*, Westinghouse Hanford Company, Richland, Washington.

9.2 HYDROGEN MIXER PUMP CONTAINER (H-2-83750 and H-2-83734)

8
7
6
F
E
D
C
B
A
SEE H-2-83736
SH 5 DETAIL 2
1
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3
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SEE H-2-83736
SH 5 DETAIL 2
FASTEN ATTACHMENT ASSEMBLY TO
STRONGBACK WITH SIX HEX HEAD
BOLTS 1-8UNC-2Ax4 1/4" L ASTM A325
4 PL 1" ⌀ FLAT WASHER, ASTM F436
1 REQD UNDER HEAD OF EACH BOLT, 4 PL
SEE NOTE 4
PLAN
SCALE
PICK POINT FOR LIFTING
CONTAINER WHEN NOT
ATTACHED TO STRONG-BACK
℄
1
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3
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7
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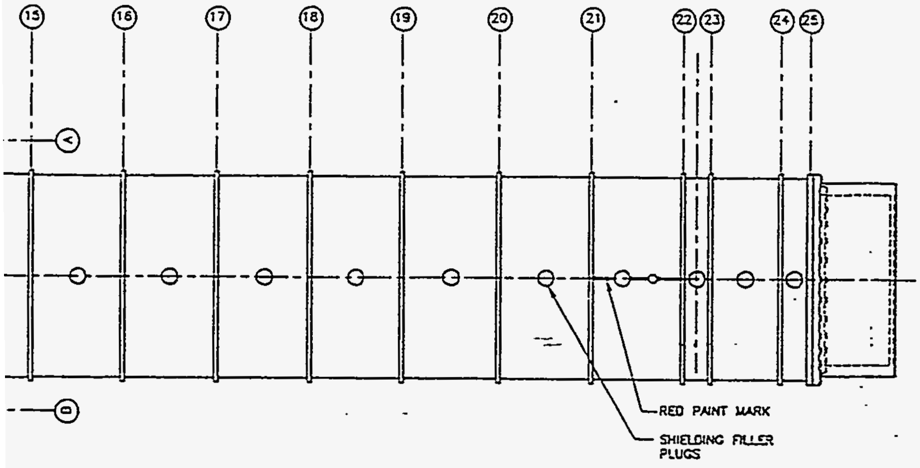
4
5
2 1/2"⌀ BOLTS
ATTACHING
CONTAINER TO
STRONG-BACK
SEE H-2-83736 SH 5
DETAIL 2
STRONG-BACK (H-2-83736)
SUPPLIED BY
TRAILER
MANUFACTURER
54-6000-027(3/89)
8
7
6



YDROGEN MIXER PUMP CONTAINER)
=1'-0"

GENERAL NOTES (UNLESS OTHERWISE SPECIFIED)

1. THREADED FASTENERS SHALL BE COATED WITH A THIN COAT OF NICKEL NEVER SEIZE #NS-160 OR LOCTITE C. THEN TORQUED TO (SEE NOTE 2) IN ACCORDANCE WITH THE GASKET SUPPLIERS INSTRUCTIONS AND PROCEDURES TO BE PROVIDED BY COGNIZANT ENGINEER.

2. BOLT TORQUES VALUES
   1-8 UNC-2B ASTM A307 GR B .= 295-305 ft-lbs

3. BOLTING OF STRONG-BACK TO CONTAINER JOINT CONNECTION. BOLTING SHALL BE PER AISC. SPECIFICATION FOR STRUCTURAL JOINTS USING A325 OR BOLTS FROM MANUAL OF STEEL CONSTRUCTION, ALLOWABLE STRESS DESIGN, 9TH EDITION. 2 1/2"⌀ BOLTS SHALL BE TIGHTENED TO SNUG TIGHT CONDITION PER WHC-SD-WM-DA170 . FASTENER THREADS SHALL NOT BE LUBRICATED BEYOND THE AS DELIVERED CONDITION AS SPECIFIED IN 8(a).

4. THE FOUR CONTAINER ATTACHMENT ASSEMBLIES SHALL BE BOLTED TO THE STRONG-BACK WITH 1-8UNC-2A HEX HEAD BOLTS AND 1-8UNC-2B HEX NUTS. THE BOLTS SHALL BE TIGHTENED TO SNUG TIGHT CONITION WHC-SD-WM-DA-170. AFTER THE CONTAINER IS IN PLACE AND FULLY BOLTED TO THE CONTAINER ATTACHMENT ASSEMBLY.

5. SHIELD WITH LEAD (Pb) SHOT OR STEEL SHOT. SHIELDING SHALL BE FIELD INSTALLED PER WHC-SD-TP-SEP-026.

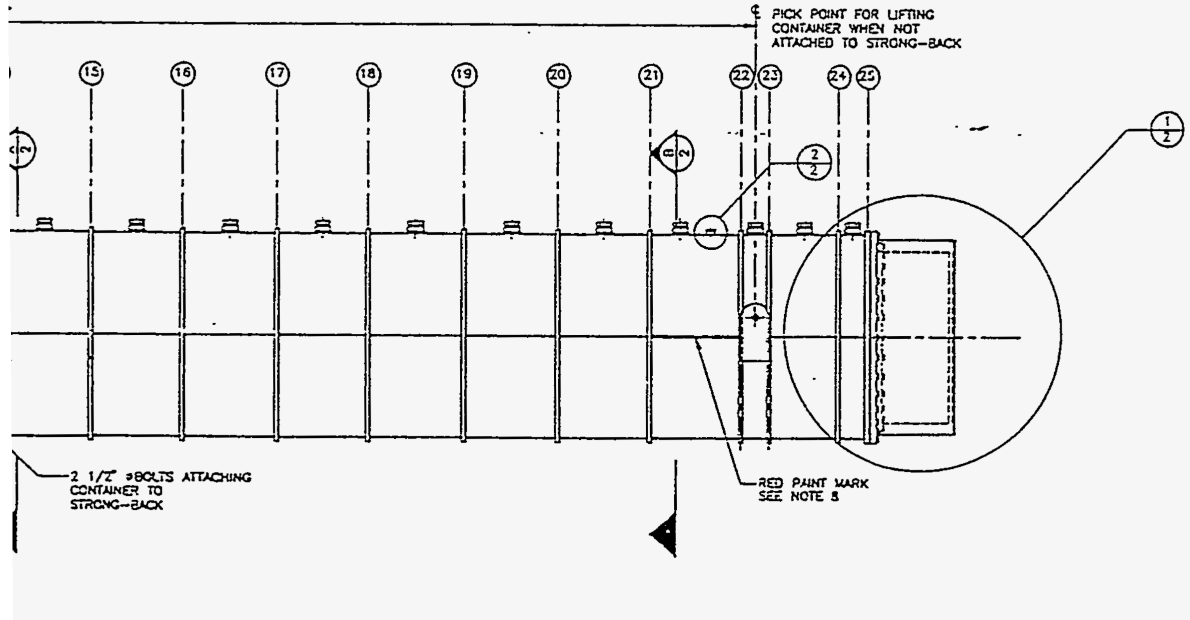
6. USE DRUM PLUG (McMASTER-CARR, #9019T11) FOR SYSTEM TEST AND TRANSPORT ONLY FOR STORAGE USE VENTED PLUG, (NUCFIL 016, 2"NPT, 304SS LID AND HOUSING) WITH DETAIL E.

7. STORAGE AND SHIPPING OF CONTAINER SHALL BE AS FOLLOWS: THE CONTAINER SHALL BE SUPPORTED DURING STORAGE AT COLUMNS 6, AND 21. DURING TRANSPORT THE CONTAINER SHALL BE SUPPORTED AT COLUMNS 3 AND 21

8. FOR ALIGNMENT OF THE CONTAINER AND STRONG-BACK IN THE VERTICAL POSITION THE RED PAINT MARK ON THE TOP OF THE CONTAINER SHALL BE IN LINE WITH THE SHIELDING FILLER PLUGS. THE RED PAINT MARK ON THE SIDES OF THE THE CONTAINER SHALL BE IN LINE WITH 2 1/2"⌀ BOLTS ATTACHING THE CONTAINER TO THE STRONG-BACK, 1/4" WIDE MAXIMUM.

9. ALIGNMENT OF CONTAINER WITH STRONG-BACK AT ASSEMBLY: LONGITUDINAL CENTER LINES OF THE CONTAINER AND STRONG-BACK SHALL BE EQUAL ±1/8".

10. ALL SPECIFICATIONS SHALL MEET THE FOLLOWING REVISIONS:
    A36/A36M-92
    A105/A105M-93
    A194/194M-93a
    A325-93
    F436-93
    A490M-93
    A516/A516M-90
    A671-89a
    A307-94



EVATION (HYDROGEN MIXER PUMP CONTAINER)
E :1/2"=1'-0"

OFFICIAL RELEASE
BY WHC
DATE SEP 15 1994

REF NUMBER	TITLE
WHC-SD-WM-WP-275	SUPPORTING DOCUMENT
H-2-83748	SUPPORT
H-2-83744	LIFTING BEAM
H-2-83736	STRONGBACK
H-2-83734	STORAGE CONTAINER

REFERENCES

DRAWING TRACEABILITY LIST

NEXT USED ON END ITEM

REVISIONS

CADFILE 3083750A
CADCODE CCS:5:AC02:12.C0:SS

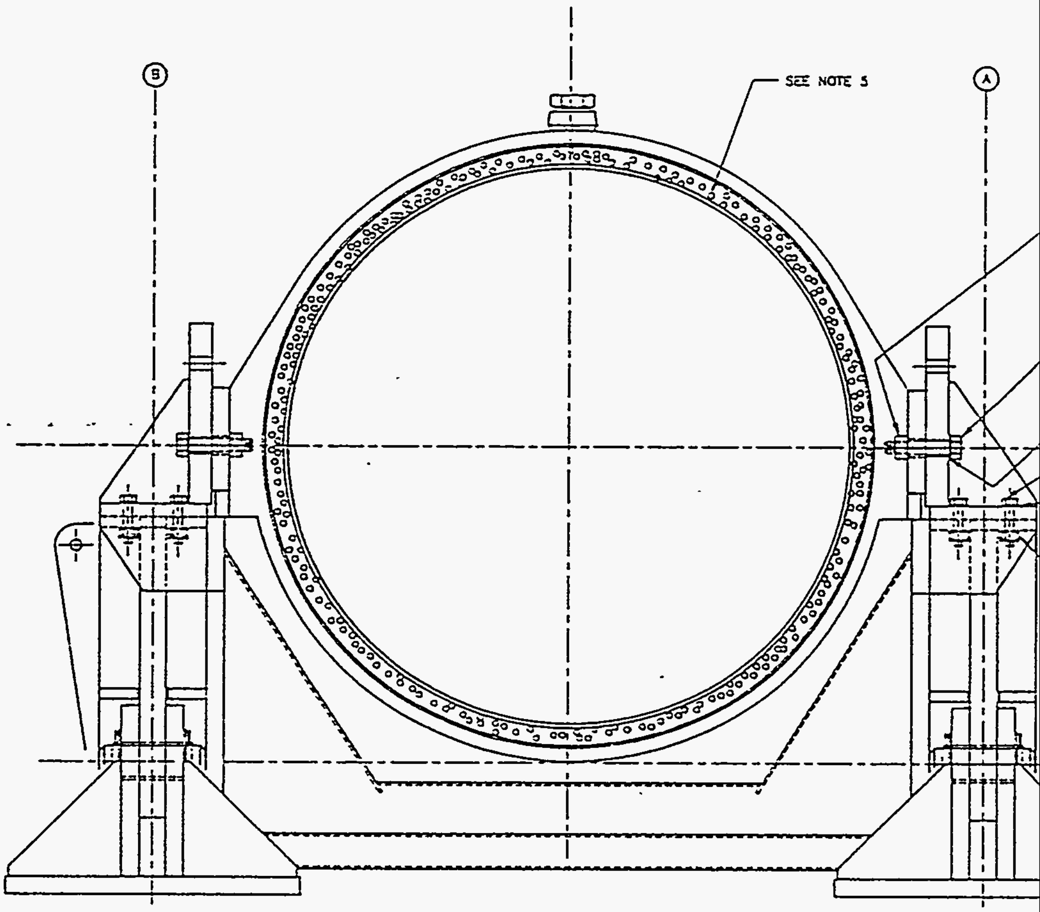
AB PHILLIPS 6/7/94
9/94
9/94
US CSTROM 16/94
9/94

U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

HYDROGEN MIXER PUMP STORAGE TRANSPORT ASSEMBLY ARRANGEMENT

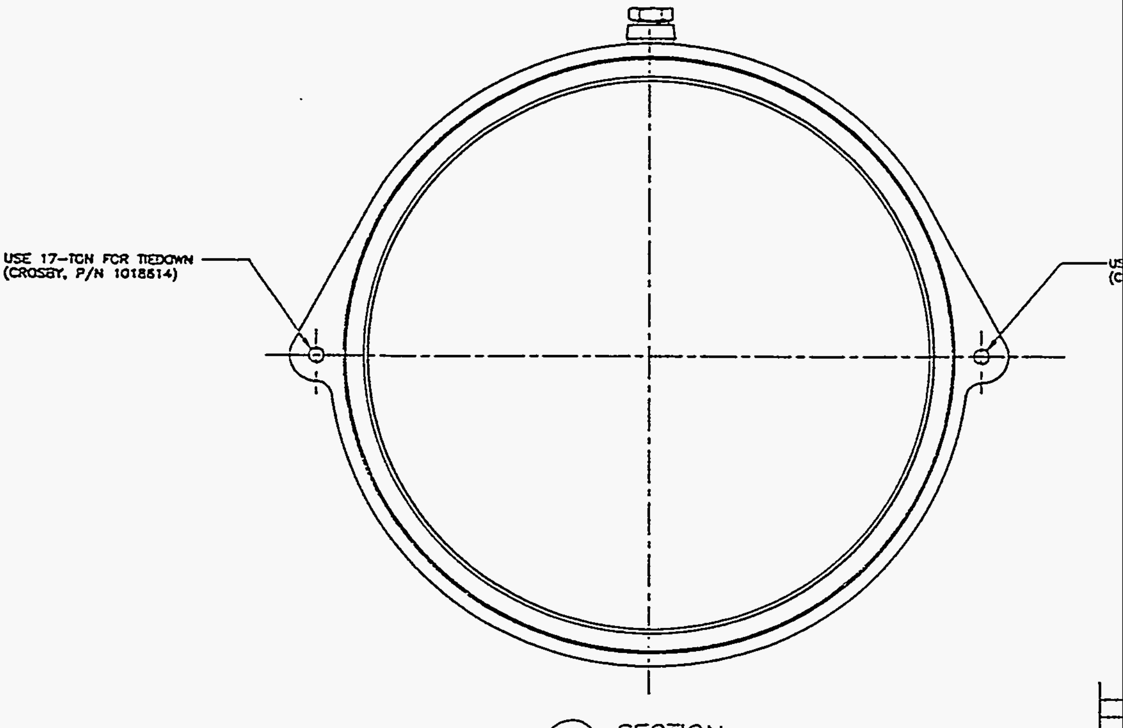
SIZE	BLDG NO	INDEX NO	DWG NO	REV
F	200G	2303	H-2-83750	0

SCALE SHOWN
CF 701229
SHEET 1 OF 3



A/1 SECTION

SCALE :1 1/2"=1'-0"



B/1 SECTION

SCALE :1 1/2"=1'-0"

NUT,HEAVY HEX 2 1/2-4 UNC-2B, ASTM A194 GR 2H 1 REQUIRED, 4 PL

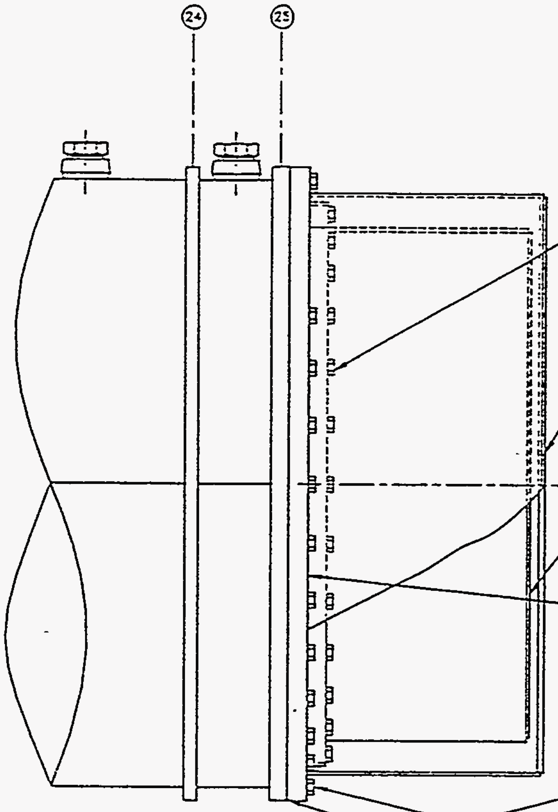
HEX HEAD BOLT 2 1/2-4 UNC-2A x 7 1/2" LONG ASTM A 449, TYPE 1,W/ 4 1/4" THREAD 1 REQD, 4 PL SEE NOTE 3.

2 1/2"ø FLAT WASHER,ASTM F436, 2 REQD. 1 UNDER HEAD OF BOLT AND 1 UNDER NUT, 4 PL

HEX HEAD BOLTS 1-8UNC-2A ASTM A325, TYPE 1, 1REQUIRED, 24 PL SEE NOTE 4

1"ø FLAT WASHER, ASTM F436, 1 REQUIRED, UNDER HEAD OF BOLT

NUT, HEAVY HEX 1-8UN-2B ASTM A194 GR 2H 1 REQUIRED, 24 PL PREVIOUSLY INSTALLED IN NUT CUPS ON STRONGBACK (H-2-83750)



HEX HEAD BOLT, 1-8 UNC-2Ax4" LONG
ASTM A307, GR. B
WASHER, FLAT 1", ASTM F-436
WASHER, SPLIT-LOCK 1" ANSI B18.21.1
28 EACH REQUIRED FOR INNER TOP CAP
SNUG TIGHT

OUTER TOP CAP
(H-2-83734) SH 6 DETAIL 3

INNER TOP CAP
(H-2-83734) SH 5 DETAIL 9

INNER TOP CAP
GASKET 1/8" THICK FLEXITALLIC,
FLEXICARB MRG GASKETS
REQUIRED FOR (H-2-83734 SH 2 DETAIL 19)
TEMPLATE HOLES FROM (H-2-83734 SH 4)

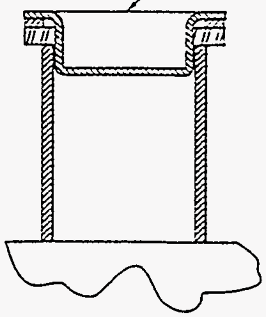
HEX HEAD BOLT, 1"-8 UNC 2A x 4" LONG,
ASTM A307 GR. 3
WASHER, FLAT 1" ASTM F-436
WASHER, SPLIT-LOCK 1" ANSI B18.21.1
32 EACH REQUIRED FOR OUTER TOP CAP
SEE NOTE 1

OUTER TOP CAP
GASKET 1/8" THICK FLEXITALLIC,
FLEXICARB MRG GASKETS
REQUIRED FOR (H-2-83734 SH 2 DETAIL 19)
TEMPLATE HOLES FROM (H-2-83734 SH 4)

1/1 DETAIL
SCALE :1 1/2"=1'-0"

-TON FOR TIEDOWN
. P/N 1018614)

USE DRUM PLUG (McMASTER-CARR,# 90119T1) FOR CONTAINER TRANSPORT. USE CARBON COMPOSITE FILTER (NUCLEAR FILTER TECHNOLOGY INC., MODEL #NUCFIL 016, DIA 2",304 STAINLESS STEEL LID AND HOUSING , FLOW RATE >1000Ml/MIN], FOR STORAGE.



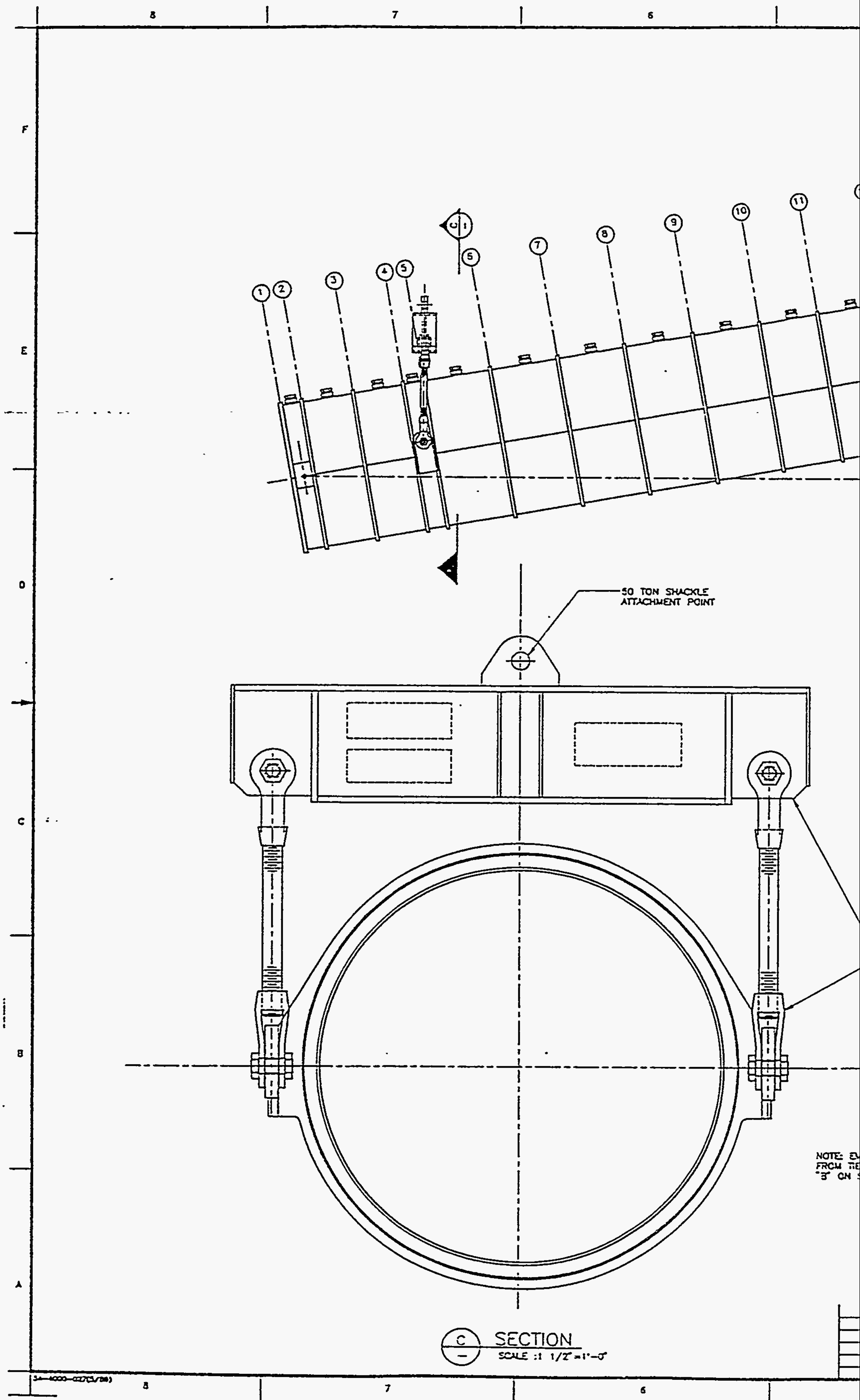
DATE SEP 15 1994

2/1 DETAIL
SCALE :FULL

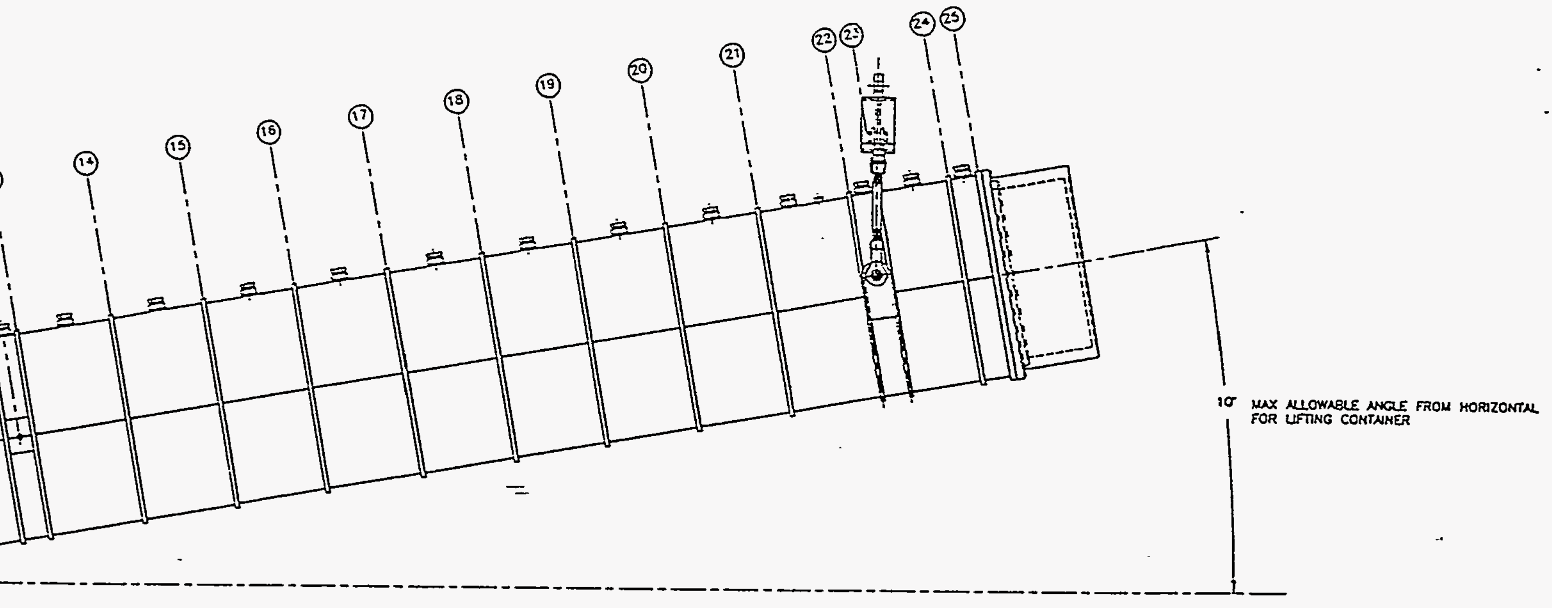
FOR GENERAL NOTES SEE SHEET 1

AB PHILLIPS 6/94	U.S. DEPARTMENT OF ENERGY DOE Field Office, Richland Westinghouse Hanford Company
D.HAWKS 10/94	HYDROGEN MIXER PUMP STORAGE TRANSPORT ASSEMBLY ARRANGEMENT
10/94	F 2006 2303 H-2-83750 0
VS OSTROM 6/94	SHOWN 701228 2
9/94	

DRAWING TRACEABILITY LIST | TITLE | NEXT USED ON SH 1 | REFERENCES | REVISIONS | CADFILE 80837508 | CADCODE DOS:5:ACD2:12.0:SS



C SECTION
SCALE :1 1/2"=1'-0"



ASSEMBLY
SCALE :1/2" = 1'-0"

— SEE DWG H-2-83744

ONTAINER MAY BE LIFTED
LUGS SHOWN IN SECTION
2

OFFICIAL RELEASE
BY WHC
DATE SEP 15 1994

FOR GENERAL NOTES SEE SHEET 1

AB PHILLIPS 6/94
9/94
10/94
US OSTROM 6/94
9/94

U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

HYDROGEN MIXER PUMP
STORAGE TRANSPORT
ASSEMBLY ARRANGEMENT

F 200G 2303 H-2-83750 0
SCALE SHOWN 701228 SHEET 3

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NEXT USED ON SH — REF NUMBER — TITLE — REFERENCES
REVISIONS
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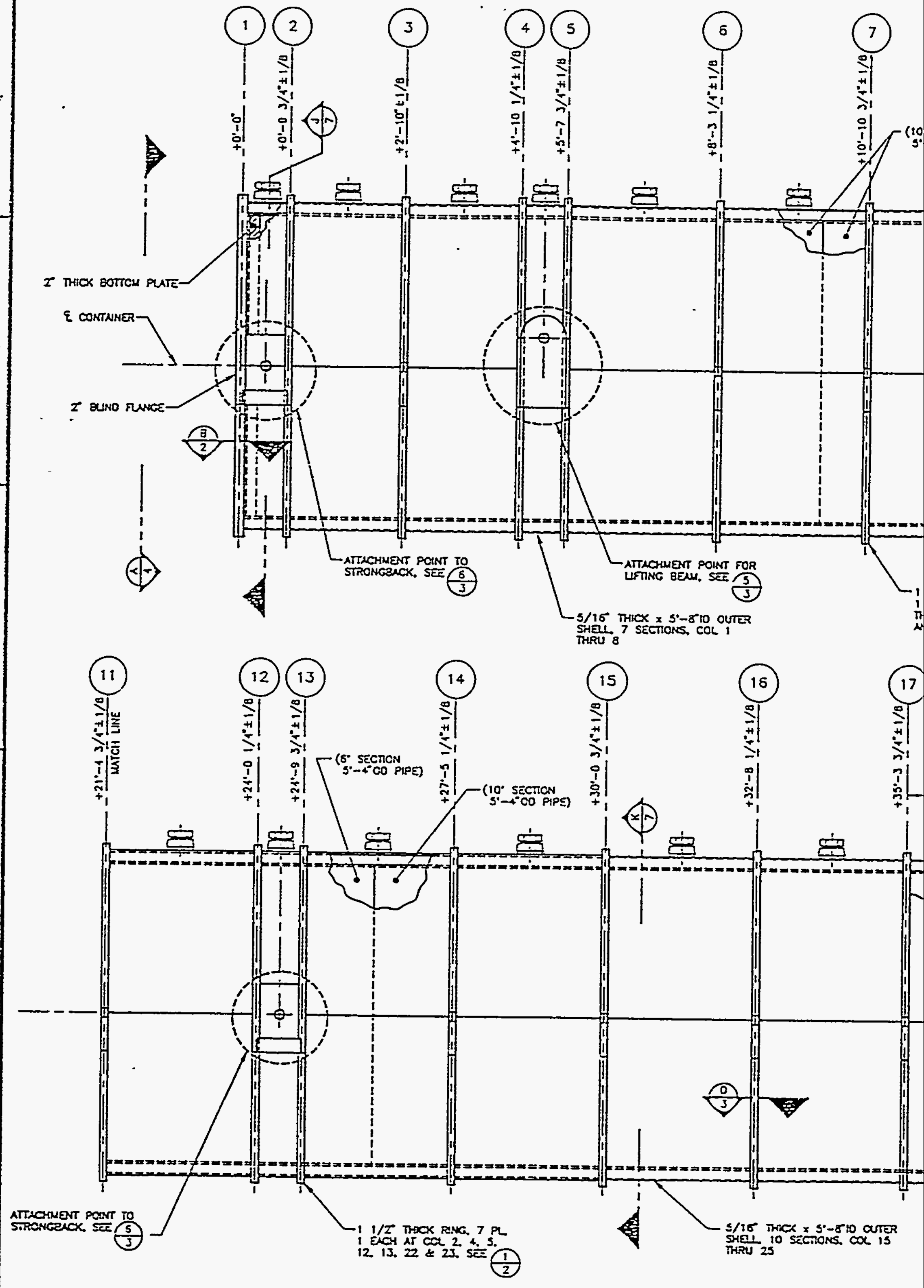
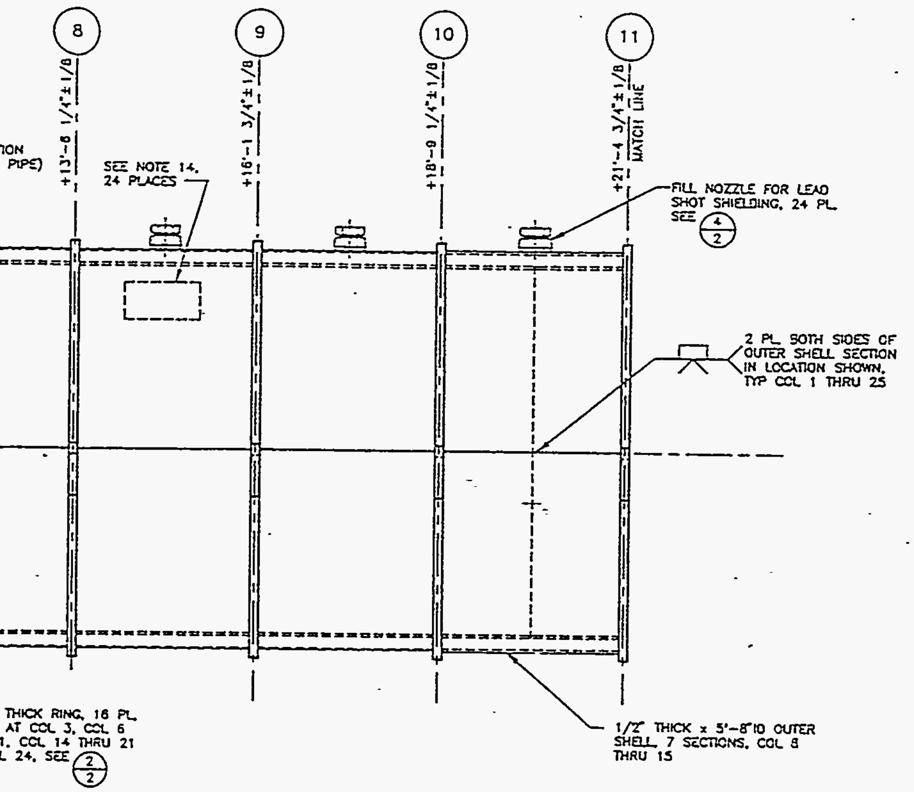


NOTE: SEE SHEET 8 FOR SECTIONAL VIEW
OF CONTAINER SHOWING INTERIOR
SADDLE, SADDLE SUPPORT AND
FUNNEL

ELEV

SCALE: 1"

54-6000-027(3/88)



GENERAL NOTES (UNLESS OTHERWISE SPECIFIED)

1. REMOVE ALL BURRS AND BREAK ALL SHARP EDGES.
2. WELD AND INSPECT PER AWS D1.1-1994. ALSO SEE NOTE 10. VT FINAL PASS OF ALL WELDS. VT FIT UP, ROOT PASS AND FINAL PASS OF ALL CONTAINMENT WELDS AND LIFTING WELDS. MT OR PT FINAL PASS OF DESIGNATED WELDS. FINAL PASS OF WELDS MADE BY PIPE SUPPLIER ON PROCURED PIPE SHALL BE VT AND RT BY THE PIPE SUPPLIER. WELDER QUALIFCATIONS AND WELD PROCEDURES PER ASME SECTION IX ARE AN ACCEPTABLE SUBSTITUTION. STAINLESS TO STAINLESS STEEL AND STAINLESS TO CARBON STEEL WELDING SHALL BE PERFORMED PER HS-VS-0013.
3. MATERIAL SHALL CONFORM TO THE FOLLOWING SPECIFICATIONS:

   5'-4"OD PIPE: ASTM A671, GRADE CC70, CLASS 31 - 1993

   2" BOTTOM PLATE, OUTER TOP CAP FLANGE, INNER TOP CAP, INNER CONTAINER FLANGE AT COL 25, INNER RETAINING PLATE, INNER TOP CAP FLANGE, AND VENT PLATE: ASTM A516, GRADE 70, NORMALIZED - 1990

   1 1/2" THICK RINGS, LIFTING LUG, ATTACHMENT PLATE, SUPPORT BAR, 2" BLIND FLANGE, OUTER TOP CAP, SPACERS, BACKING BAR, OUTER CONTAINER FLANGE AT COL 25, OUTER SHELL, SADDLE SUPPORT PLATE AND SADDLE SUPPORT STIFFENER PLATE: ASTM A36 - 1993

   VENT PIPE: ASTM A106 - 1994

   FUNNEL GUSSET PLATES, FUNNEL PLATES, FUNNEL RING AND SADDLE PLATE: ASTM A240 REV B 304L - 1993

   HEAVY HEX HEAD BOLTS: ASTM A307 GRADE B - 1993

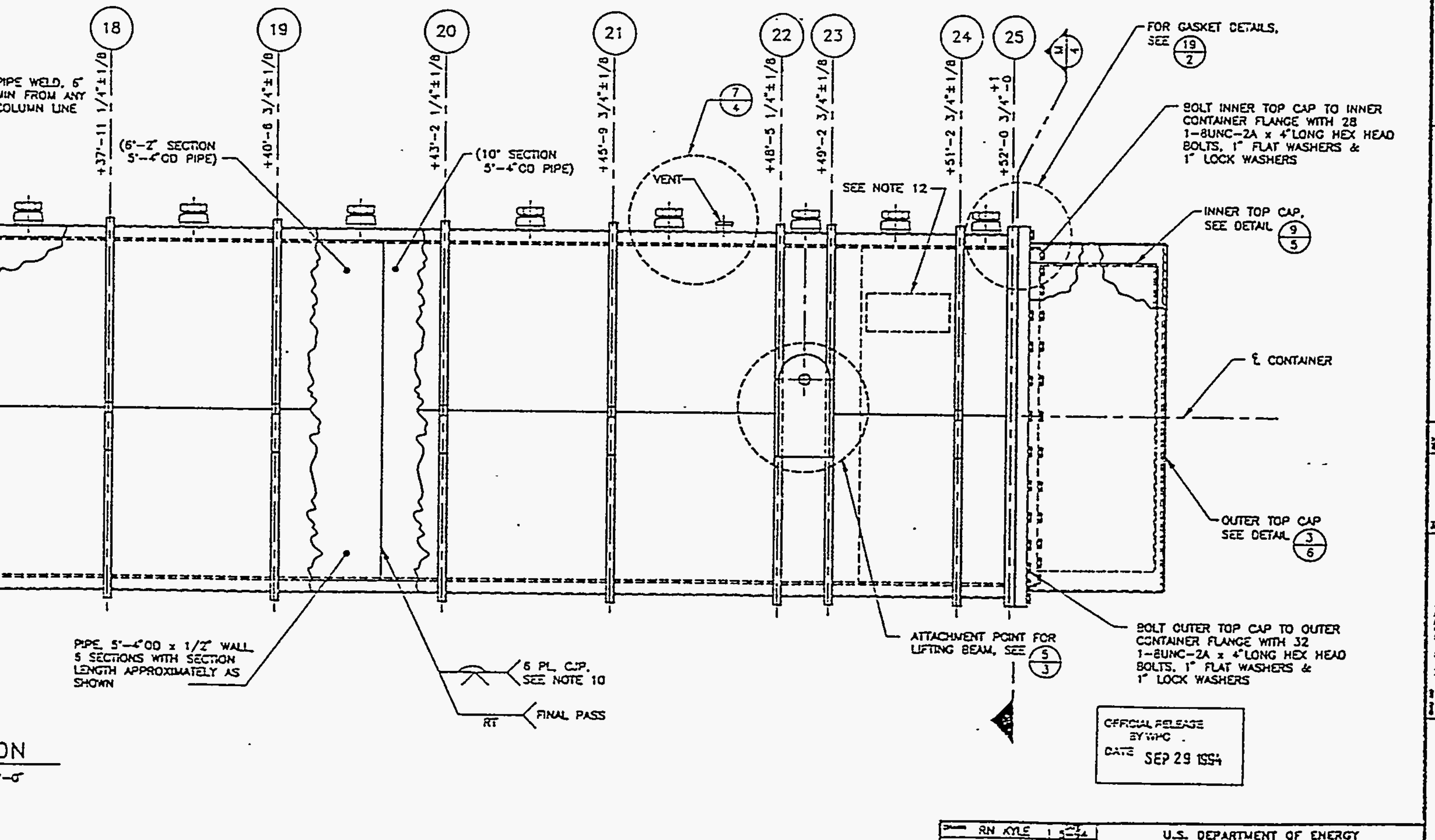
   FLAT WASHERS: ASTM F436 - 1993

   LOCK WASHERS: ANSI B18.21.1

   HEX HEAD PLUG: ASTM A105 - 1993

   FLANGE GUIDE PINS: ASTM A322 GR4130, HEAT TREATED TO A MINIMUM TENSILE STRENGTH OF 135 KSI AND HARDNESS OF HB 270 - 1991
4. ALL MACHINED SURFACES SHALL BE IN ACCORDANCE WITH ANSI B46.1.
5. GASKETS SHALL BE FLEXICARB MRG GASKETS BY FLEXITALLIC AND SHALL HAVE A NOMINAL CORE THICKNESS OF 1/8" OF A-304 MATERIAL. GASKETS SHALL HAVE A 0.030" GRAPHITE LAYER ON EACH SIDE.
6. PAINT ALL EXTERIOR SURFACES WITH ONE COAT OF AMERLOCK 400 FOLLOWED WITH ONE TOP COAT OF AMERSHIELD. FINAL COLOR SHALL BE AMERON WHITE. DO NOT PAINT SURFACES OF FLANGES. PREPARATION AND APPLICATION SHALL BE PER MANUFACTURER'S INSTRUCTIONS.

(GENERAL NOTES CONTINUED ON SHEET 8, ZONE 2F)



OFFICIAL RELEASE
BY WHC
DATE SEP 29 1994

H-2-83744	LIFTING BEAM
H-2-83736	STRONGBACK
H-2-83750	ASSEMBLY ARRANGEMENT
WHC-SD-WM-DA-165	SUPPORTING DOC
REF NUMBER	TITLE
REFERENCES	
NEXT USED ON H-2-83750	

DRAWING TRACEABILITY LIST

REVISIONS

CADFILE - 3083734A

CADCODE DOS:5.0:AC02:12.00:SS

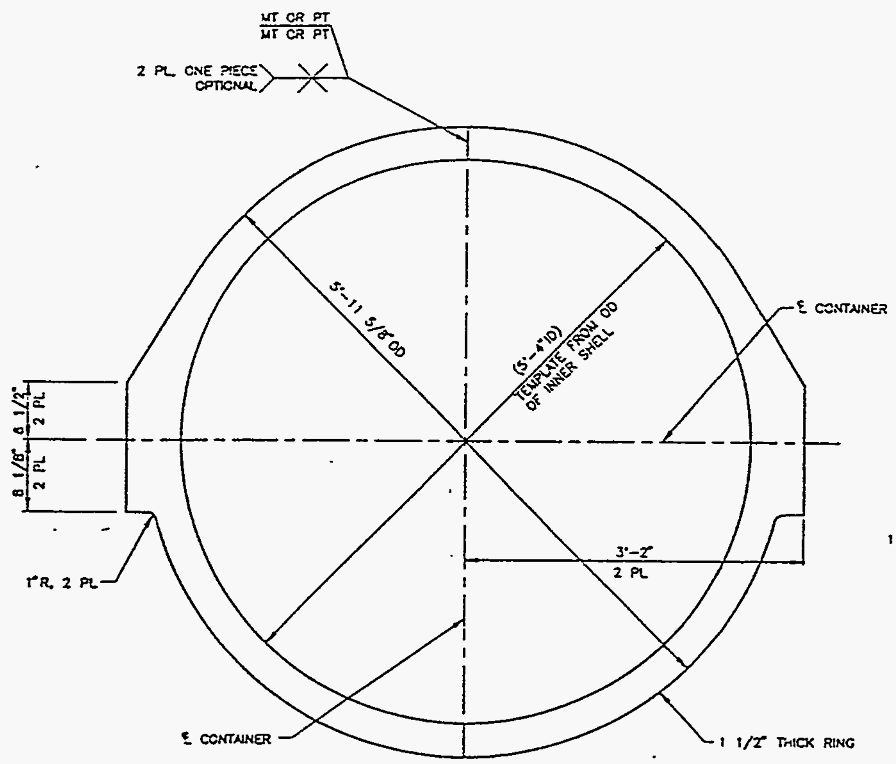
RN KYLE	5-94
D. HAROS	9-94
	9-94
QJ OSTROM	5-94
	7-94

U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

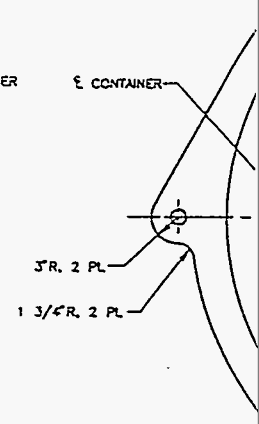
HYDROGEN MIXER PUMP
STORAGE CONTAINER

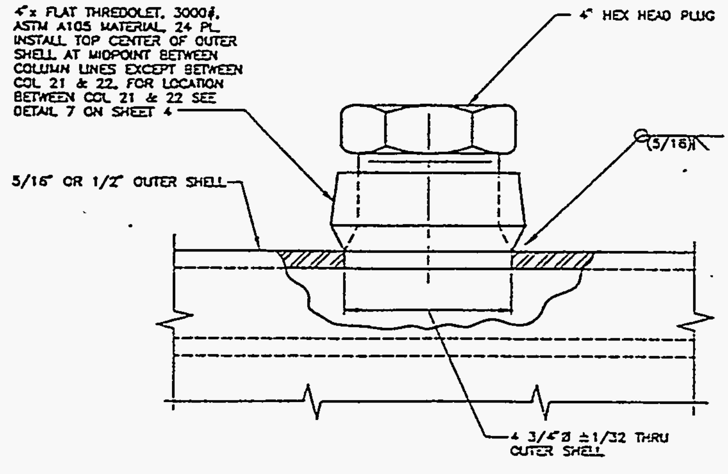
F | 200-G | 1001 | H-2-83734 | 0

SCALE SHOWN | 700434 | SHEET 1 OF 9



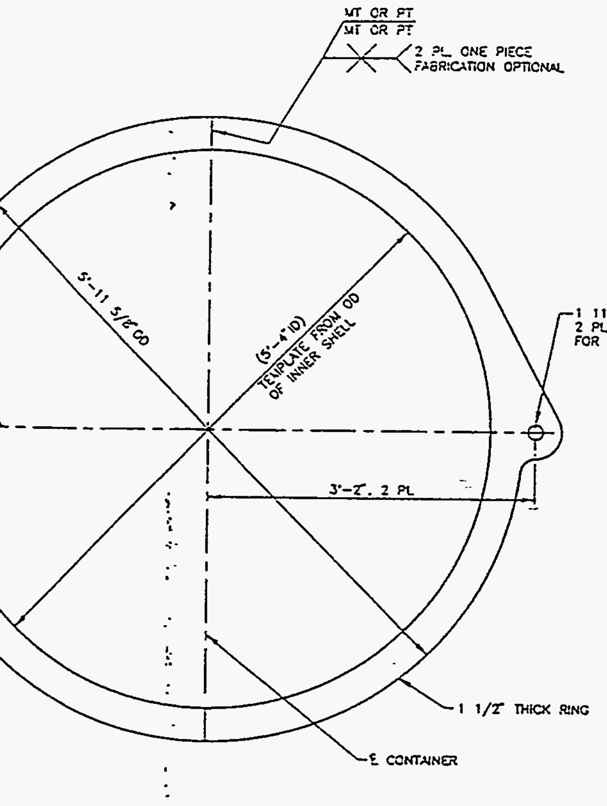
1/1 DETAIL (7 REQD, 1 EACH AT COLUMN 2, 4, 5, 12, 13, 22 & 23
SCALE: 1 1/2" = 1'-0"



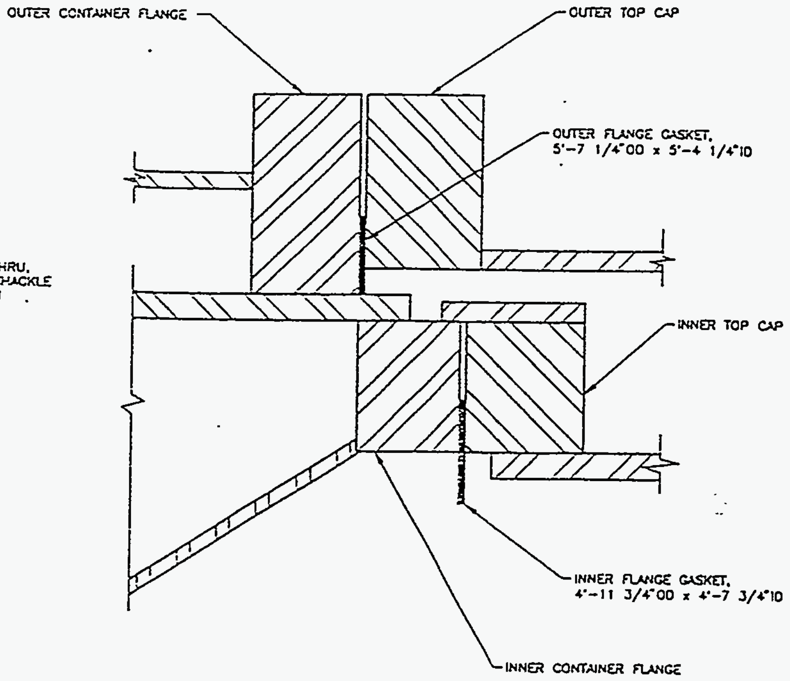


2" THICK BLIND FLAN

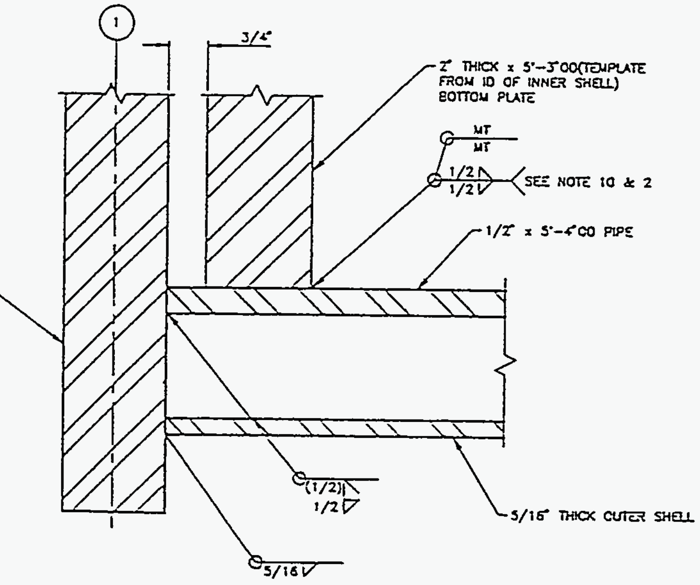
4/1 4/4 DETAIL
SCALE: 1/2 SIZE



2/1 DETAIL (16 REQD, 1 EACH AT COLUMN 3, 6, 7, 8, 9, 10, 11, 16, 17, 18, 19, 20, 21 & 24)
SCALE: 1 1/2" = 1'-0"



19/1 DETAIL
SCALE: 3/4 SIZE



a/1 SECTION
SCALE: 3/4 SIZE

OFFICIAL RELEASE BY WHC
DATE SEP 29 1994

FOR GENERAL NOTES SEE SHEET 1

DRAWN	RN KYLE
CHECKED	D. HAWKINS 9-94
	7-94
	WJ OSTROM 5-94

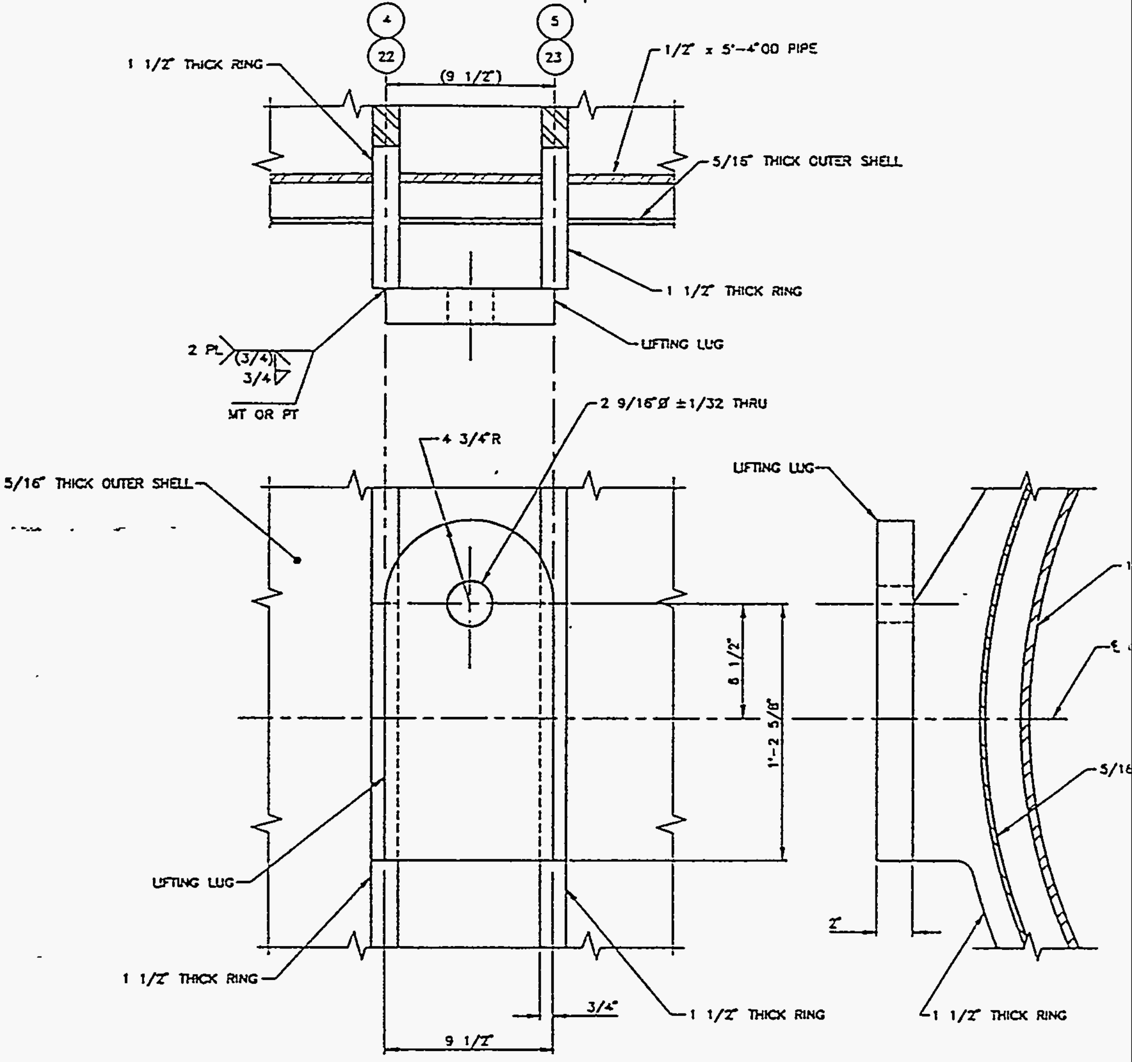
U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

HYDROGEN MIXER PUMP STORAGE CONTAINER

SIZE	BLDG NO	INDEX NO	DWG NO	REV
F	200-G	1001	H-2-83734	0

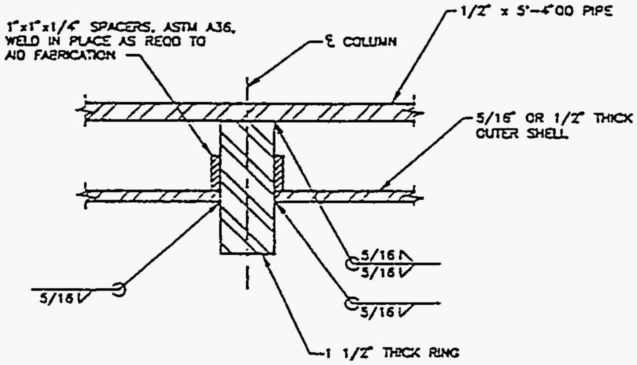
SCALE SHOWN   700434   SHEET 2

DRAWING TRACEABILITY LIST   NEXT USED ON H-2-83734 SH 1   REFERENCES   REVISIONS
CADFILE 30837348   CADCODE 90S:5.0:C02:12.00:SS



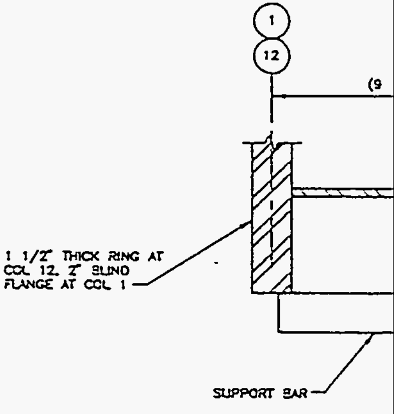
(5/1) DETAIL (4 PL, 1 ON EACH SIDE OF CONTAINER IN LOCATION SHOWN BEWTWEEN COL 4 & 5 AND COL 22 & 23)

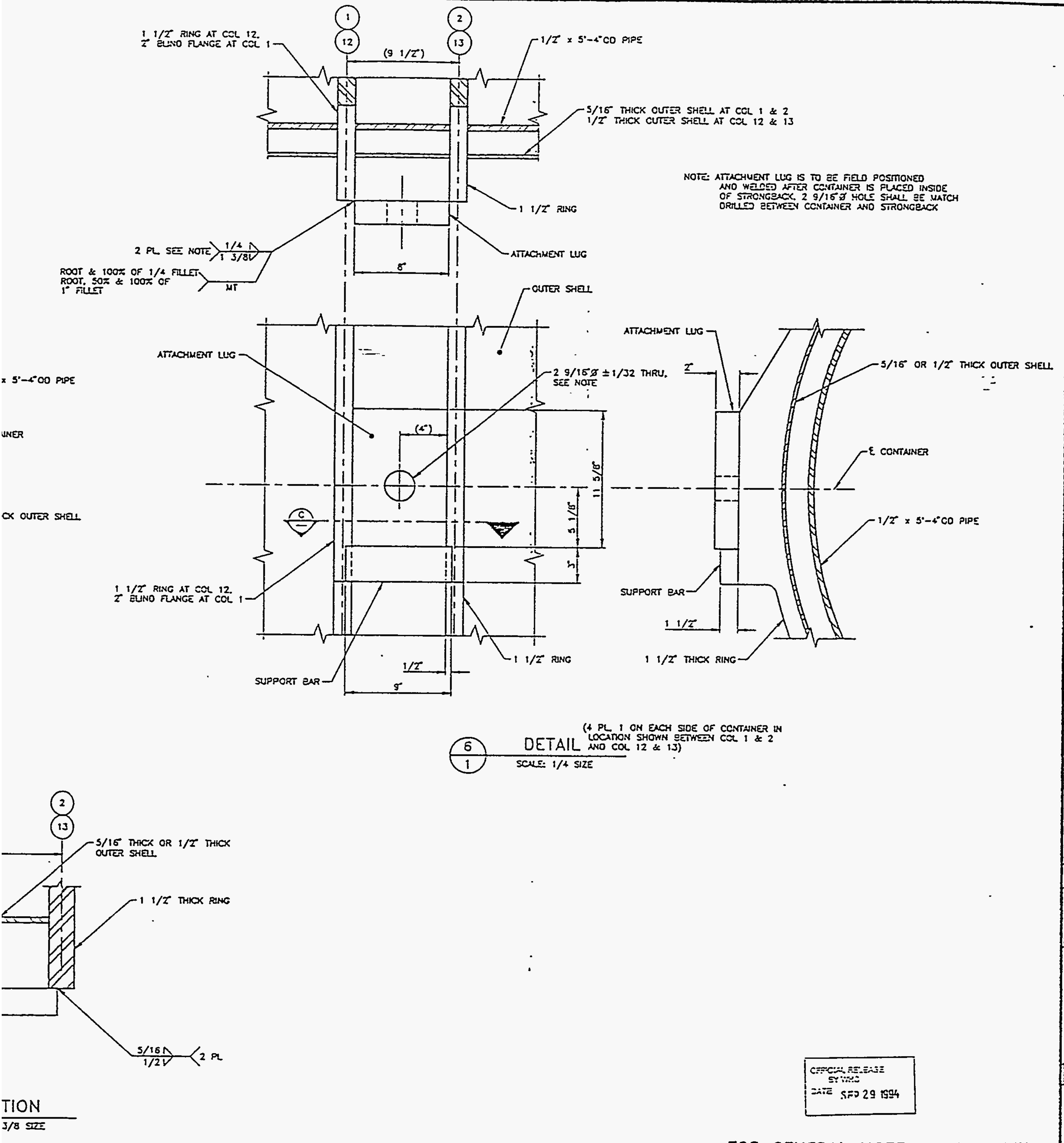
SCALE: 1/4 SIZE



(D/1) SECTION (23 PL)

SCALE: 1/2 SIZE





NOTE: ATTACHMENT LUG IS TO BE FIELD POSITIONED AND WELDED AFTER CONTAINER IS PLACED INSIDE OF STRONGBACK. 2 9/16"Ø HOLE SHALL BE MATCH DRILLED BETWEEN CONTAINER AND STRONGBACK

6
1
DETAIL (4 PL, 1 ON EACH SIDE OF CONTAINER IN LOCATION SHOWN BETWEEN COL 1 & 2 AND COL 12 & 13)

SCALE: 1/4 SIZE

OFFICIAL RELEASE
BY WHC
DATE SEP 29 1994

FOR GENERAL NOTES SEE SHEET 1

RN KYLE	
D. WAVAKS	9-94
	11-10
WJ OSTROM	5-94

U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

HYDROGEN MIXER PUMP
STORAGE CONTAINER

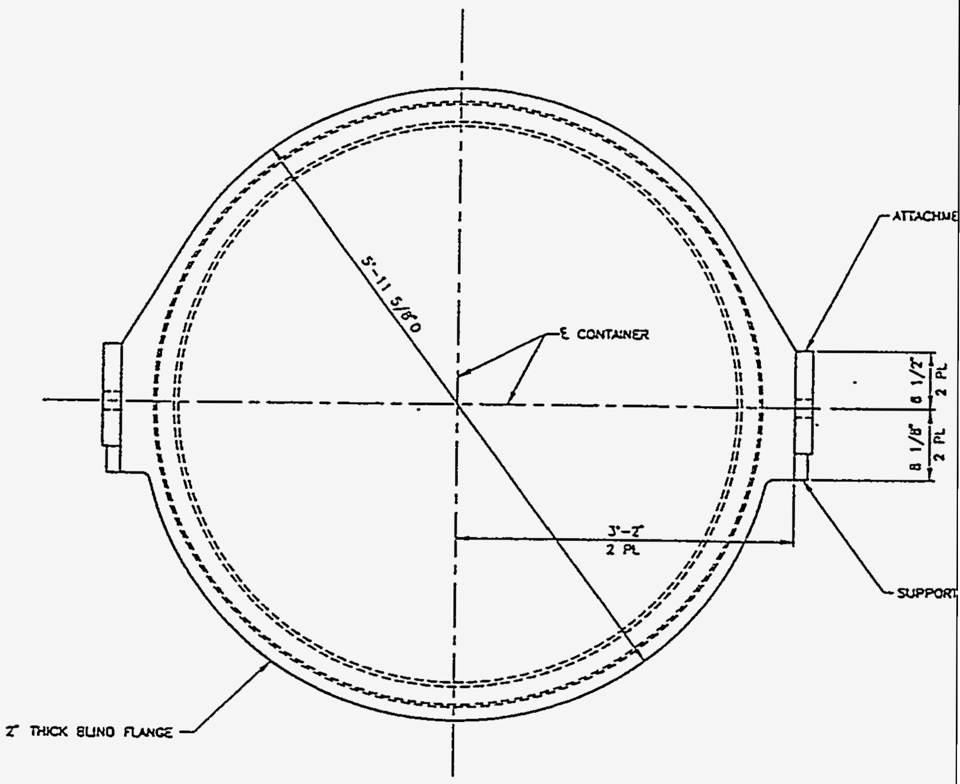
SIZE	BLDG NO	INDEX NO	DWG NO	REV
F	200-G	1001	H-2-83734	0

SCALE SHOWN CODE 700434 SHEET 3

NO	TITLE	REF NUMBER	TITLE
DRAWING TRACEABILITY LIST		NEXT USED ON H-2-83734 SH 1	

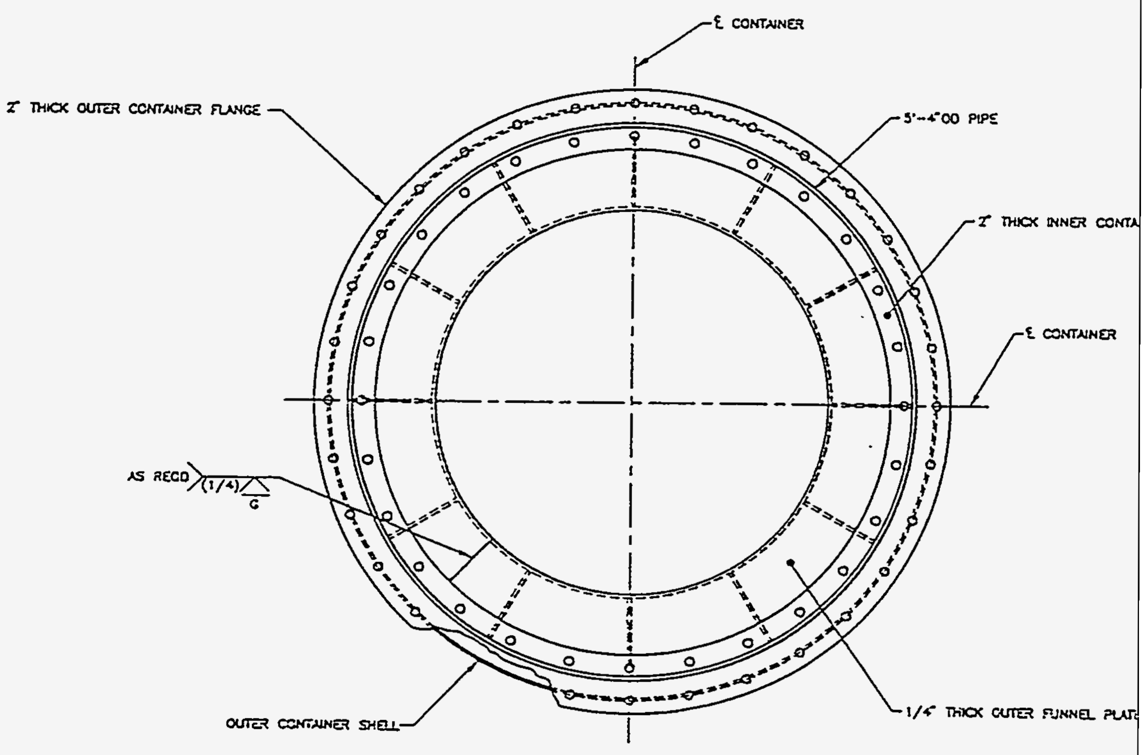
CADFILE 3C83734C CADCODE GOS.5.0:ACD2:12.30:55

REVISIONS



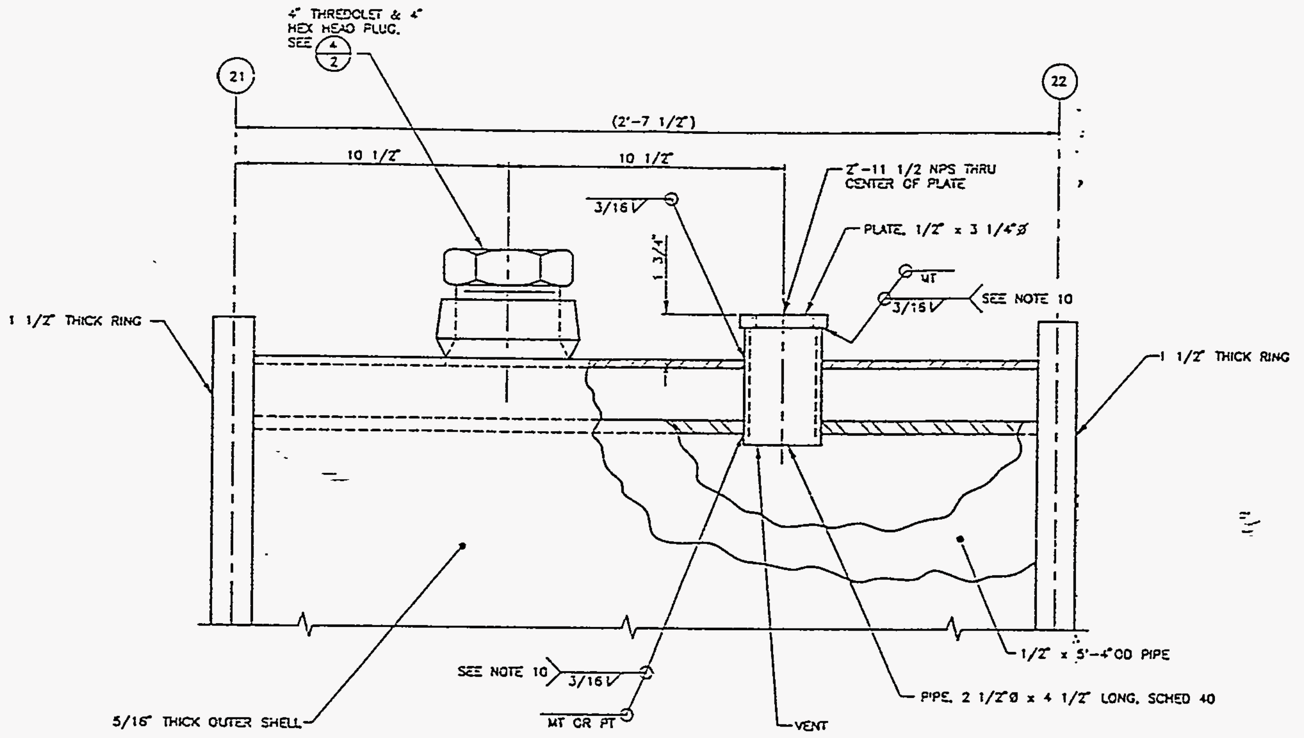
A/1 VIEW

SCALE: 1 1/2" = 1'-0"



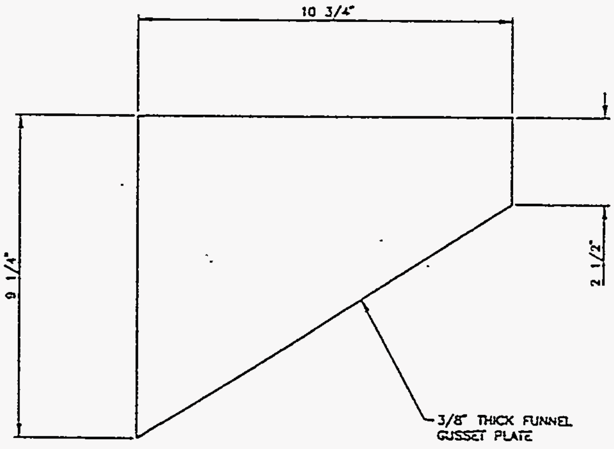
M/1 SECTION

SCALE: 1 1/2" = 1'-0"



DETAIL 7/1

SCALE: 3/8 SIZE



DETAIL 18/9

SCALE: 1/2 SIZE

FOR GENERAL NOTES SEE SHEET 1

RN KYLE
D. HAMERK 9-94
5-94
W OSTPCM

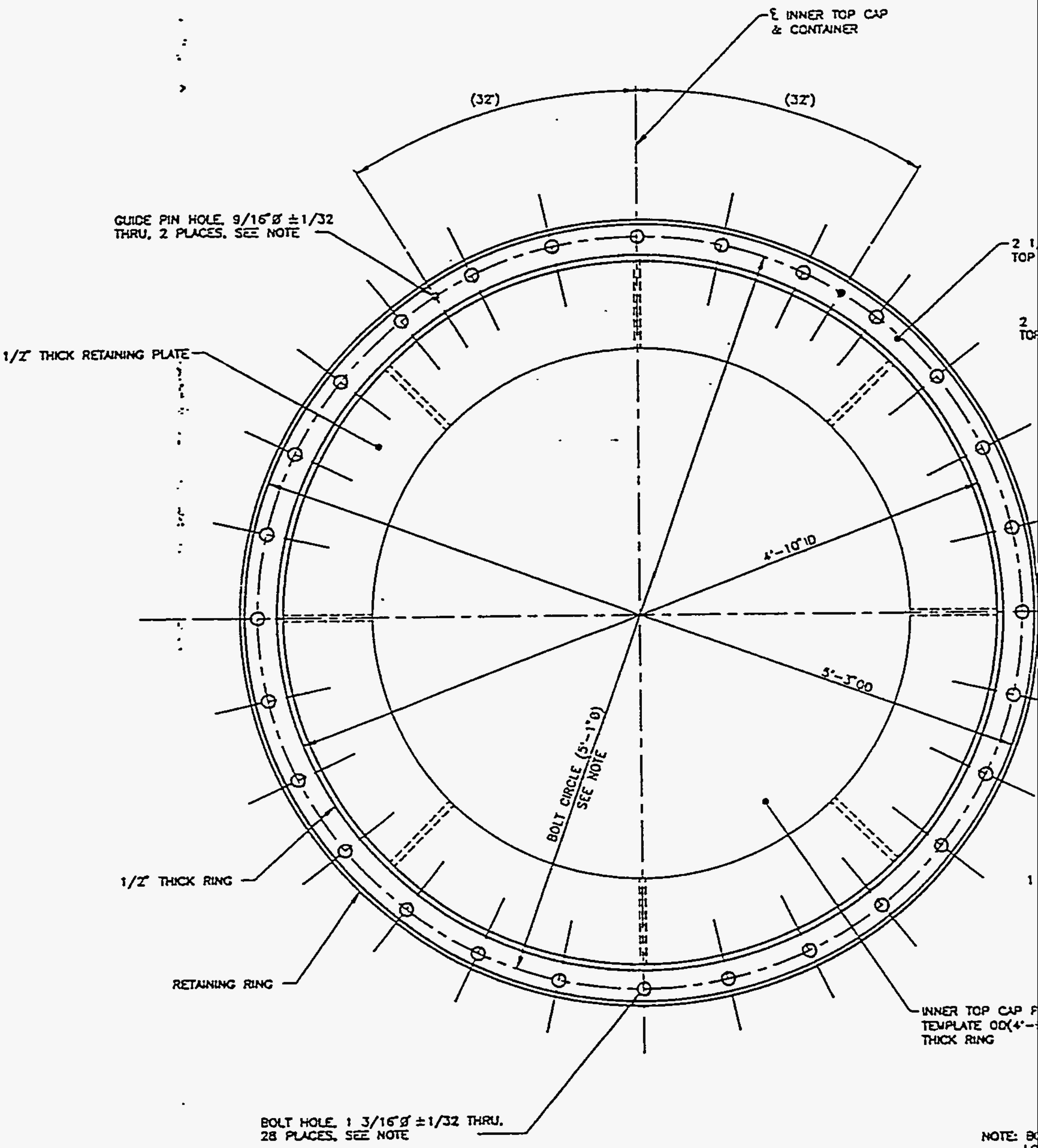
U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

HYDROGEN MIXER PUMP
STORAGE CONTAINER

F 200-G 1001 H-2-83734 0

SCALE SHOWN 700434 SHEET 4

DRAWING TRACEABILITY LIST
NEXT USED ON H-2-83734 SH 1
REFERENCES
REVISIONS
CADFILE ES37340



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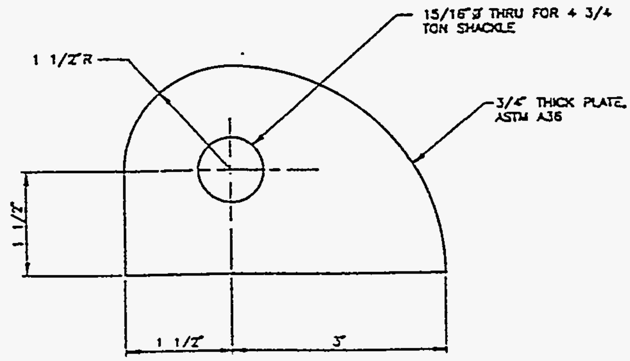
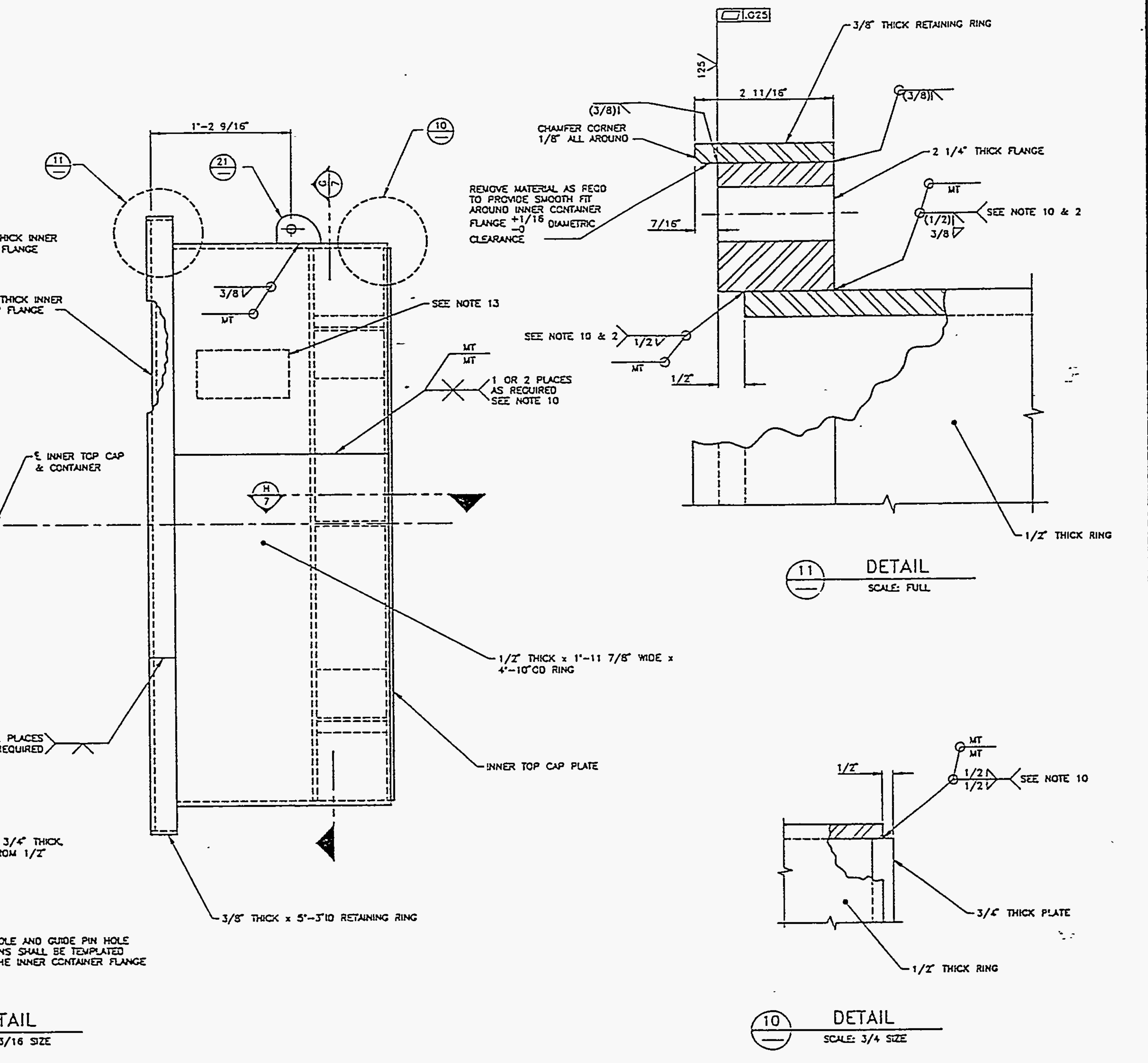
SC



21
DETAIL
SCALE: FULL SIZE



TAIL
3/16 SIZE

11 DETAIL
SCALE: FULL

10 DETAIL
SCALE: 3/4 SIZE

OFFICIAL RELEASE BY WHC
DATE SEP 29 1994

FOR GENERAL NOTES SEE SHEET 1

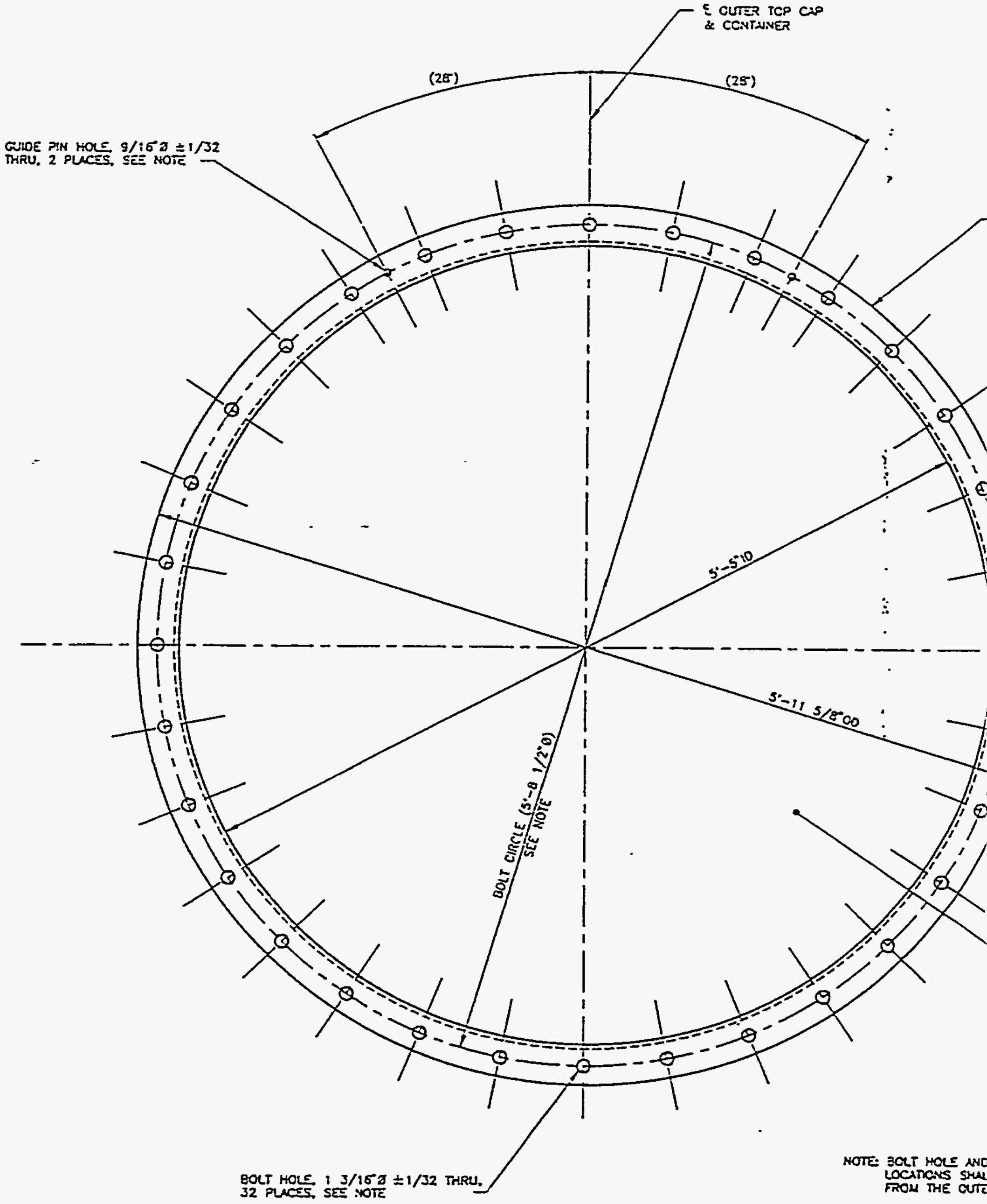
RN KYLE	5-94	U.S. DEPARTMENT OF ENERGY DOE Field Office, Richland Westinghouse Hanford Company
D. HANCKS	5-94	HYDROGEN MIXER PUMP STORAGE CONTAINER INSIDE TOP CAP
W OSTROM	5-94	

SIZE	BLDG NO	INDEX NO	DWG NO	REV
F	200-G	1001	H-2-83734	0

SCALE SHOWN CP 700434 SHEET 5 OF

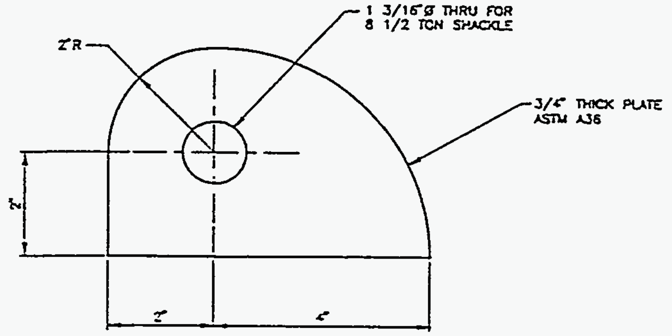
DRAWING TRACEABILITY LIST
NEXT USED ON H-2-83734 SH 1
CADFILE 3083734E
CADCODE DOS:5 0:AC02:12.00:SS
REVISIONS
REFERENCES

H-2-83734



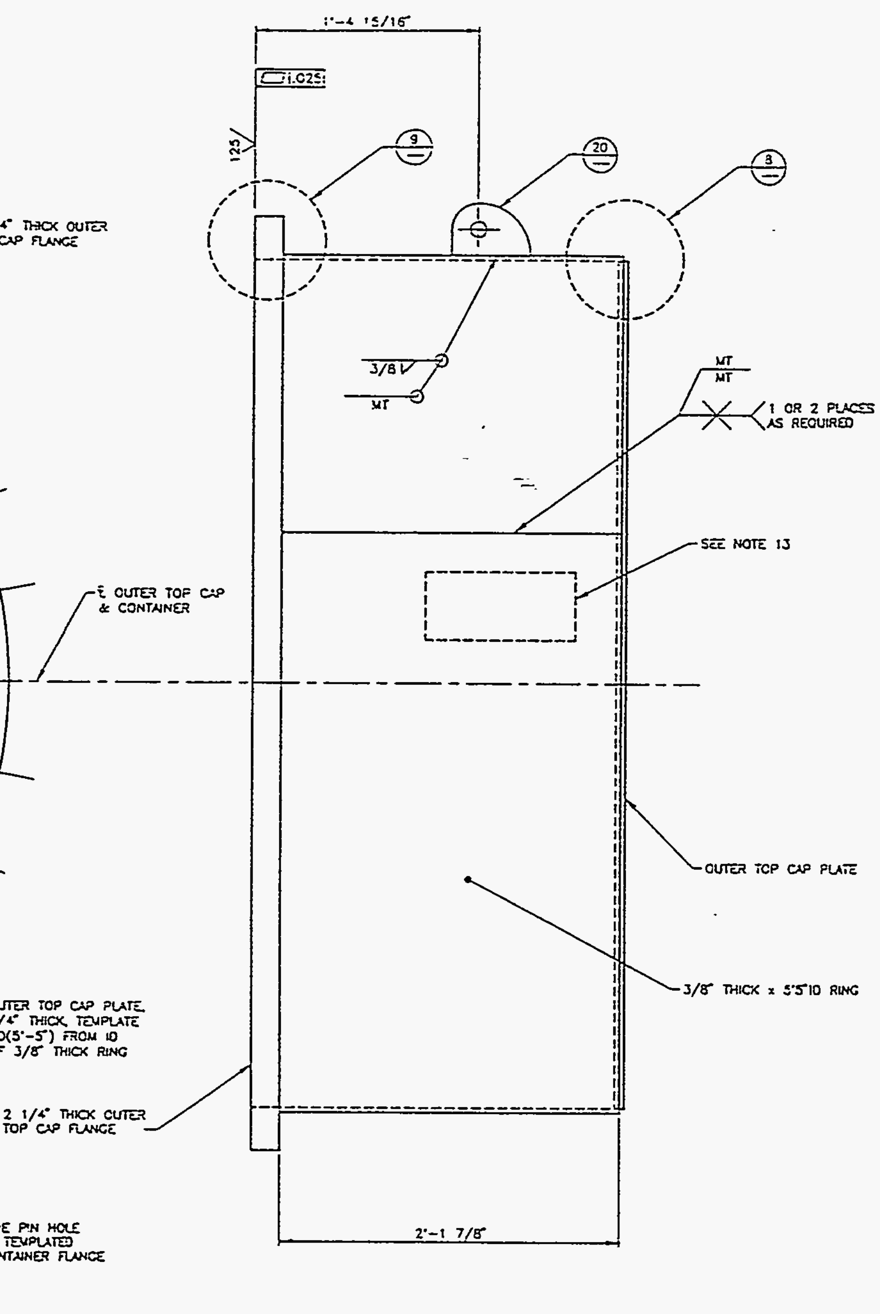
NOTE: BOLT HOLE AND
LOCATIONS SHAL
FROM THE OUTE

3
1

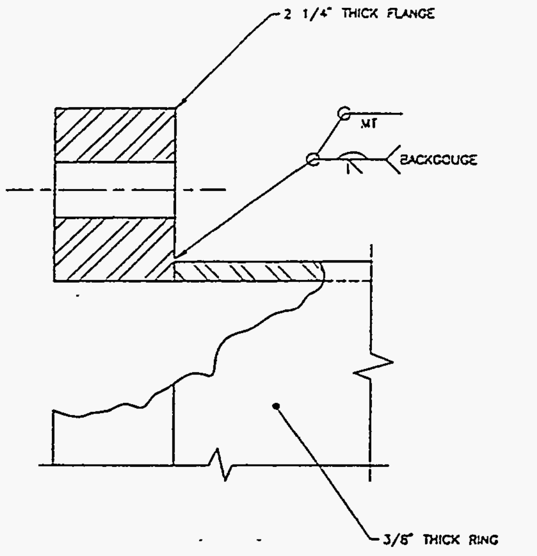


20
DETAIL
SCALE: 3/4 SIZE

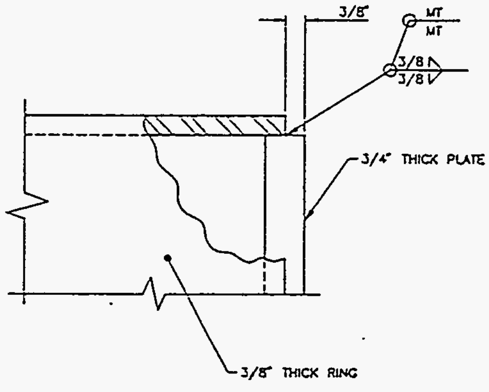
54-1000-C27(3/89)



DETAIL
ALE: 3/16 SIZE



9 DETAIL
SCALE: 3/4 SIZE



8 DETAIL
SCALE: 3/4 SIZE

DATE SEP 29 1994

FOR GENERAL NOTES SEE SHEET 1

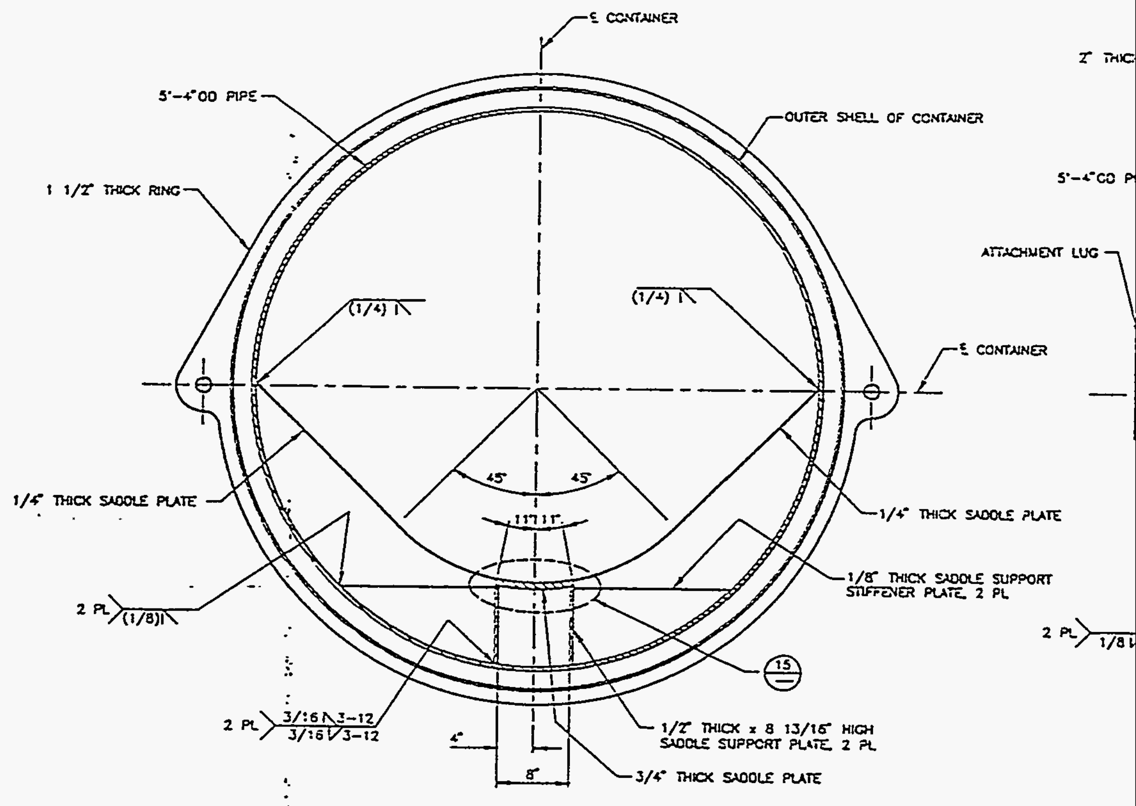
RN KYLE
D. HAMEUS 9-94
W OSTROM 5-94

U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

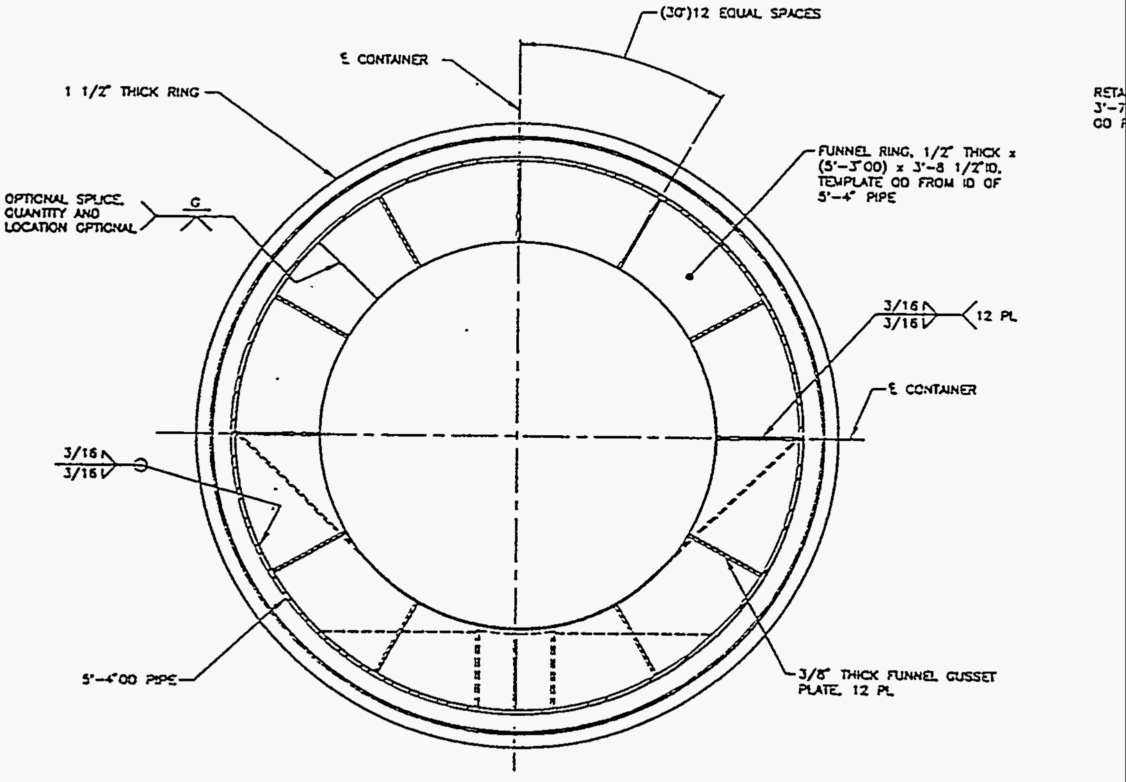
HYDROGEN MIXER PUMP
STORAGE CONTAINER
OUTER TOP CAP

F 200-G 1001 H-2-83734 0
SCALE SHOWN 700434 SHEET 6

DRAWING TRACEABILITY LIST
NEXT USED ON H-2-83734 SH 1
CADFILE 5083734F
REVISIONS

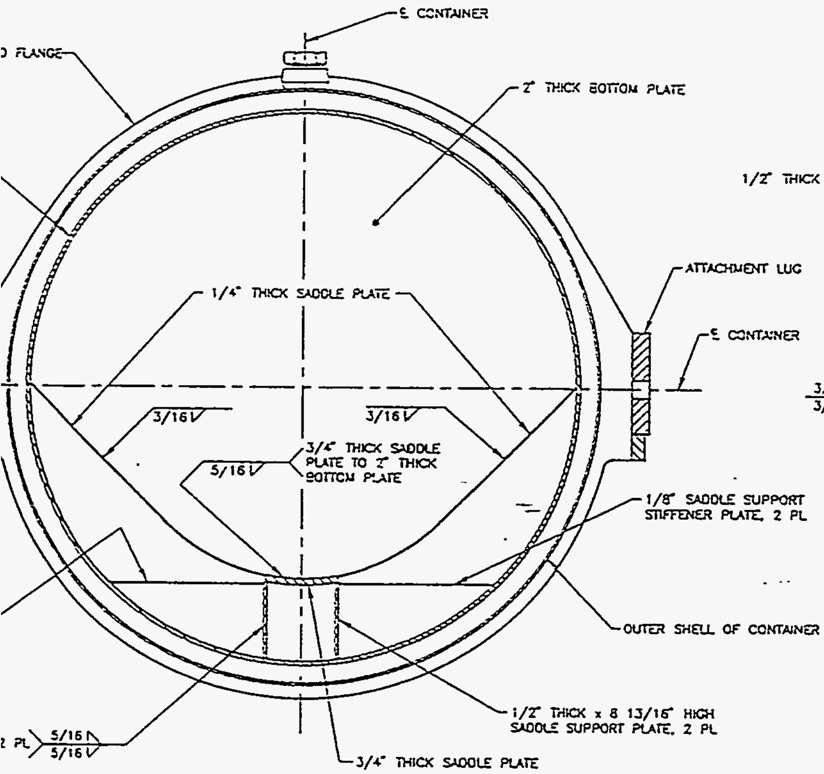


K
1
SECTION
SCALE: 1 1/2"=1'-0"

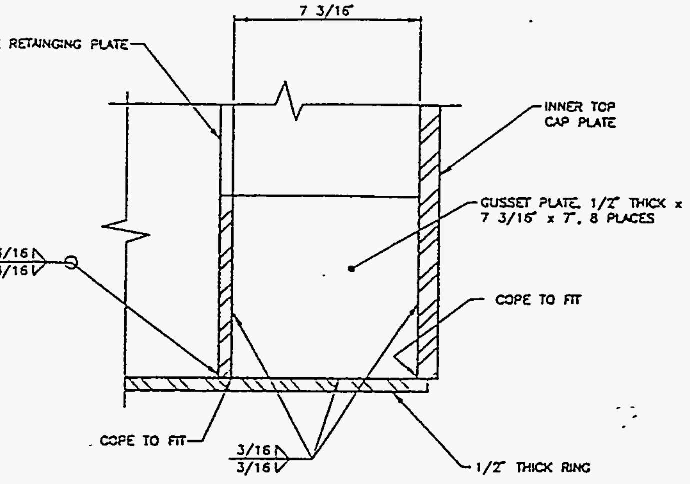


L
9
SECTION
SCALE: 1 1/2"=1'-0"

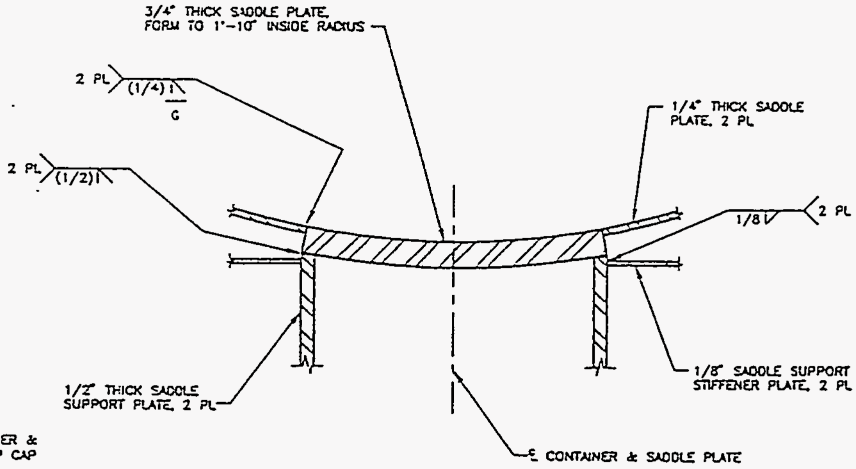
SA-4000-C27(3/89)



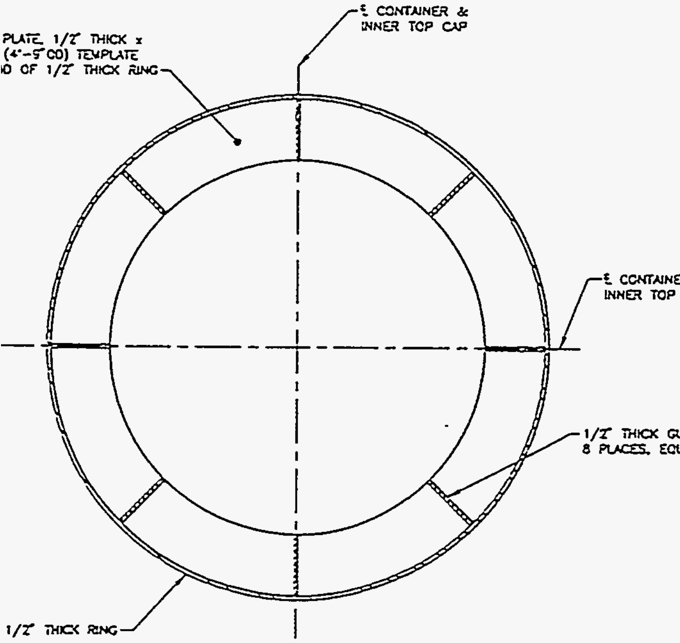
SECTION J/1
SCALE: 1 1/2"=1'-0"



SECTION H/5
SCALE: 3/8 SIZE



DETAIL 15
SCALE: 1/2 SIZE



SECTION G/5
SCALE: 1 1/2"=1'-0"

OFFICIAL RELEASE
BY WHC
DATE SEP 29 1994

FOR GENERAL NOTES SEE SHEET 1

RN KYLE
D. Hanks 9-94
W OSTROM 5-94

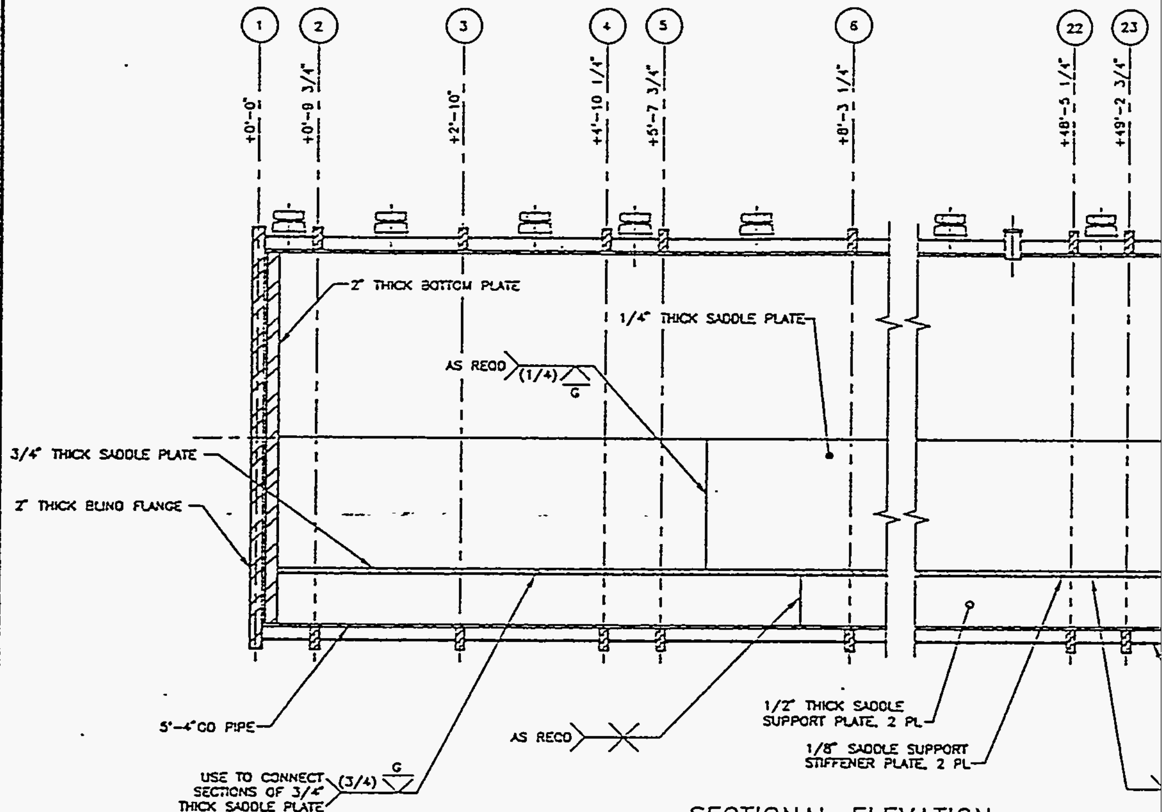
U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

HYDROGEN MIXER PUMP STORAGE CONTAINER

F | 200-G | 1001 | H-2-83734 | 0
SCALE SHOWN | CV 700434 | SHEET 7

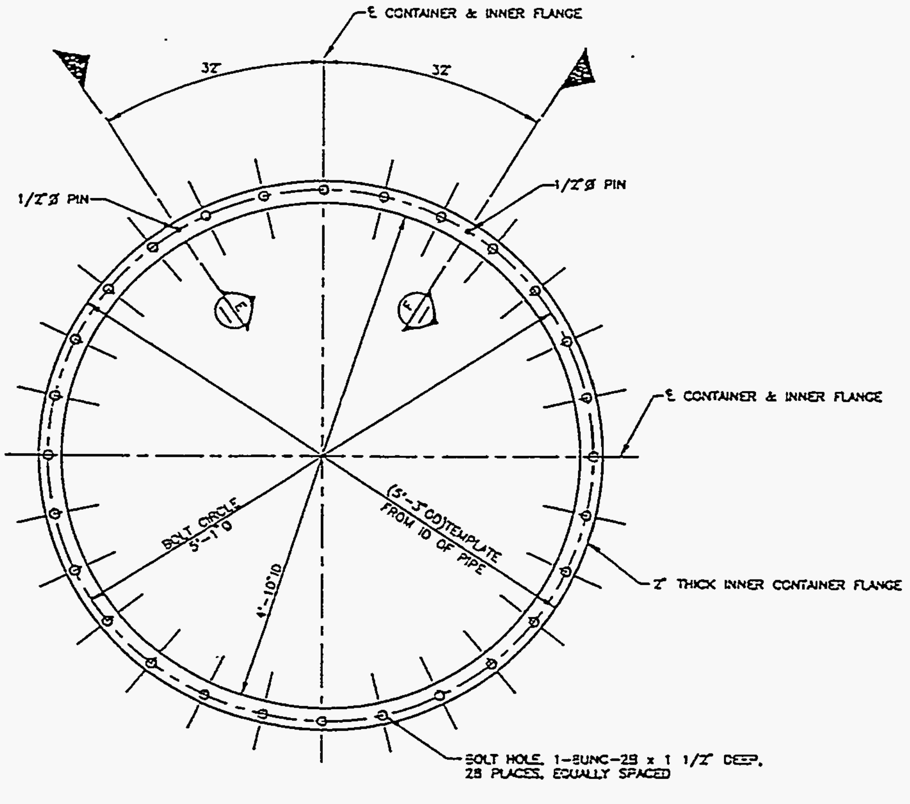
DRAWING TRACEABILITY LIST
NEXT USED ON H-2-83734 SH 1
REFERENCES
REVISIONS
CADFILE E08373-G
CADCODE 00S.3.0:AC02:12.00:55

H-2-83734



SECTIONAL ELEVATION

SCALE: 1"=1'-0"



12/9 DETAIL

SCALE: 1 1/2"=1'-0"

GENERAL NOTES (CONTINUED FROM SHEET 1)

7. THREADED FASTENERS SHALL BE COATED WITH NICKEL NEVER SEIZE #NS-160 OR LOCTITE C.
8. MATERIAL SHALL BE MARKED SUCH THAT IT IS TRACEABLE TO THE CHEMICAL ANALYSIS AND MECHANICAL TEST REPORTS. HEAT NUMBER TRACEABILITY OF MATERIAL SHALL BE MAINTAINED ON THE BILL OF MATERIALS.
9. EACH ANNULUS SHALL BE PRESSURE DECAY TESTED TO 11.2 PSI PER HS-BS-0076 TYPE I, HOLD 10 MINUTES (NO LEAKAGE ALLOWED).
10. WELD AND INSPECT ALL PRIMARY CONTAINMENT WELDS PER ASME B & PV CODE, SECTION VIII.
11. GRIND WELD BEAD ON STIFFENING RINGS AS NECESSARY TO ALLOW FITTING OF OUTSIDE SHELL.
12. MARK PER HS-BS-0015, TYPE 8, IN LOCATION INDICATED USING 1" HIGH BLACK CHARACTERS:

    DWG. NO., REV. NO. ____________
    CONTAINER WT.____________LBS

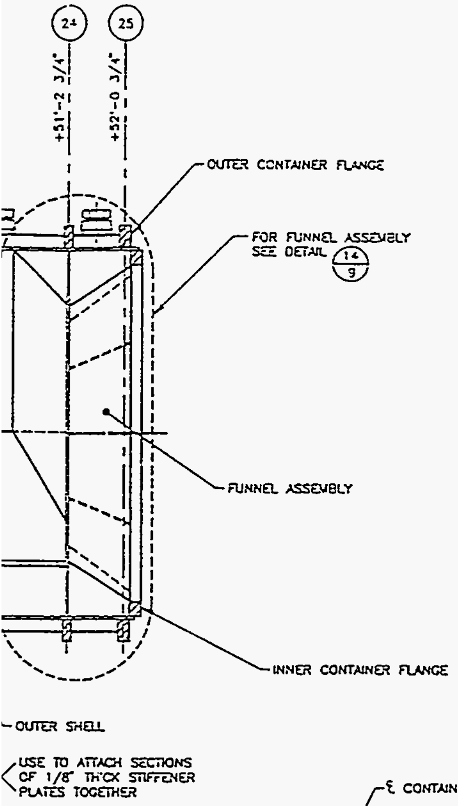
13. MARK PER HS-BS-0015, TYPE 8, IN LOCATION INDICATED USING 1" HIGH BLACK CHARACTERS:

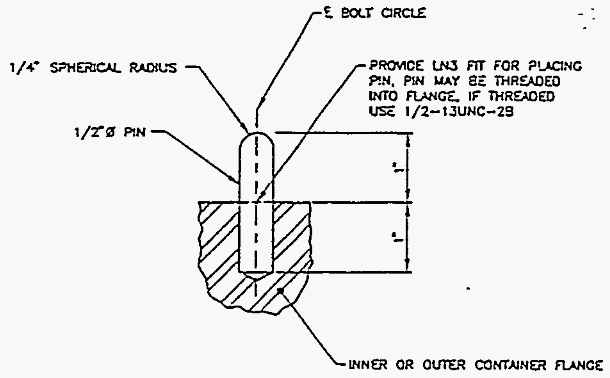
    DWG. NO., REV. NO. ____________
    TOP CAP WT.____________LBS

14. MARK PER HS-BS-0015, TYPE 8, IN LOCATION INDICATED USING 2" HIGH BLACK CHARACTERS:

    ANNULUS NO. ____________

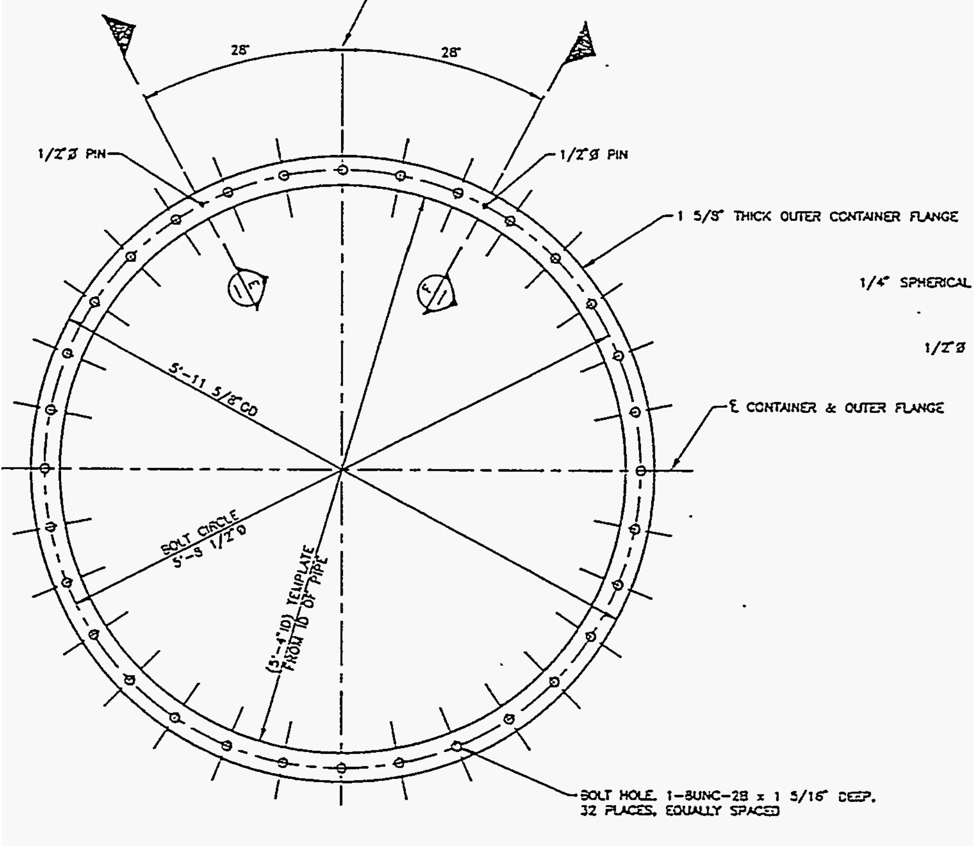
    ANNULUS NUMBER IS THE SAME AS THE COLUMN LINE NUMBER ON THE LEFT SIDE OF ANNULUS.

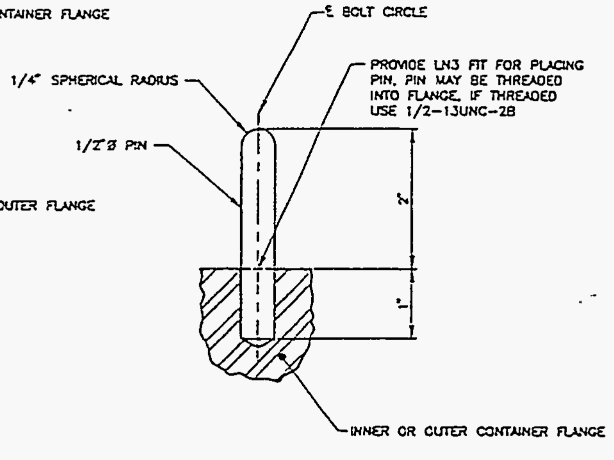




F SECTION

SCALE: FULL





E SECTION

SCALE: FULL

OFFICIAL RELEASED BY WHC
DATE SEP 29 1994

13/9 DETAIL

SCALE: 1 1/2"=1'-0"

FOR GENERAL NOTES SEE SHEET 1

RN KYLE
D. Hawes 9-94
W. OSTROM 5-94

U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

HYDROGEN MIXER PUMP
STORAGE CONTAINER

F | 200-G | 1001 | H-2-83734 | 0

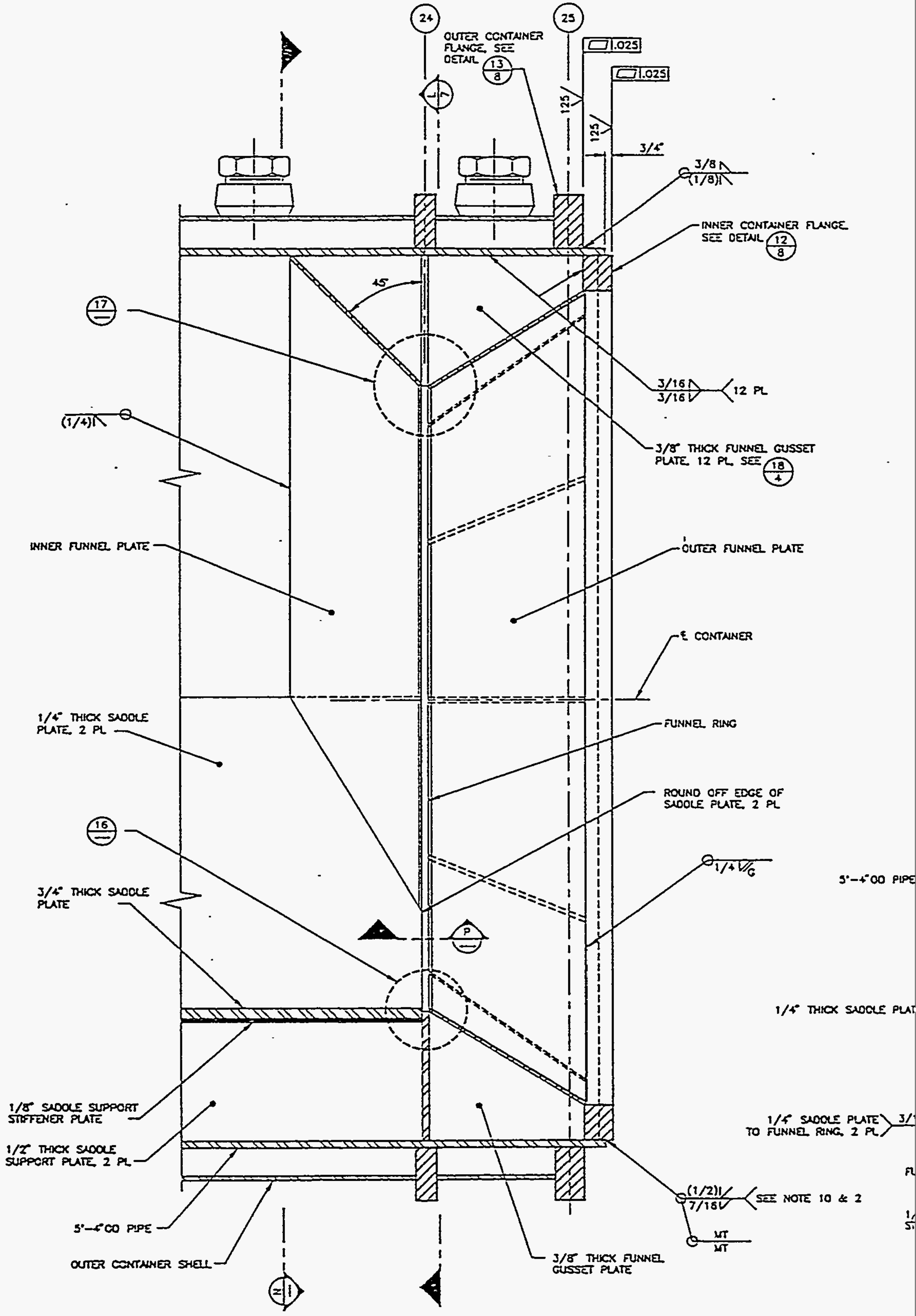
SCALE SHOWN | 700434 | SHEET 8

DRAWING TRACEABILITY LIST

NEXT USED ON H-2-83734 SH 1

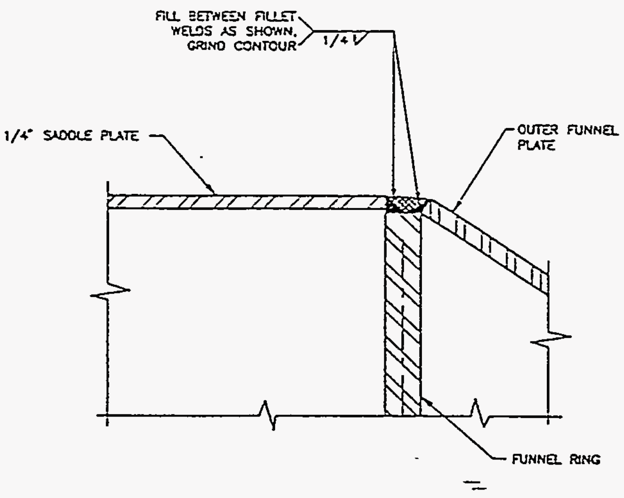
CADFILE 5083734H

CADCODE COS:5.0:ACD2:12.CO:SS

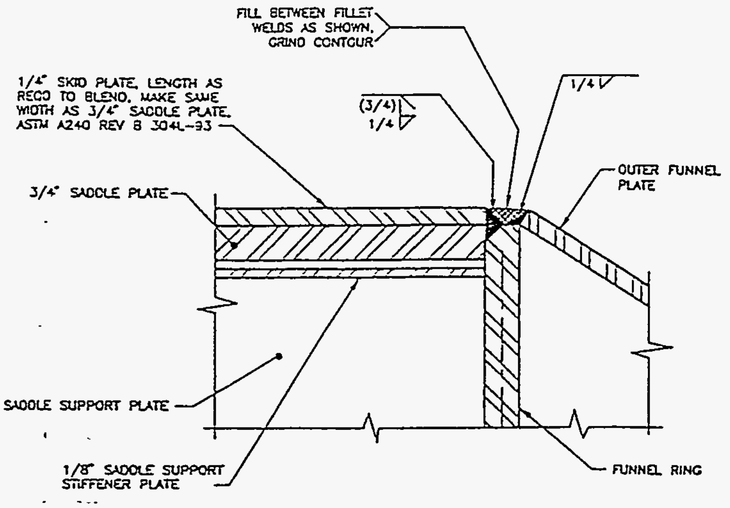


14/8 DETAIL

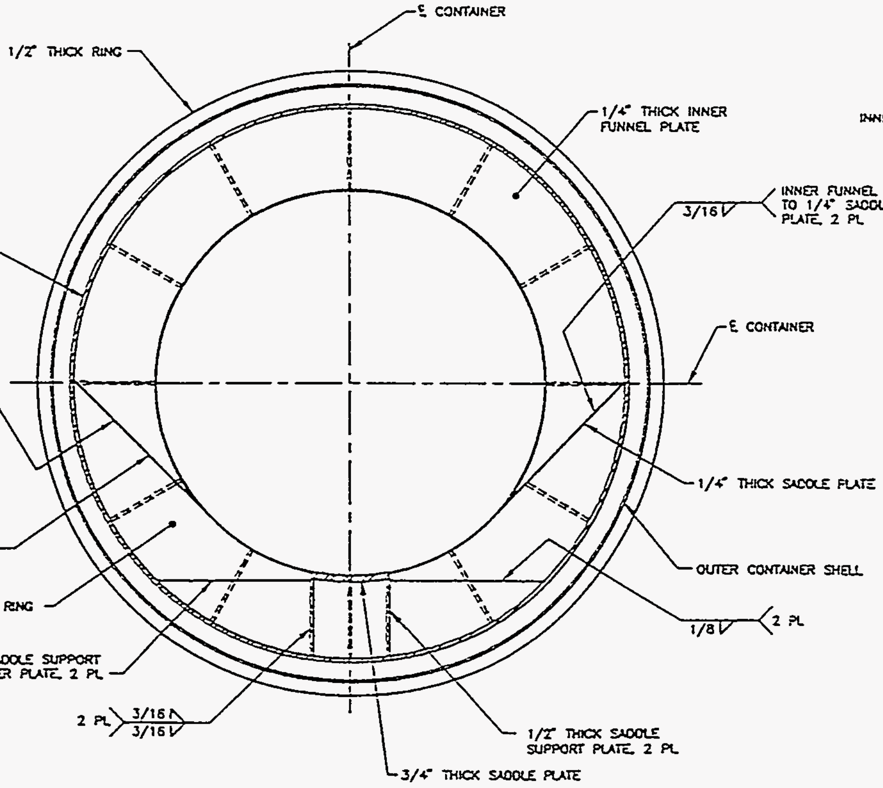
SCALE: 1/4 SIZE



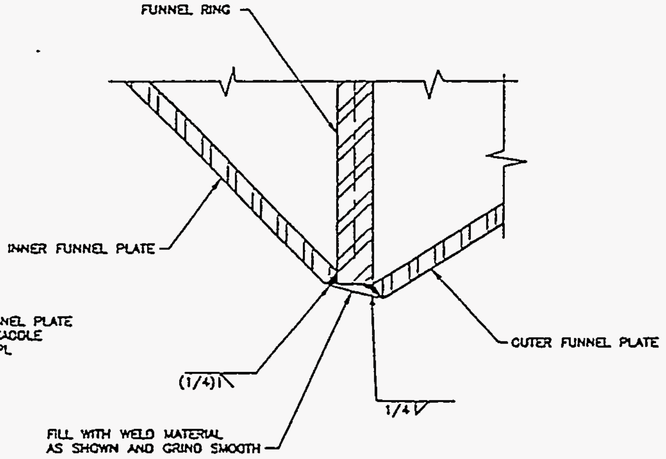
P SECTION
SCALE: FULL



16 DETAIL
SCALE: FULL



N SECTION
SCALE: 1 1/2"=1'-0"



17 DETAIL
SCALE: FULL

OFFICIAL RELEASE
DATE SEP 29 1994

FOR GENERAL NOTES SEE SHEET 1

RN KYLE
D. HAWKINS 9-94
9-94
WJ OSTROM 5-94

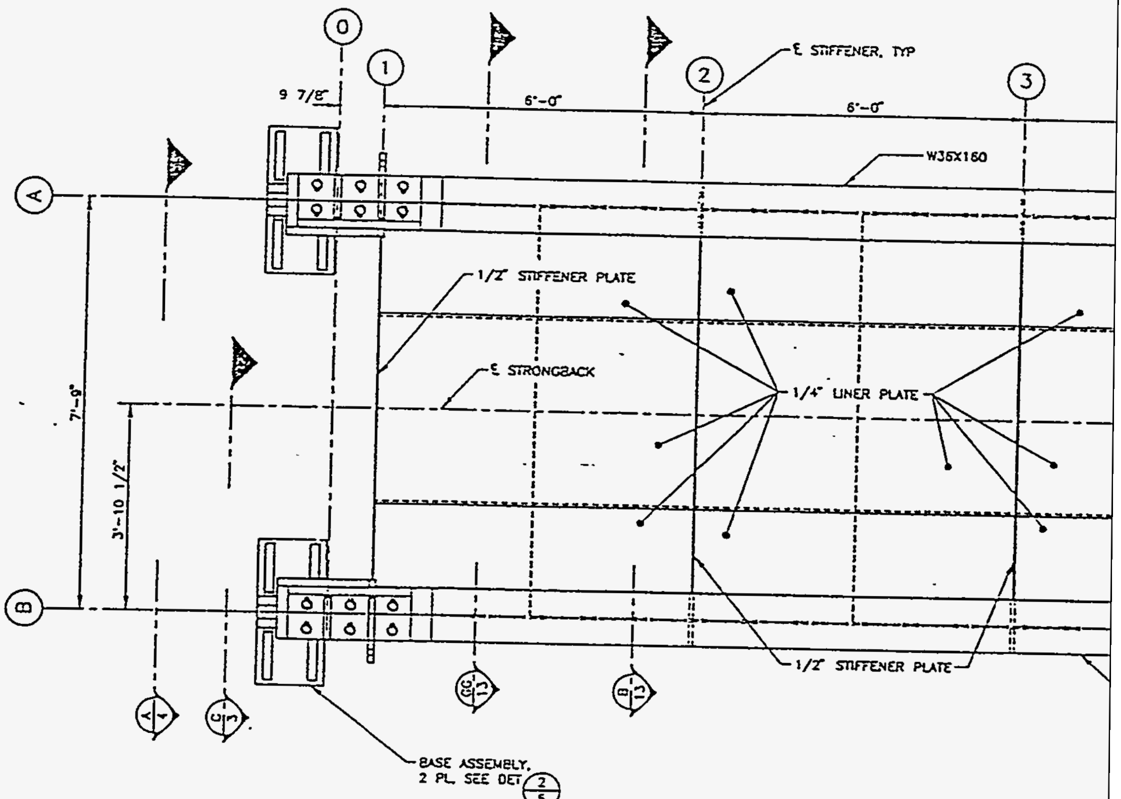
U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

HYDROGEN MIXER PUMP
STORAGE CONTAINER

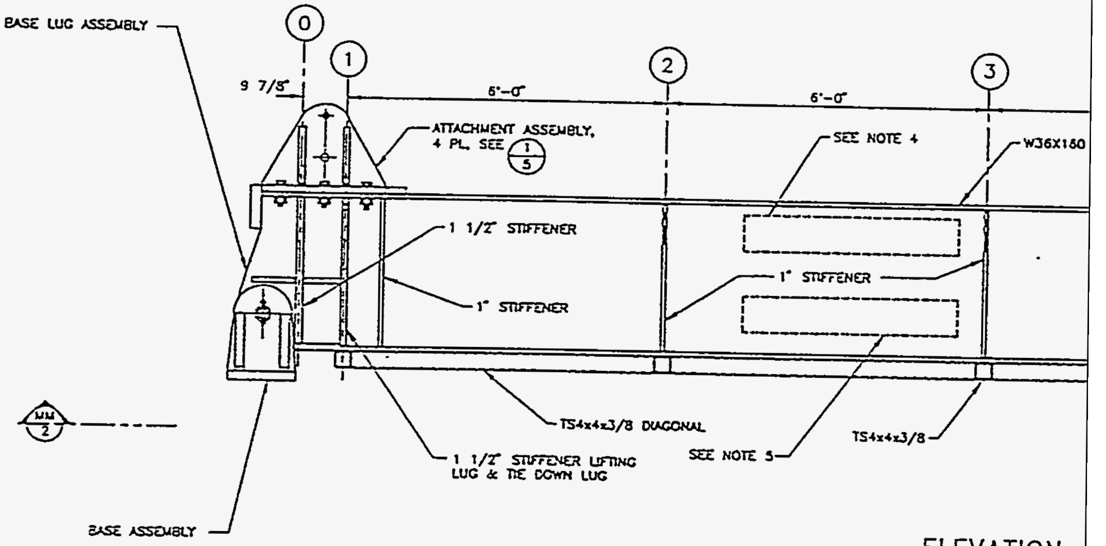
F 200-G 1001 H-2-83734 0
SCALE SHOWN 700434 SHEET 9

NEXT USED ON H-2-83734 SH 1
DRAWING TRACEABILITY LIST
REFERENCES
REVISIONS
CADFILE E083734J
CADCODE DOS:5.0:ACD2:12.0G:SS

9.3 STRONGBACK SECTIONS AND DETAILS (H-2-83736)



TOP PLAN
SCALE: 3/4"=1'-0"



ELEVATION
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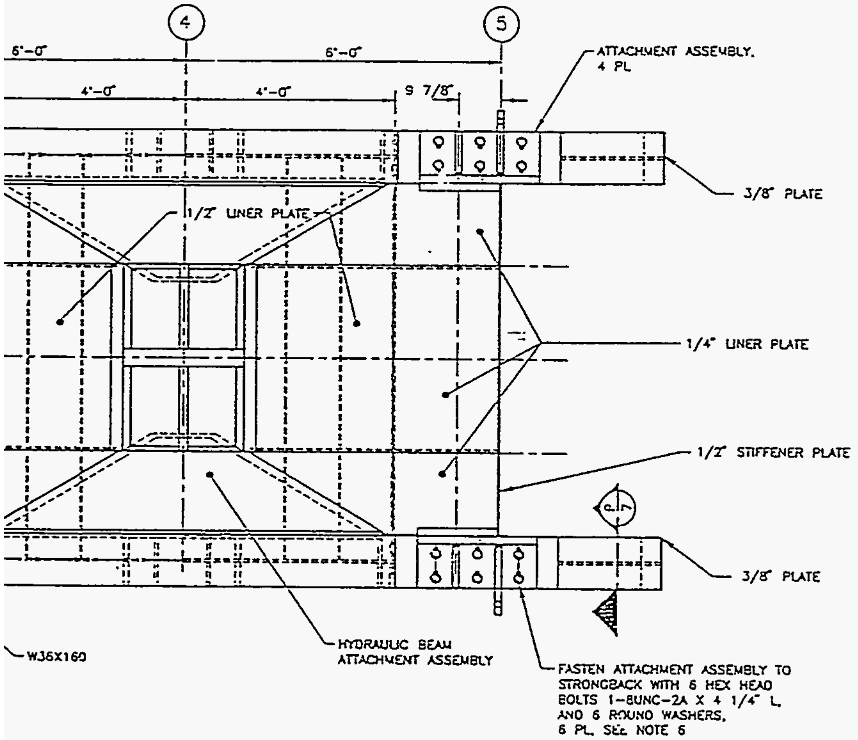
54-6600-227(5/89)



GENERAL NOTES

(UNLESS OTHERWISE SPECIFIED)

1. ALL PLATE, SHEET, FLAT BAR, AND WIDE FLANGES SHALL CONFORM TO ASTM A36-1992 CARBON STEEL. ALL STRUCTURAL TUBING SHALL CONFORM TO ASTM A500-1992 GRADE B CARBON STEEL. HEX HEAD BOLTS SHALL CONFORM TO ASTM A325-1993 CARBON STEEL. HEX NUTS SHALL CONFORM TO ASTM A194 GRADE 2H CARBON STEEL.

2. WELD AND INSPECT PER AWS D1.1-1992. VT FINAL PASS OF ALL WELDS. MT FINAL PASS OF DESIGNATED WELDS. WELD QUALIFICATIONS AND WELDING PROCEDURES PER ASME SECTION IX-1992 ARE AN ACCEPTABLE SUBSTITUTION.

3. REMOVE ALL BURRS AND BREAK ALL SHARP EDGES.

4. IDENTIFY ASSEMBLY WITH THE DRAWING NUMBER AND DRAWING REVISION NUMBER IN THE LOCATION INDICATED ON THE DRAWING ON BOTH SIDES OF THE STRONGBACK PER HS-BS-0015, TYPE 8. CHARACTERS SHALL BE 2" HIGH AND SHALL BE PAINTED WITH BLACK ENAMEL.

5. PAINT "STRONGBACK WEIGHT **** LBS" IN THE LOCATION INDICATED ON THE DRAWING ON BOTH SIDES OF THE STRONGBACK PER HS-BS-0015, TYPE 8. THE ASSEMBLY SHALL BE WEIGHED PRIOR TO PAINTING THE ABOVE AND THE WEIGHT TO THE NEAREST POUND SHALL BE INSERTED WHERE THE **** ARE. THE CHARACTERS SHALL BE 2" HIGH AND SHALL BE BLACK ENAMEL ON A YELLOW ENAMEL BACKGROUND.

6. THE FOUR CONTAINER ATTACHMENT ASSEMBLIES SHALL BE BOLTED TO THE STRONGBACK WITH 1-8UNC-2A HEX HEAD BOLTS AND 1-8UNC-2B HEX NUTS. THE BOLTS AND NUTS SHALL BE FULLY TIGHTENED AFTER THE CONTAINER IS IN PLACE AND FULLY BOLTED TO THE CONTAINER ATTACHMENT ASSEMBLY BY USING THE TURN OF THE NUT METHOD PER AISC STEEL CONSTRUCTION MANUAL, 9TH EDITION.

7. AFTER FABRICATION, PREPARE AND PAINT ALL EXPOSED CARBON STEEL EXCEPT NUTS, BOLTS, BOLT AND WASHER CONTACT SURFACES, BOLT HOLES, BEARINGS AND PINS WITH TWO COATS OF AMERLOCK 400 AND ONE TOP COAT OF AMERCOAT 450 HS. FINAL COLOR SHALL BE BEIGE RT-8304. PREPARATION AND APPLICATION SHALL BE PER MANUFACTURER'S INSTRUCTIONS.

8. ROUND BAR USED FOR PINS SHALL CONFORM TO ASTM A331-1990, STANDARD SPECIFICATION FOR COLD-FINISHED ALLOY STEEL BARS, GRADE E4340. THE ROUND BAR SHALL BE COLD DRAWN AND SHALL BE QUENCHED AND TEMPERED. THE ROUND BAR SHALL HAVE A MINIMUM HARDNESS OF HRC 51. WORK SHALL BE DONE BY TRAILER MANUFACTURER.

9. HOLES THROUGH CLEVIS PLATES AND LUGS AT CONNECTIONS A AND B SHALL BE IN-LINE WITHIN A DIAMETER OF .0035 INCH. WORK SHALL BE DONE BY TRAILER MANUFACTURER.

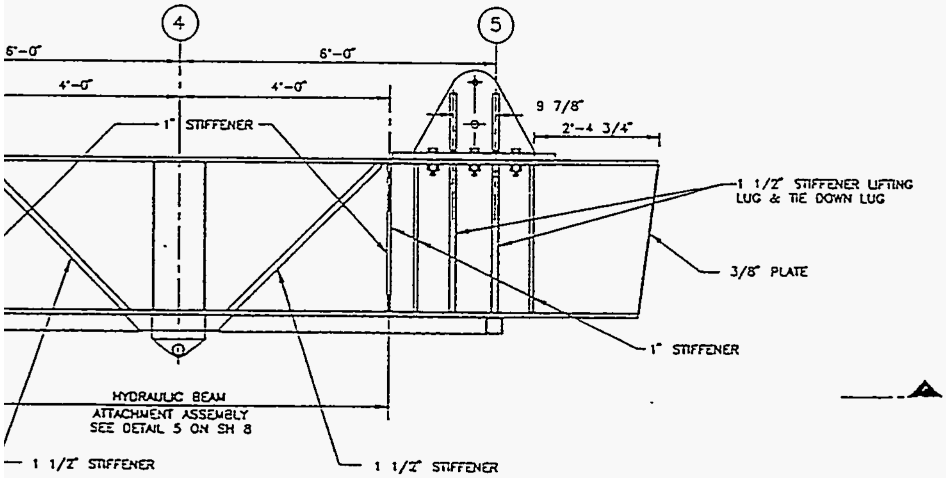
10. RING PINS SHALL BE INSTALLED THROUGH THE 3" DIAMETER PIN ON BOTH SIDES OF THE ASSEMBLY AS SHOWN. RING PINS SHALL BE 1/2" DIAMETER x 3 1/4" EFFECTIVE LENGTH AND SHALL BE SUPPLIED WITHOUT A COLLAR. RING PINS SHALL BE ZINC PLATED CARBON STEEL. RING PINS SHALL BE SUPPLIED WITH A #5 COTTER PIN FOR SECURING IN PLACE. RING PINS MAY BE PROCURED FROM:

    AIMSCO, INC.
    P.O. BOX 80304
    SEATTLE, WA
    98108
    1-800-426-0244

    RING PINS TO BE INSTALLED BY TRAILER MANUFACTURER.

11. BEARINGS SHALL BE GAR-MAX, FILAMENT WOUND, HIGH LOAD, SELF-LUBRICATING BEARINGS AS MANUFACTURED BY GARLOCK BEARINGS, INC., BEARING #GM4856. BEARINGS SHALL HAVE A NOMINAL SIZE OF 3"ID x 3 1/2"OD. BEARINGS FOR THE 2" CLEVIS PLATES SHALL BE 1 15/16" LONG. BEARINGS FOR THE 3" LUGS SHALL BE 2 15/16" LONG. BEARINGS SHALL BE PRESS FIT AND SHALL BE INSTALLED PER MANUFACTURER'S INSTRUCTIONS. BEARINGS TO BE INSTALLED BY TRAILER MANUFACTURER.

12. SEAL WELD ALL JOINTS THAT ARE NOT WELDED.



WHC-SD-WM-CA-165	SUPPORTING DOC
H-2-83734	STORAGE CONTAINER
REF NUMBER	TITLE

REFERENCES

NEXT USED ON H-2-83750

DRAWING TRACEABILITY LIST

REVISIONS

CADFILE 8083736A

CADCODE 20S-3.3-ACD2-12-20-SS

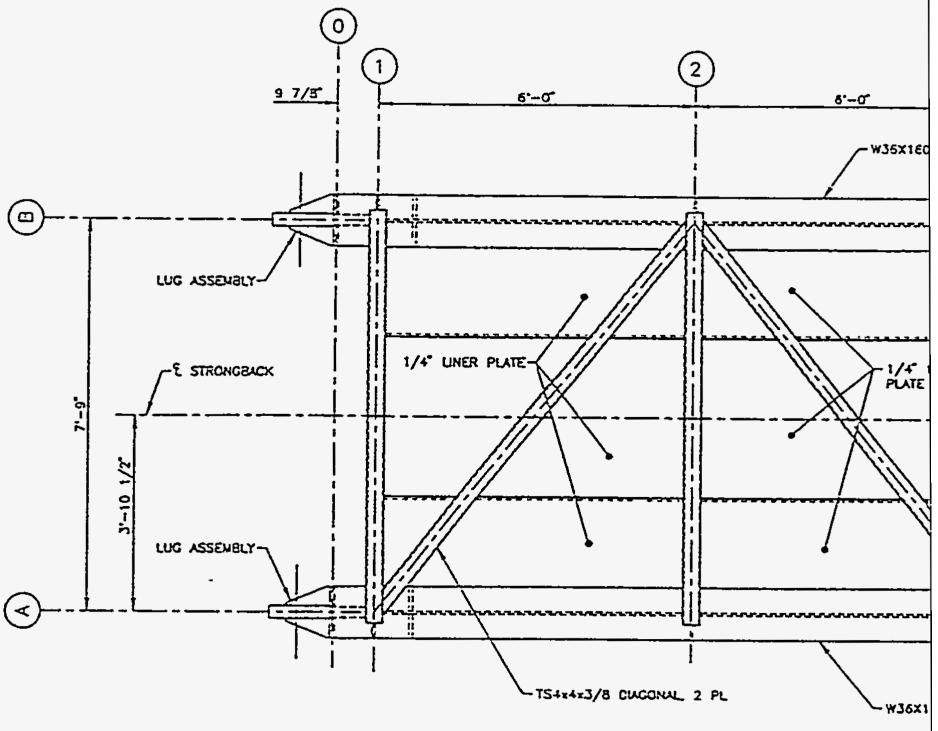
DRAWN	KD JUNT	5-94
CHECKED	D. KNOX	18-94
		5-94
	TR BENEGASI	5-94

U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

STRONGBACK PLAN AND ELEVATION

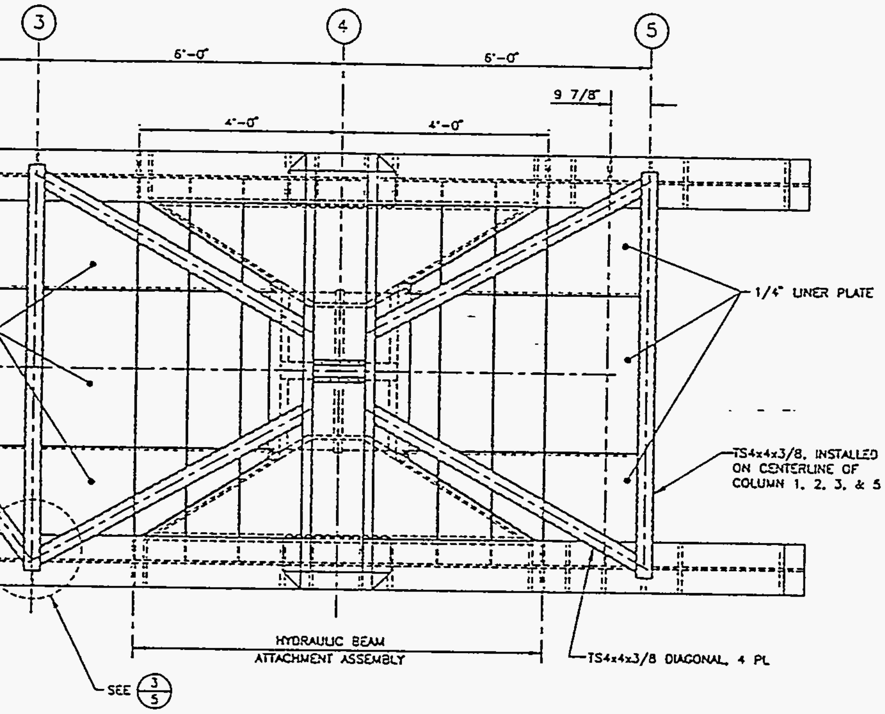
SIZE			DWG NO	REV
F	200-G	1001	H-2-83736	0

SCALE SHOWN | 700433 | SHEET 1 OF 15



MM
1
BOTTOM VI
SCALE: 3/4" = 1'-

54-6000-C27(3/89)



(SHOWN WITHOUT BASE ASSEMBLIES)

FOR GENERAL NOTES SEE SHEET 1

KD JUNT	5-94	U.S. DEPARTMENT OF ENERGY DOE Field Office, Richland Westinghouse Hanford Company
D. HAVENS	5-94	
	5-94	STRONGBACK SECTIONS AND VIEWS
TR SENECAS	5-94	

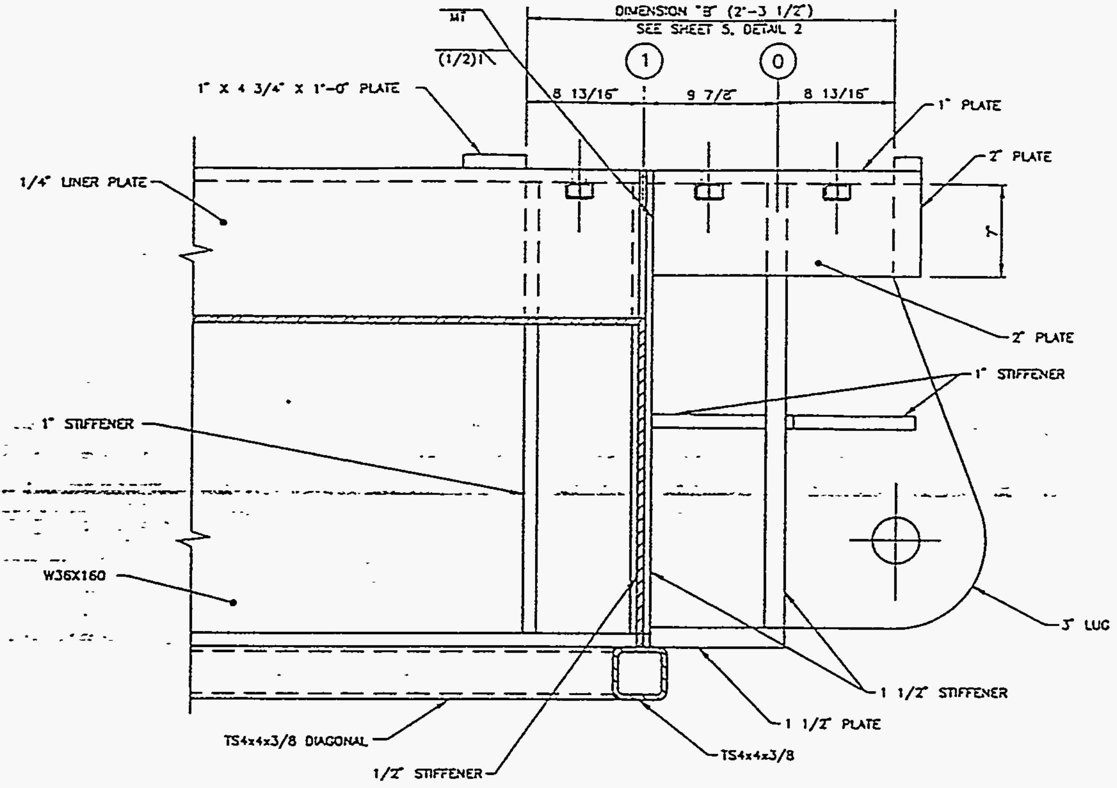
SIZE	BLDG NO	INDEX NO	DWG NO	REV
F	200-G	1001	H-2-83736	0

SCALE SHOWN | 700433 | SHEET 2

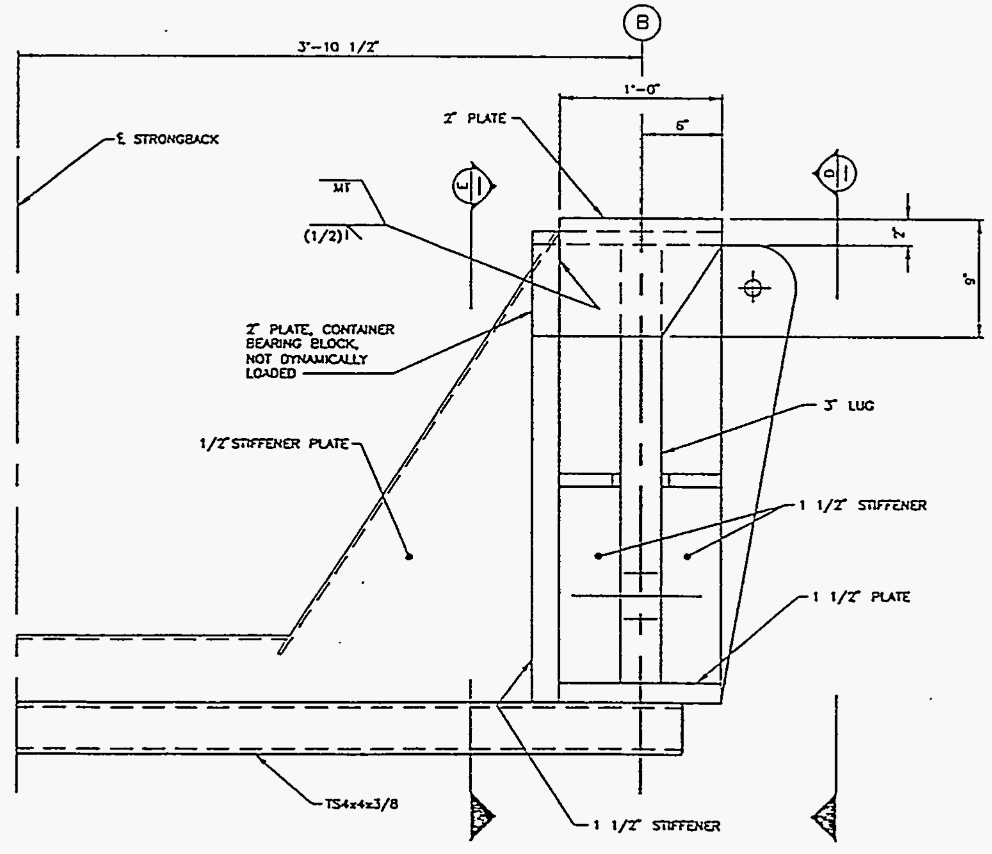
DRAWING TRACEABILITY LIST | NEXT USED ON SHEET 1 | REFERENCES | REVISIONS

CADFILE E0837368 | CADCODE 30S-3.3:ACD2:12 CO-SS

H-2-83736 0



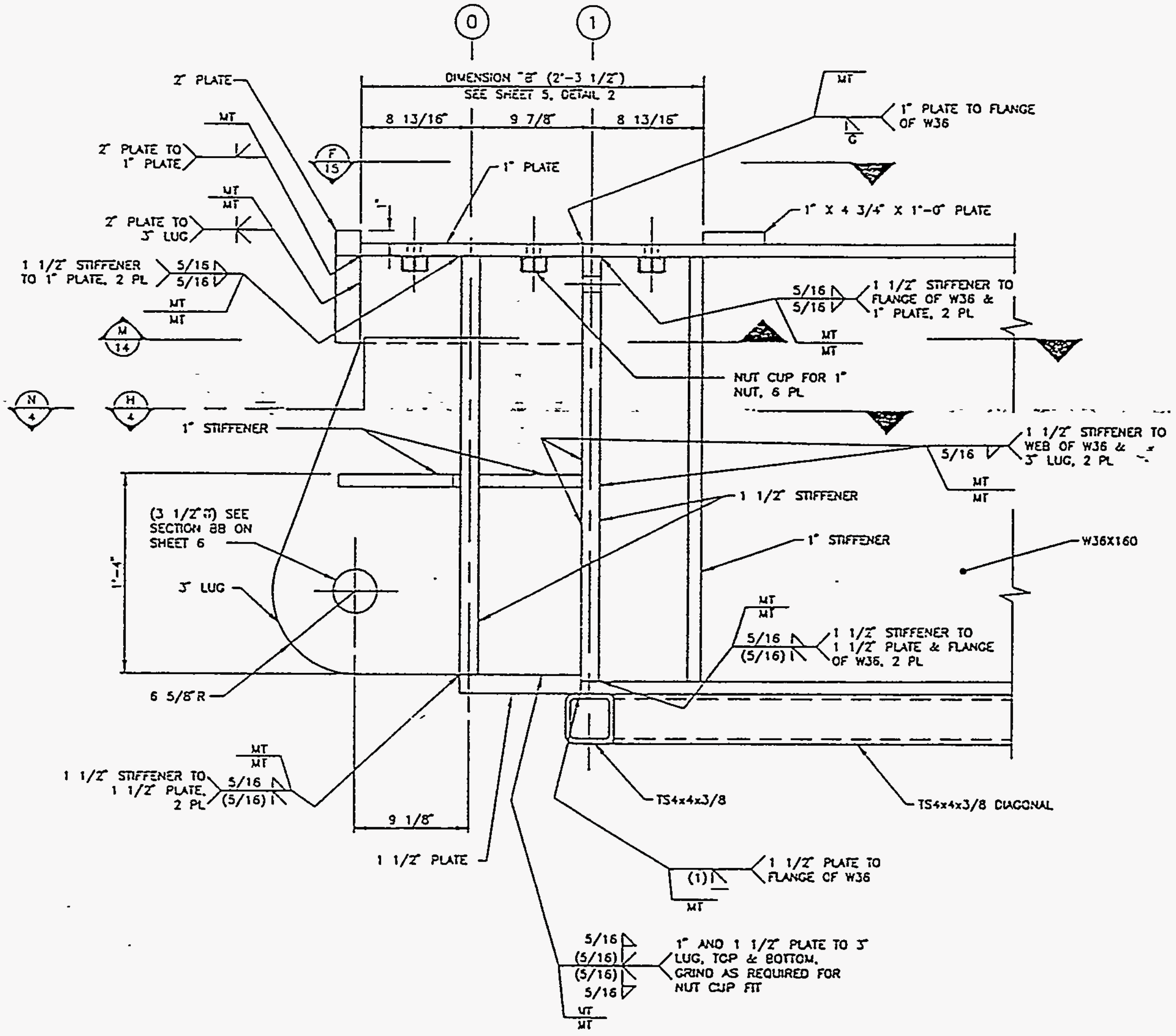
E
—
SECTION
SCALE: 3/16 SIZE



C
1
VIEW
SCALE: 3/16 SIZE

(SHOWN WITH BASE ASSEMBLY AND CONTAINER ATTACHMENT ASSEMBLY REMOVED)

54-6000-027(3/89)



D SECTION (2 PL)
SCALE: 3/16 SIZE

NOTE: PROVIDE CMTR TRACEABILITY FOR 3" LUG

FOR GENERAL NOTES SEE SHEET 1

DRAWN	KD JUNT	5-94
CHECKED	D. HAVENS	5-94
	GDW	1-94
COG ENGR	TR BENECAS	5-94

U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

STRONGBACK
SECTIONS AND VIEWS

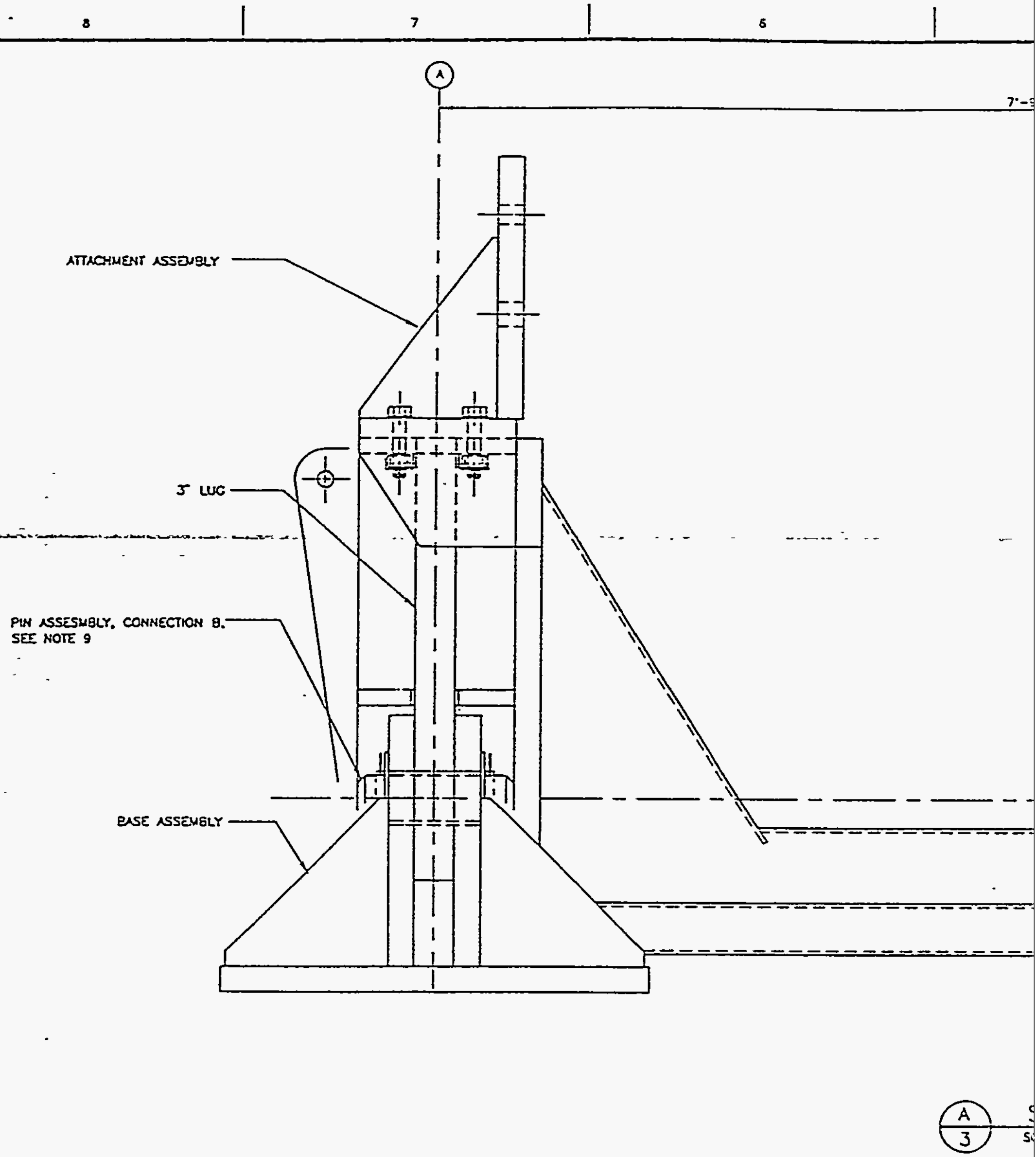
SIZE	BLDG NO	INDEX NO	DWG NO	REV
F	200-G	1001	H-2-83736	0

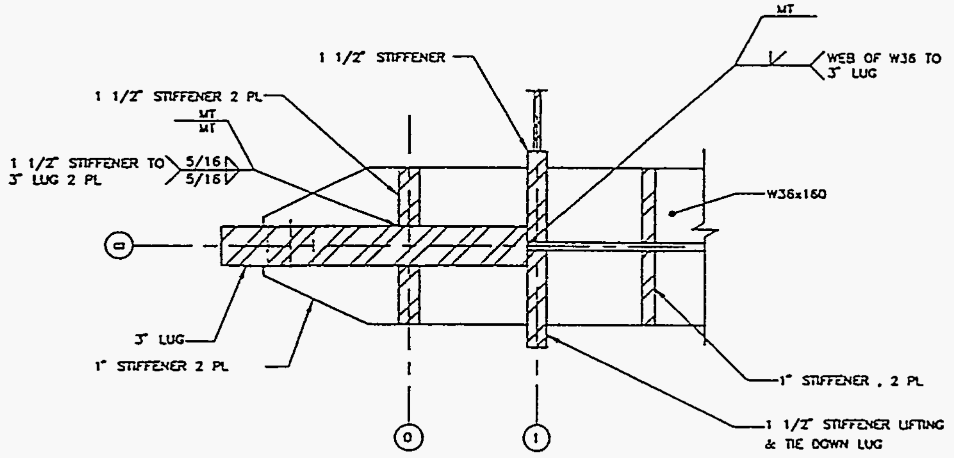
SCALE SHOWN | 700433 | SHEET 3

DRAWING TRACEABILITY LIST | REFERENCES | NEXT USED ON SHEET 1 | REVISIONS

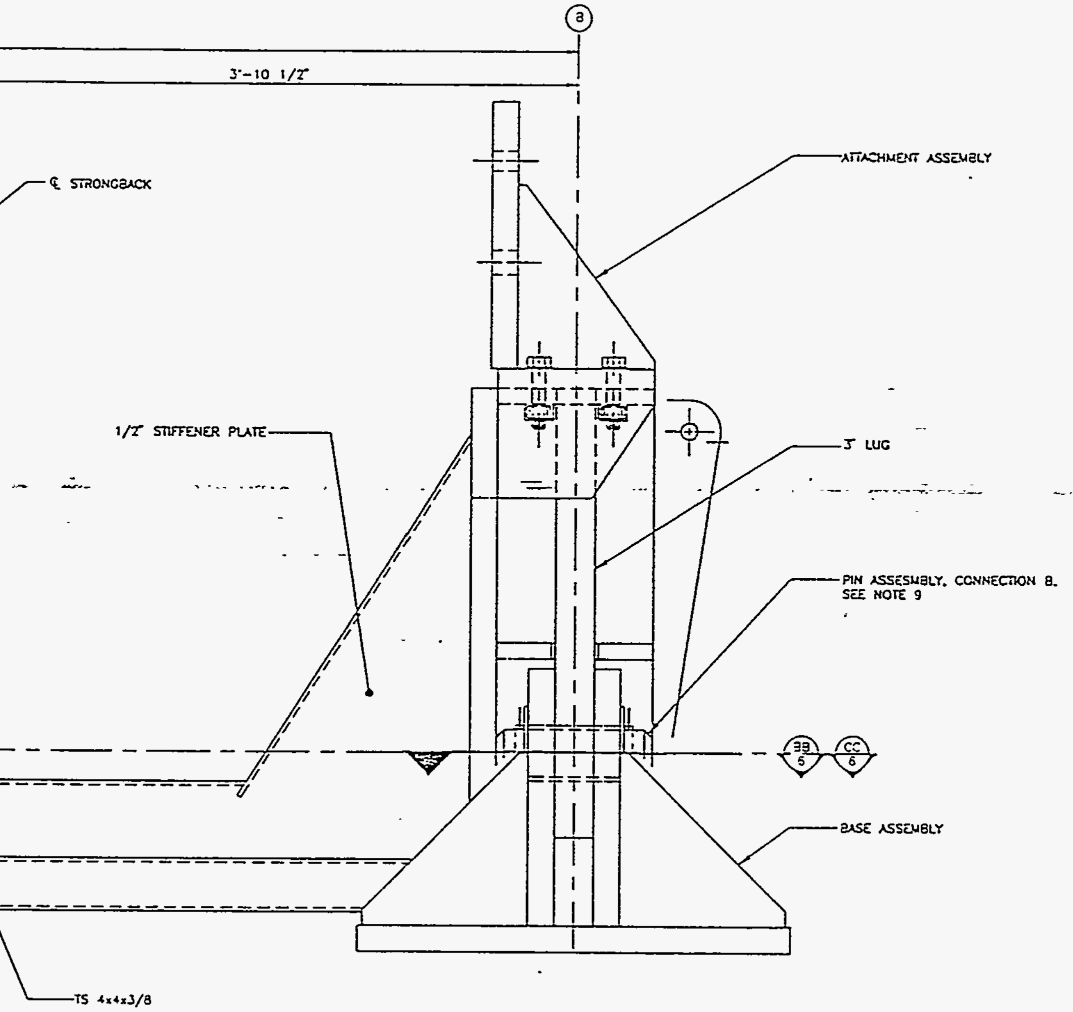
CADFILE E083736C | CADCODE 20S-3.3:ACD2-12 00:SS

H-2-83736



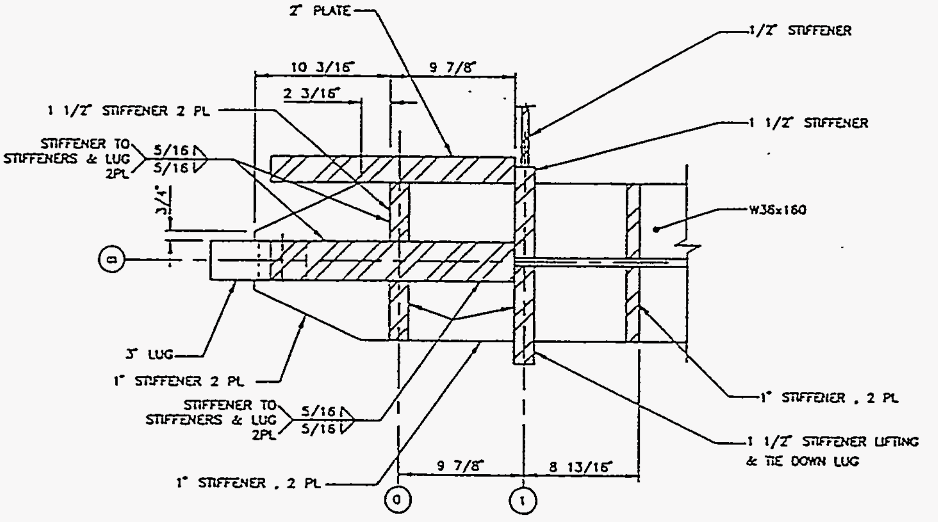


N
3
SECTION
SCALE: 3/16 SIZE



TION

3/16 SIZE



H/3 SECTION

SCALE: 3/16 SIZE

FOR GENERAL NOTES SEE SHEET 1

A PHILLIPS	4-94
D. HAVENS	6-94
	5-94
TR BENEGAS	4-94

U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

STRONGBACK
SECTIONS

SIZE			DWG NO	REV
F	20G-G	1001	H-2-83736	0

SCALE SHOWN 700433 SHEET 4

DRAWING TRACEABILITY LIST | NO | TITLE | REF NUMBER | TITLE

NEXT USED ON SH 1

REVISIONS | DESCRIPTION

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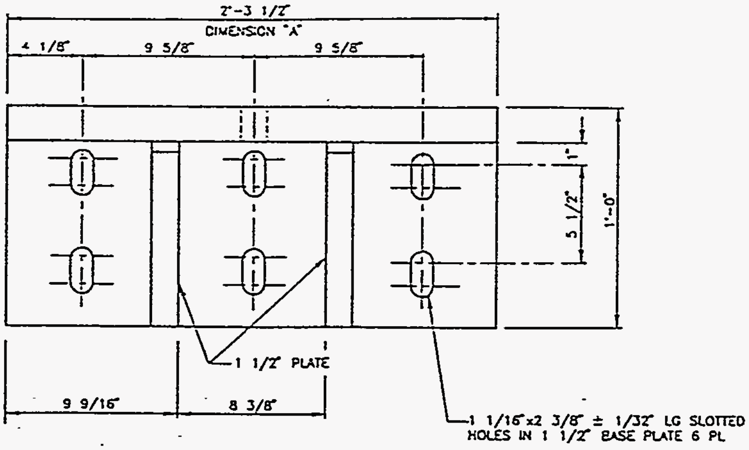
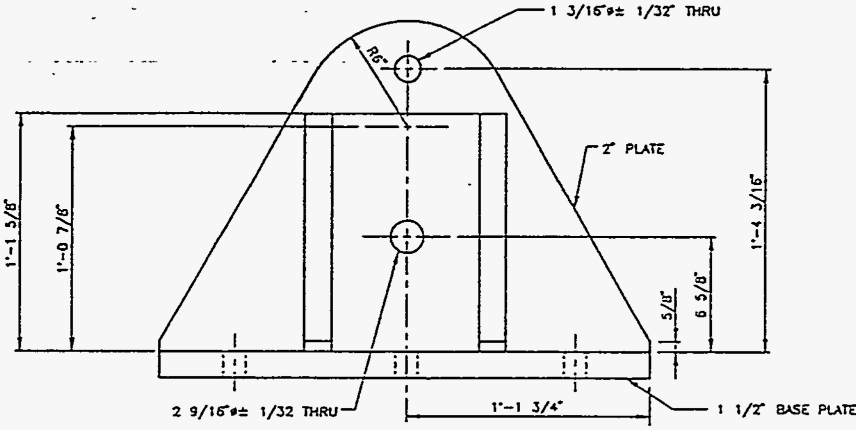
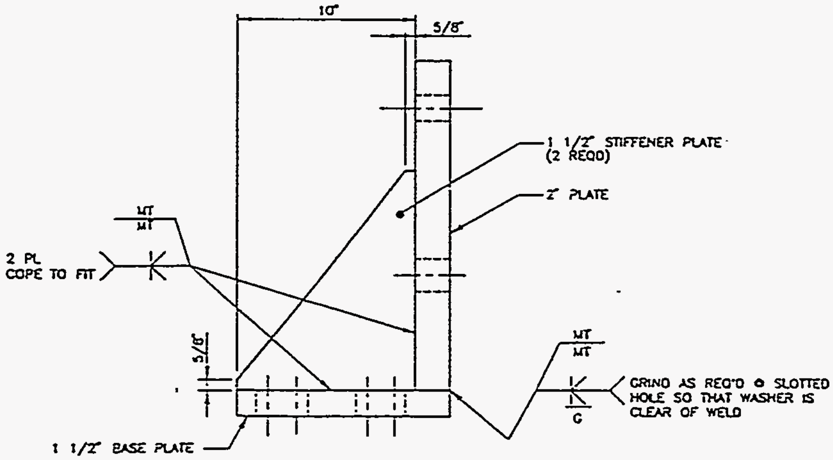


BASE PLATE PLAN



FRONT VIEW



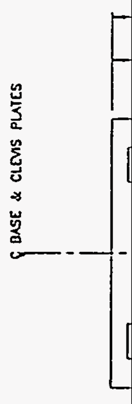
SIDE VIEW

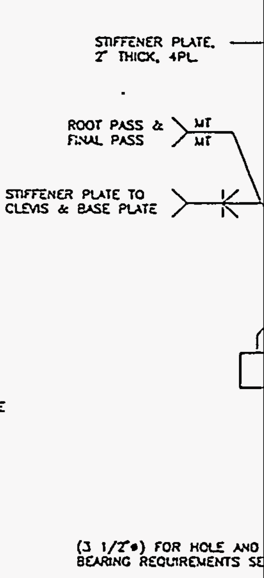
① ATTACHMENT ASSEMBLY

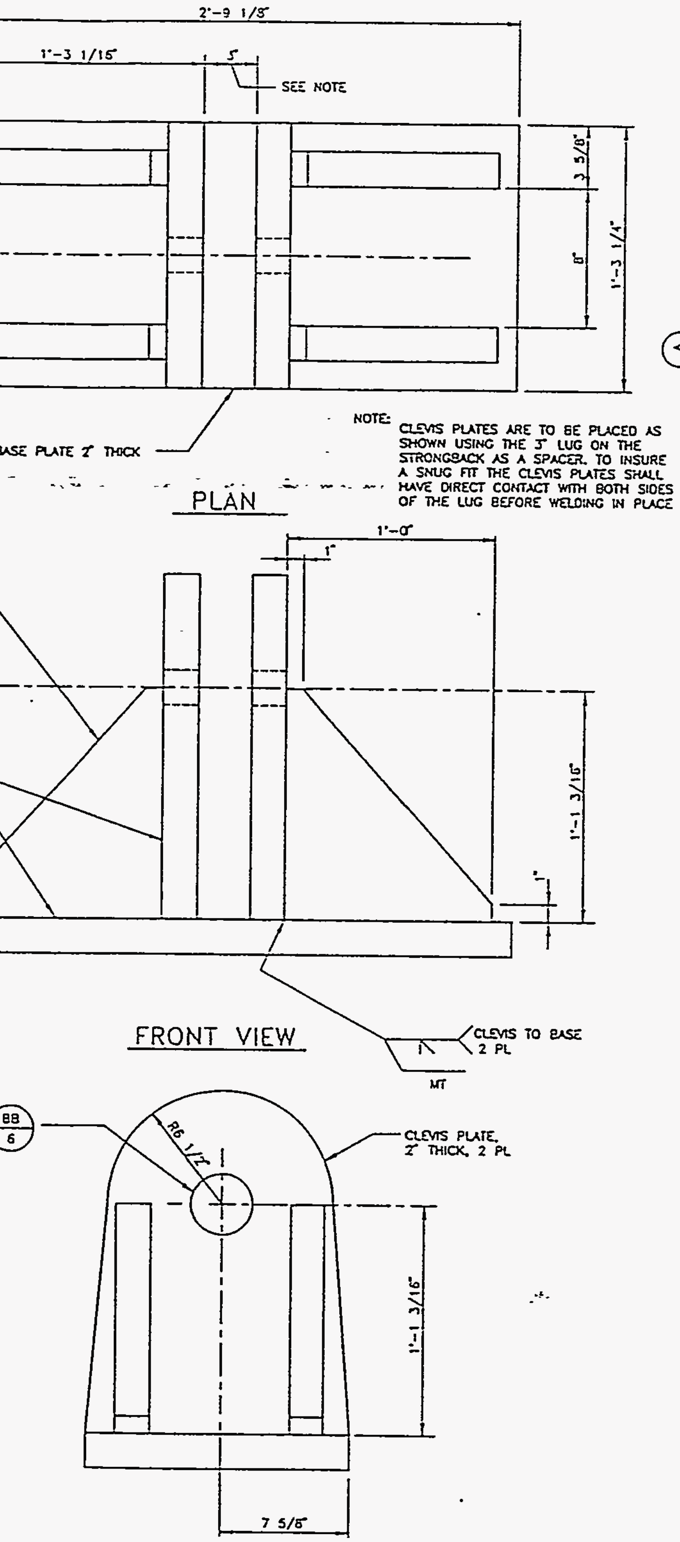
SCALE: 3"=1'-0" (4 REQD)

(PROVIDE CMTR TRACEABILITY FOR THIS ITEM)

NOTE: THE SIDES OF THIS ASSEMBLY WHICH COME IN CONTACT WITH THE 1"x 4 3/4"x1'-0" PLATES MOUNTED ON TOP OF THE W36 SHALL BE MACHINED AS REQUIRED SO ASSEMBLY WILL SLIDE SMOOTHLY BETWEEN PLATES. DIMENSION "A" TO BE EQUAL TO DIMENSION "B" $^{+0}_{-1/32}$ (SEE SHEET 3 AND 7 FOR DIMENSION "B")

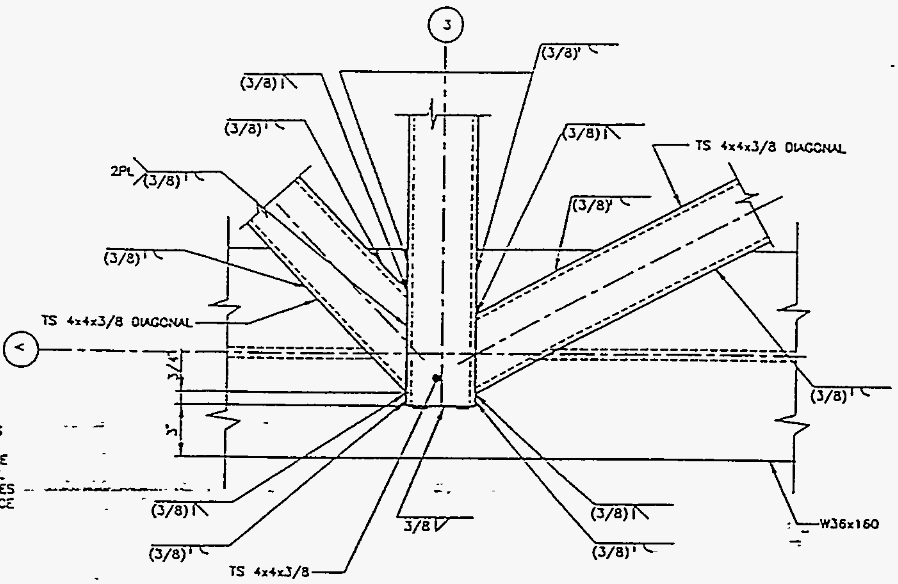






NOTE: CLEVIS PLATES ARE TO BE PLACED AS SHOWN USING THE 3" LUG ON THE STRONGBACK AS A SPACER. TO INSURE A SNUG FIT THE CLEVIS PLATES SHALL HAVE DIRECT CONTACT WITH BOTH SIDES OF THE LUG BEFORE WELDING IN PLACE

(2/1) BASE CLEVIS ASSEMBLY
SCALE: 3" = 1'-0" (2 REQD)
(DETAIL 2 SHALL BE FABRICATED BY TRAILER MANUFACTURER)



(3/2) DETAIL
SCALE: 3" = 1'-0"
(2 PL)
(6 SIMILAR)

FOR GENERAL NOTES SEE SHEET 1

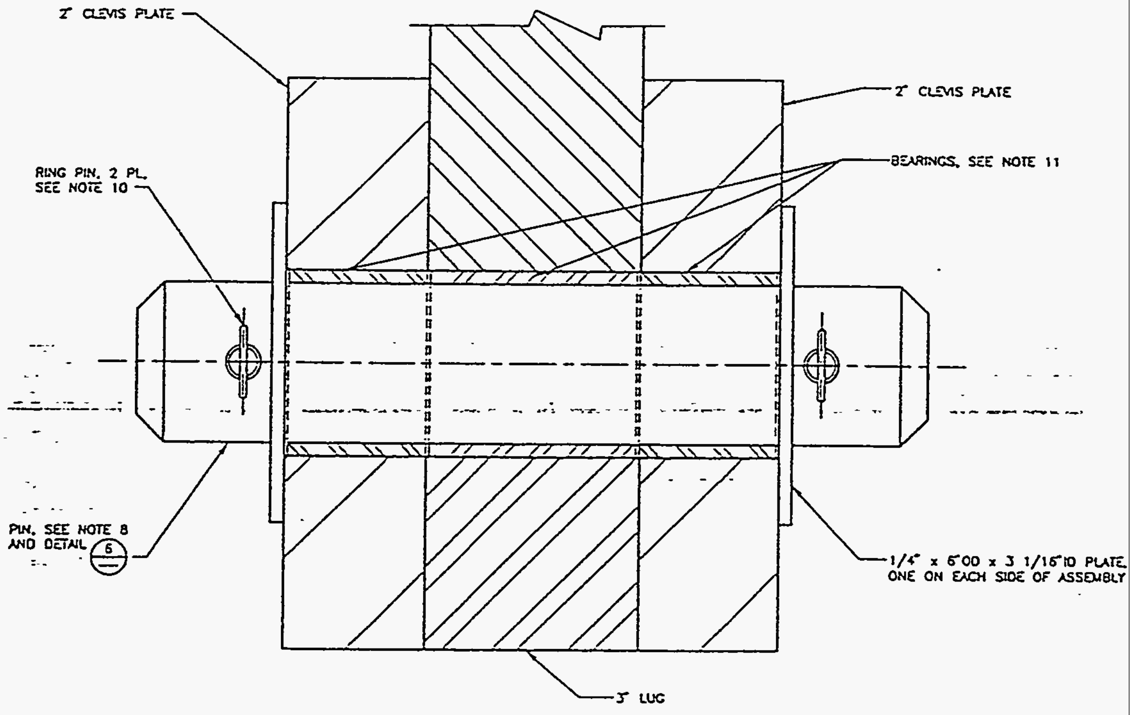
A. PHILLIPS		U.S. DEPARTMENT OF ENERGY DOE Field Office, Richland Westinghouse Hanford Company
D. HAVENS	6-94	
T. BENEGAS	4-94	STRONGBACK DETAILS

SIZE	BLDG NO	INDEX NO	DWG NO	REV
F	200-G	1C01	H-2-83736	0

SCALE SHOWN CP 700433 SHEET 5

DRAWING TRACEABILITY LIST | NEXT USED ON SH 1 | REFERENCES | REVISIONS

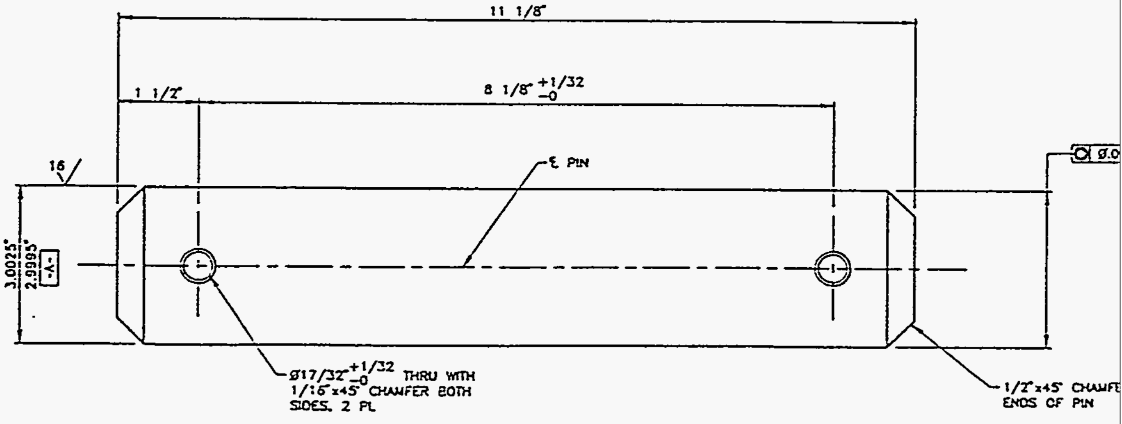
CADFILE 8083736E CADCODE DOS:3 3ACDC2:12 CO SS



CC/4 SECTION

SCALE: 3/4 SIZE

(SECTION CC SHALL BE ASSEMBLED
BY TRAILER MANUFACTURER)

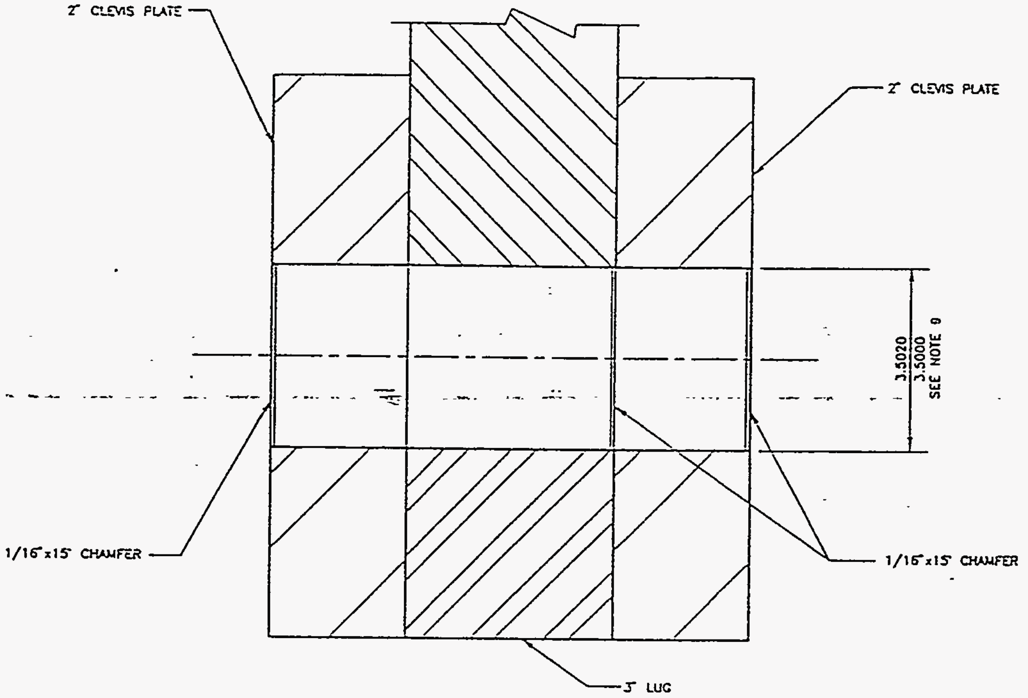


6 BASE ASSEMBLY PIN

SCALE: 3/4 SIZE

(DETAIL 6 SHALL BE SUPPLIED
BY TRAILER MANUFACTURER)

54-6000-027(3/89)



NOTE: 1/16"x15° CHAMFERS ARE TO BE PLACED ONLY ON THE SIDE OF THE LUG AND CLEVIS PLATES THAT THE BEARINGS WILL BE INSTALLED FROM

(BB/4) SECTION
SCALE: 3/4 SIZE

(SECTION BB SHALL BE FABRICATED BY TRAILER MANUFACTURER)

FOR GENERAL NOTES SEE SHEET 1

AB PHILLIPS	4-94
D. HAVENS	6-94
TR BENECAS	4-94

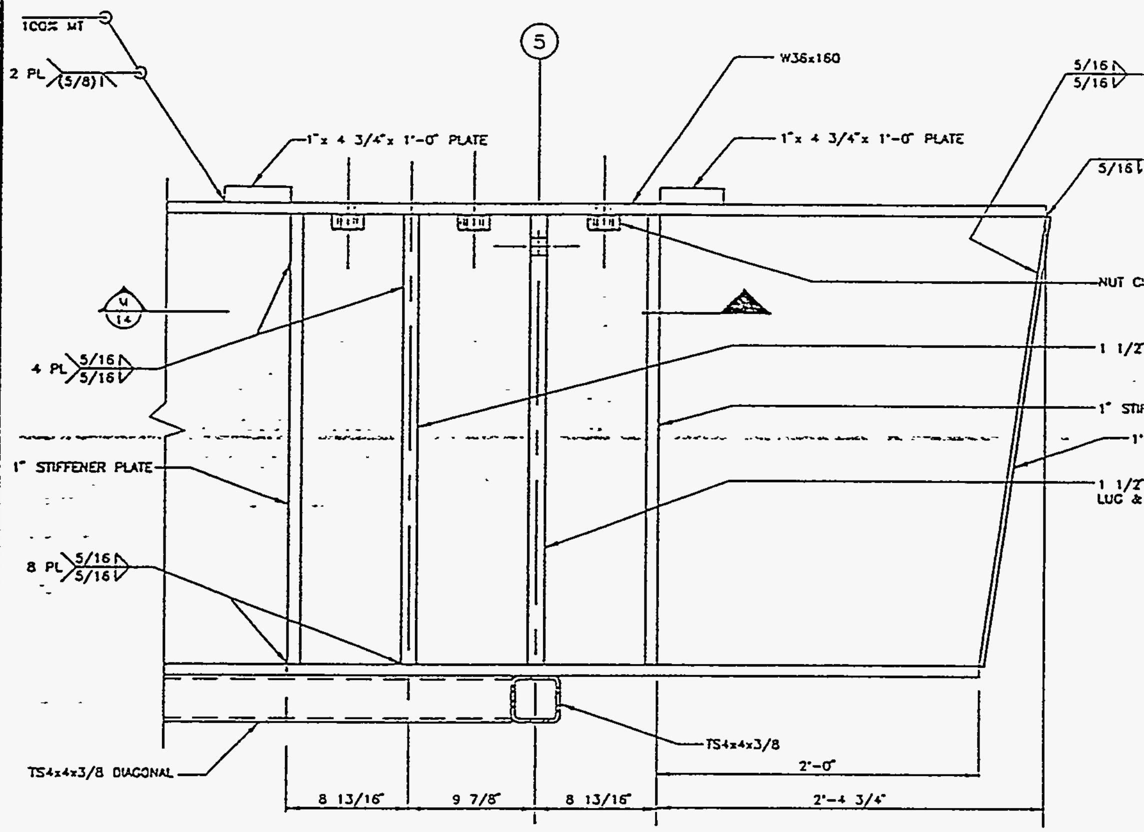
U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

STRONGBACK
PIN & SECTIONS

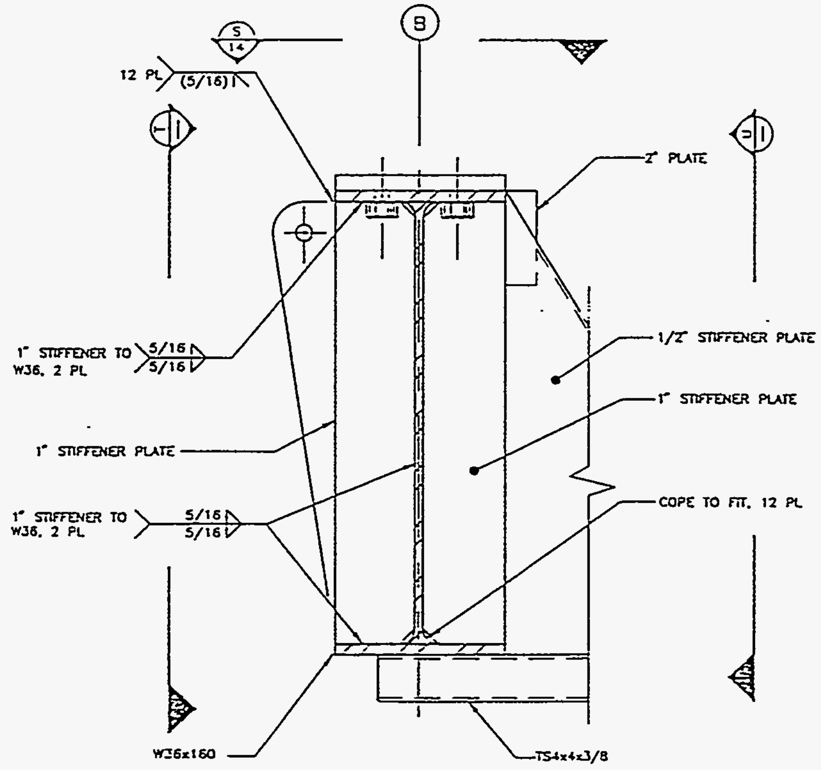
SIZE			DWG NO	REV
F	200-G	1001	H-2-83736	0

SCALE SHOWN
700433
SHEET 6

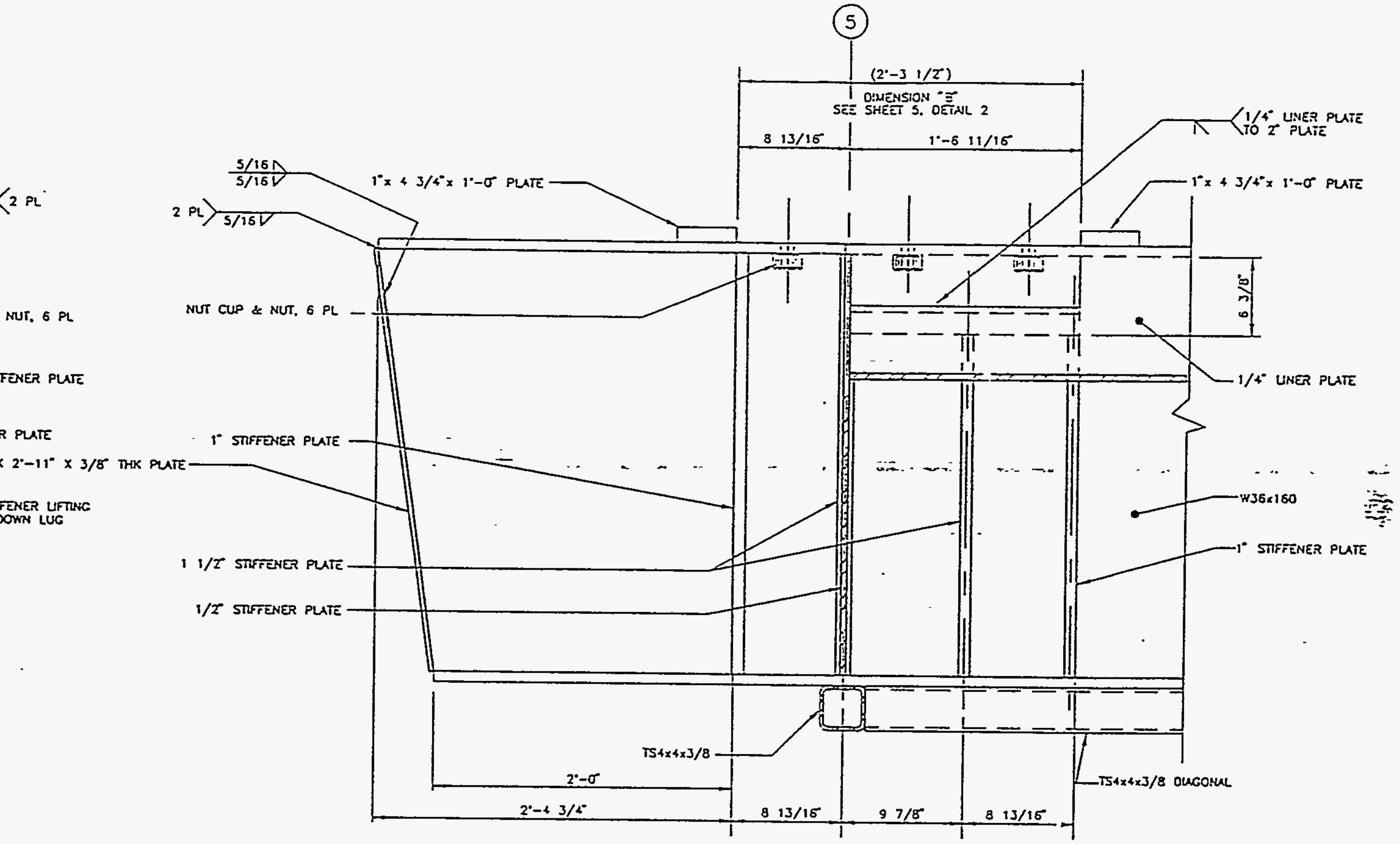
DRAWING TRACEABILITY LIST
NEXT USED ON SH 1
REVISIONS
CADFILE E083735F
CADCODE DOS:3.3:ACD2:12.C0:SS



T VIEW
SCALE: 3/16 SIZE



P VEIW
SCALE: 3/16 SIZE



U SECTION
SCALE: 3/16 SIZE

FOR GENERAL NOTES SEE SHEET 1

AL PHILLIPS 4-94
D. HAVENS 5-94
TR BENECAS 4-94

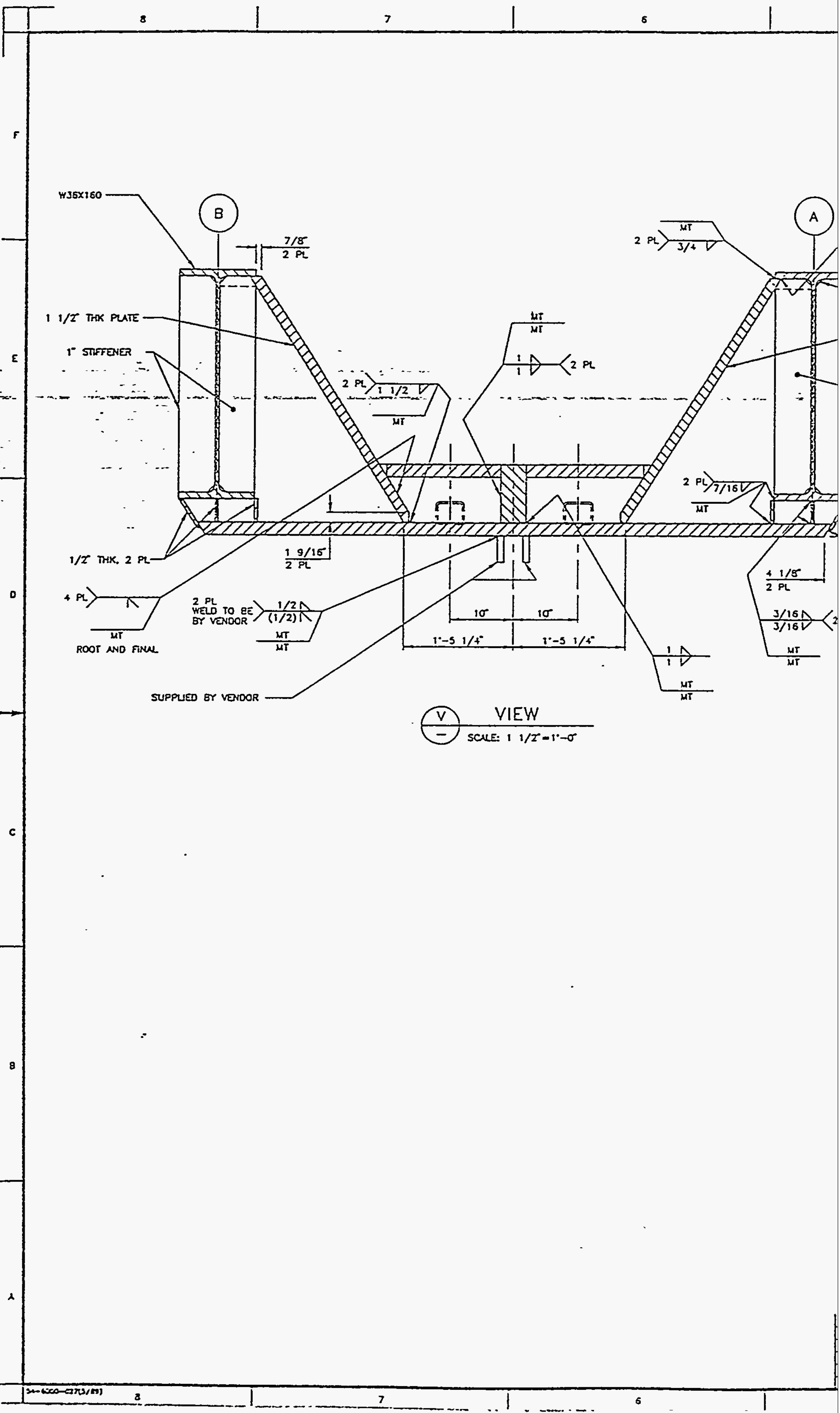
U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

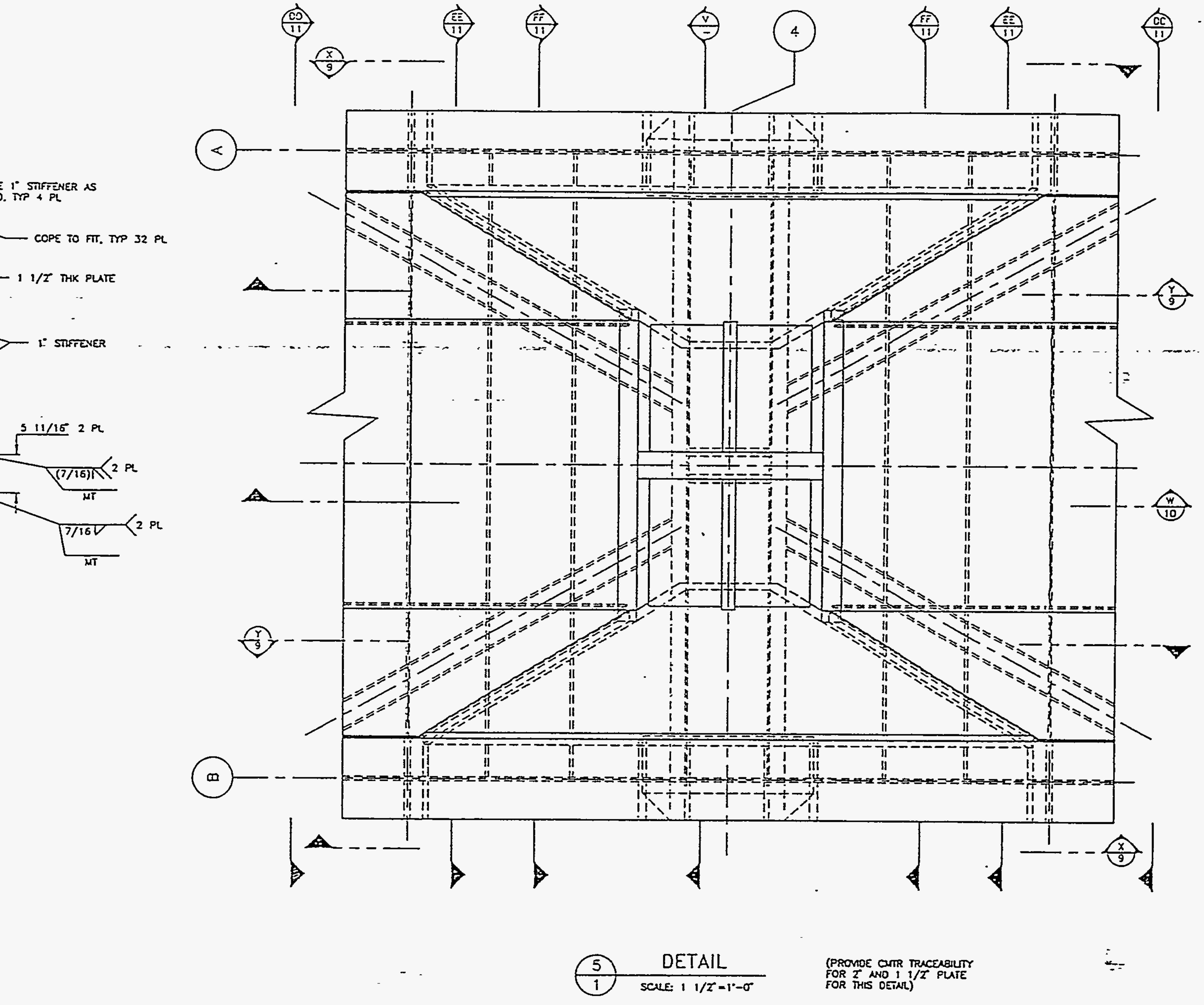
STRONGBACK
SECTIONS & VIEWS

F 200-G 1C01 H-2-83736 0
SCALE SHOWN CY 700433 SHEET 7

DRAWING TRACEABILITY LIST
TITLE
REF NUMBER
TITLE
NEXT USED ON SH 1
REVISIONS
CADFILE E083736G
CADCODE DOS:3.3:ACD2:12.00:SS

H-2-83736


8
7
6
F
E
D
C
B
A
W35X160
B
A
7/8"
2 PL
2 PL
MT
3/4
1 1/2" THK PLATE
1" STIFFENER
MT
MT
1
1
2 PL
2 PL
1 1/2
MT
2 PL
7/16
MT
1/2" THK, 2 PL
1 9/16"
2 PL
4 1/8"
2 PL
4 PL
MT
ROOT AND FINAL
2 PL
WELD TO BE
BY VENDOR
1/2
(1/2)
MT
MT
10"
10"
1'-5 1/4"
1'-5 1/4"
3/16
3/16
MT
MT
1
1
MT
MT
SUPPLIED BY VENDOR
V
VIEW
SCALE: 1 1/2"=1'-0"
54-6000-027(3/89)



5 DETAIL
1
SCALE: 1 1/2"=1'-0"

(PROVIDE CMTR TRACEABILITY FOR 2" AND 1 1/2" PLATE FOR THIS DETAIL)

AUG 12 1994

FOR GENERAL NOTES SEE SHEET 1

KD JUNT 5-94
D. HAVENS 8-94
1-94
TR BENEGASI 5-94

U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

STRONGBACK
SECTIONS AND VIEWS

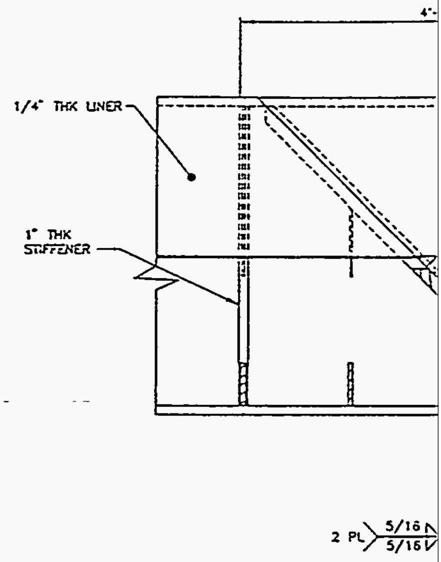
F 200-G 1001 H-2-83736 0

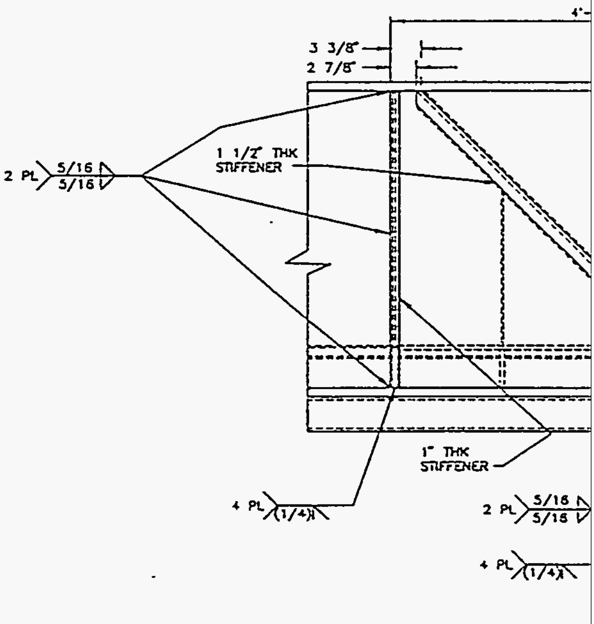
SHOWN 700433 8

REF NUMBER TITLE
REFERENCES
NEXT USED ON SHEET 1

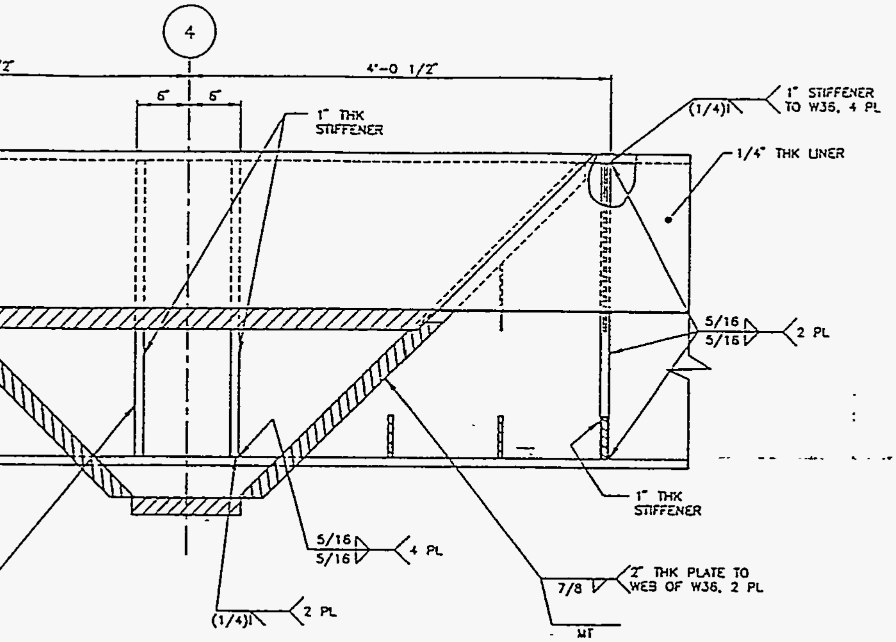
TITLE
DRAWING TRACEABILITY LIST

DESCRIPTION
REVISIONS
CADFILE E083736H
CADCODE DOS:3.3:ACD2:12.CO:SS

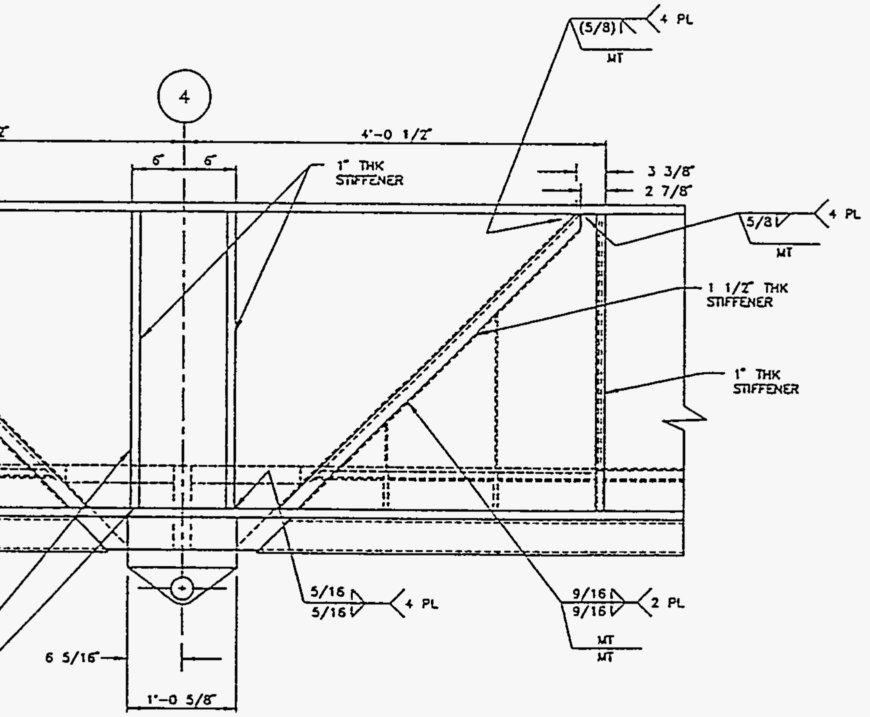




54-4000-227(5/79)



Y/8 SECTION (2 PL)
SCALE: 1 1/2"=1'-0"



X/8 VIEW (2 PL)
SCALE: 1 1/2"=1'-0"

AUG 12 1994

FOR GENERAL NOTES SEE SHEET 1

KD JUNT 5-94
D. HAVENS 18-94
TR BENECASI 5-94

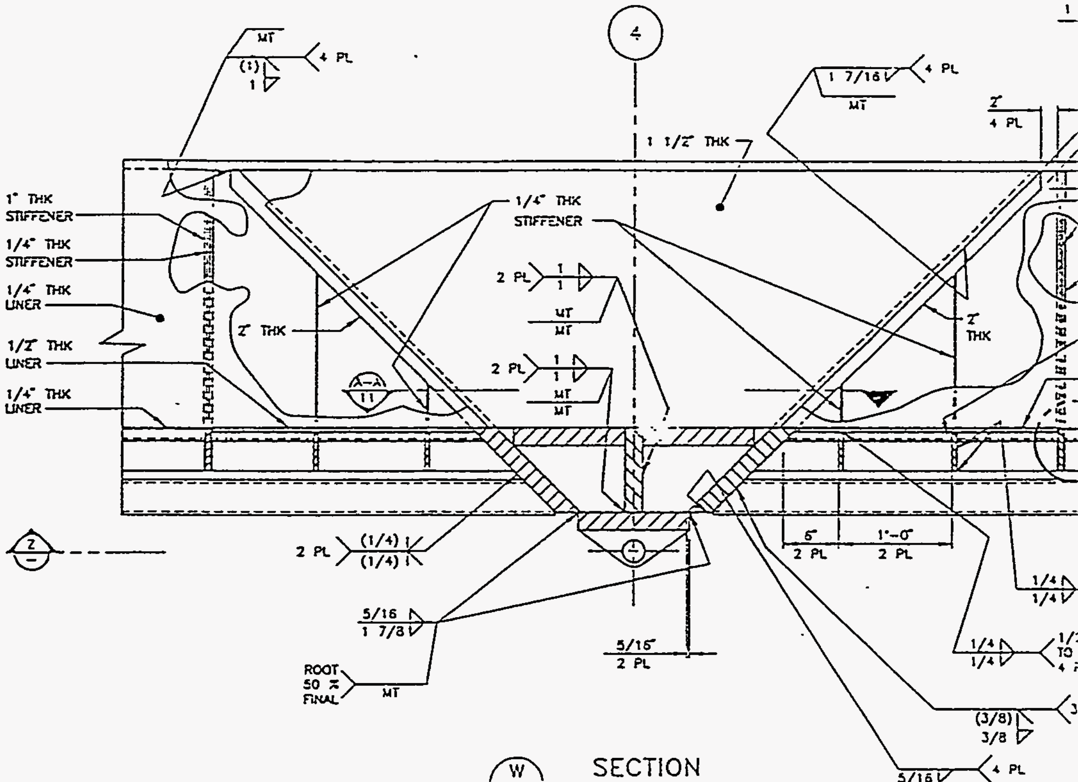
U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

STRONGBACK
SECTION AND VIEW

SIZE	BLDG NO	INDEX NO	DWG NO	REV
F	200-G	1C01	H-2-83736	0

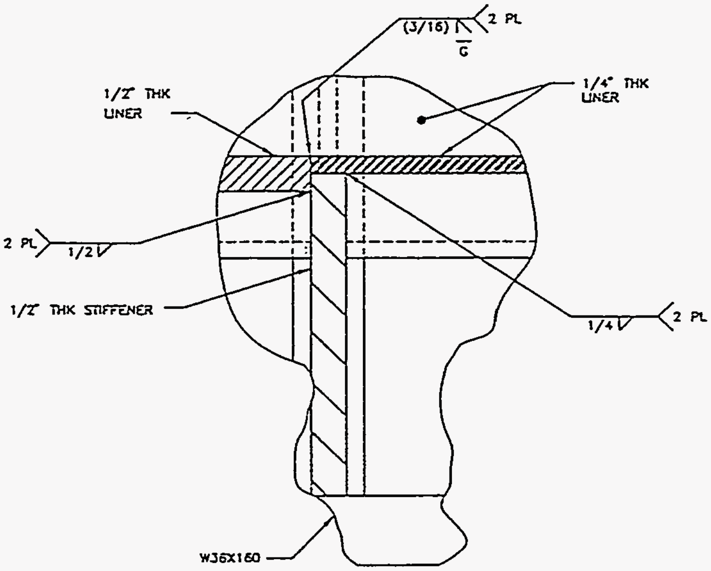
SCALE SHOWN
700433
SHEET 9

DRAWING TRACEABILITY LIST
REF NUMBER
TITLE
REFERENCES
NEXT USED ON SHEET 1
REVISIONS
CADFILE 8083736J
CADCODE DOS:3.3ACD2:12 00:55



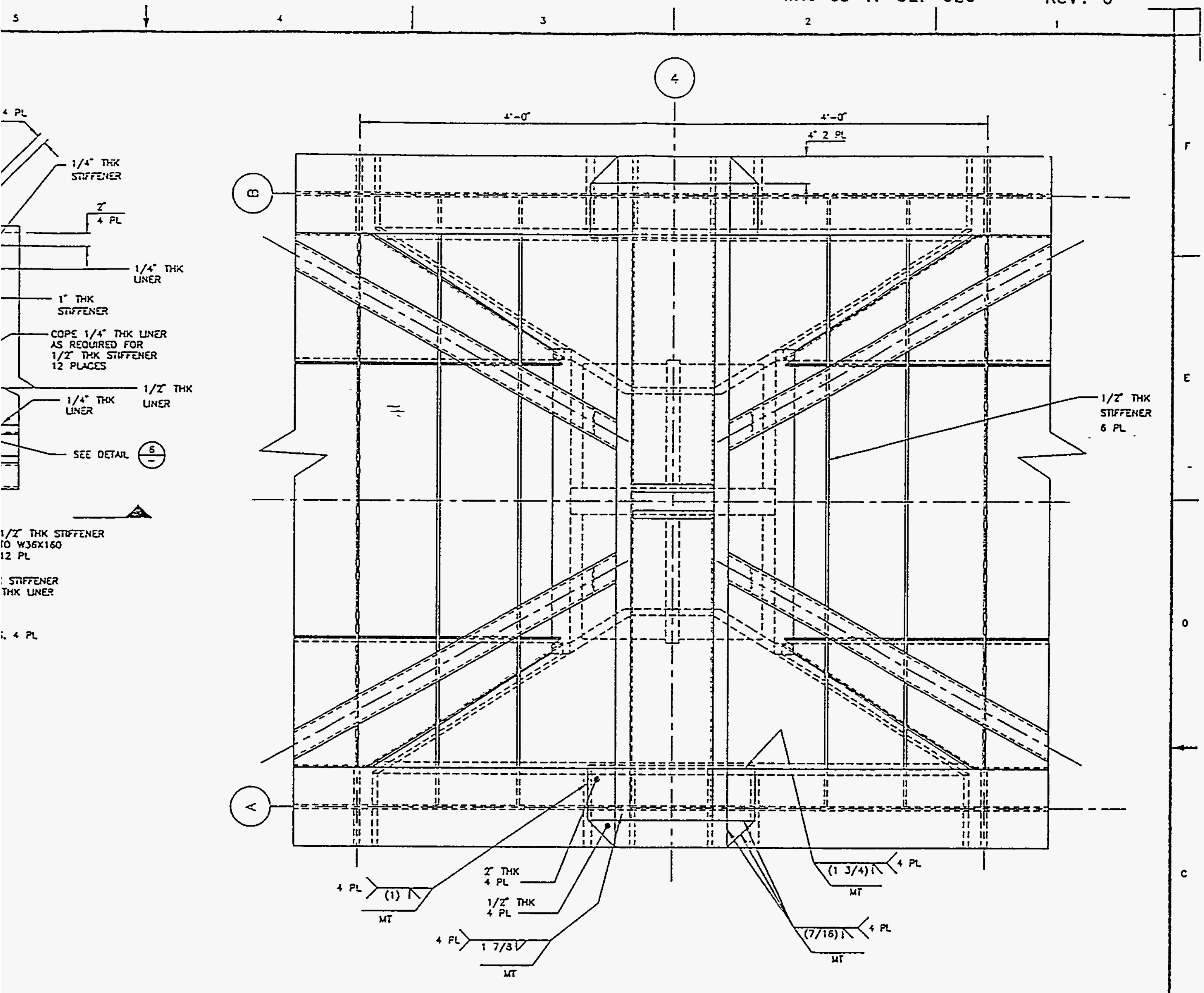
SECTION W/8

SCALE: 1 1/2"=1'-0"



DETAIL 6/—

SCALE: 1/1



Z VIEW
SCALE: 1 1/2"=1'-0"

FOR GENERAL NOTES SEE SHEET 1

KD JUNT
D. HAVENS 8-94
TR BENEGAS 5-94

U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

STRONGBACK
SECTIONS AND VIEWS

F 200-C 1001 H-2-83736 0
SHOWN 700433 SHEET 10

REF NUMBER TITLE
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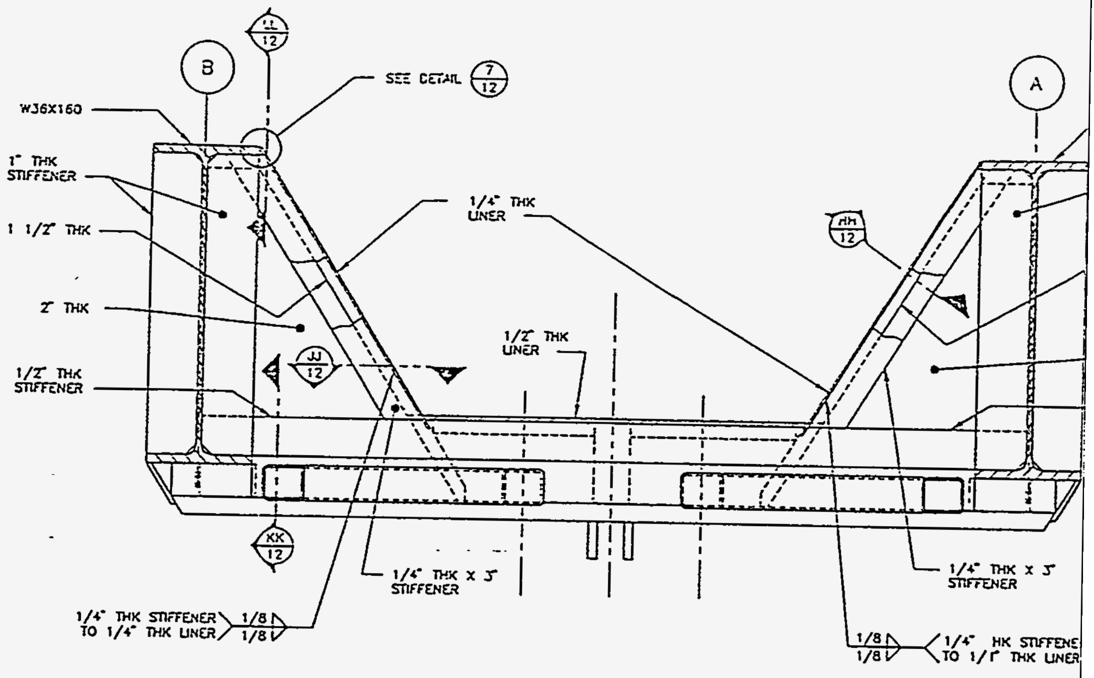
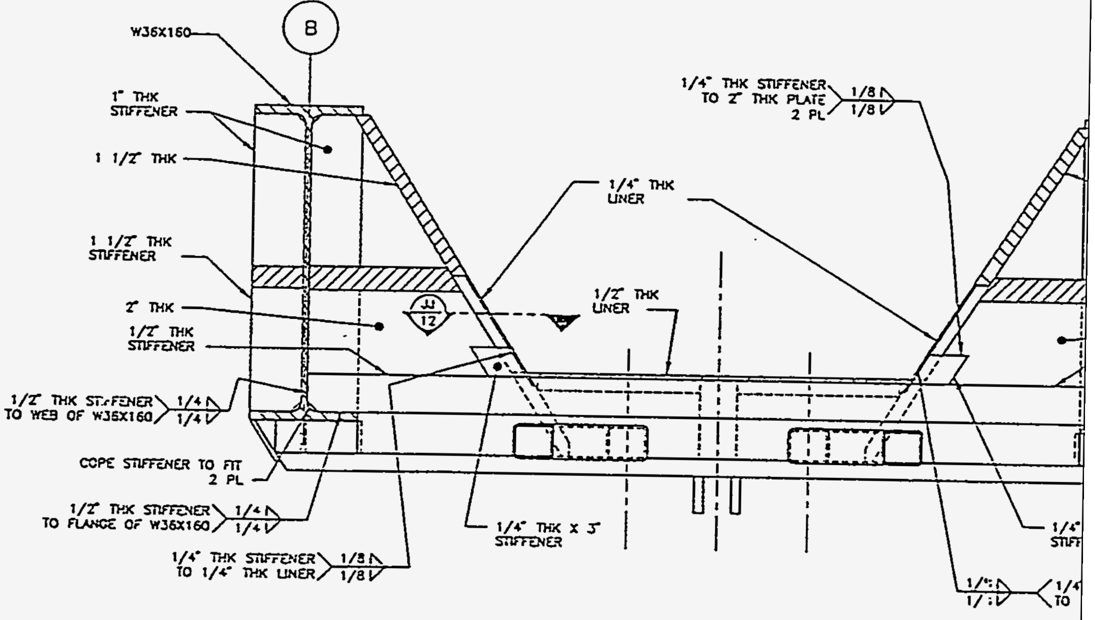


DD/8 SECTION 2 PL

SCALE: 1 1/2"=1'-0"



FF/8 SECTION 2 PL

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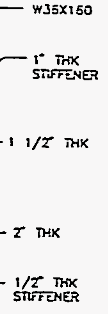
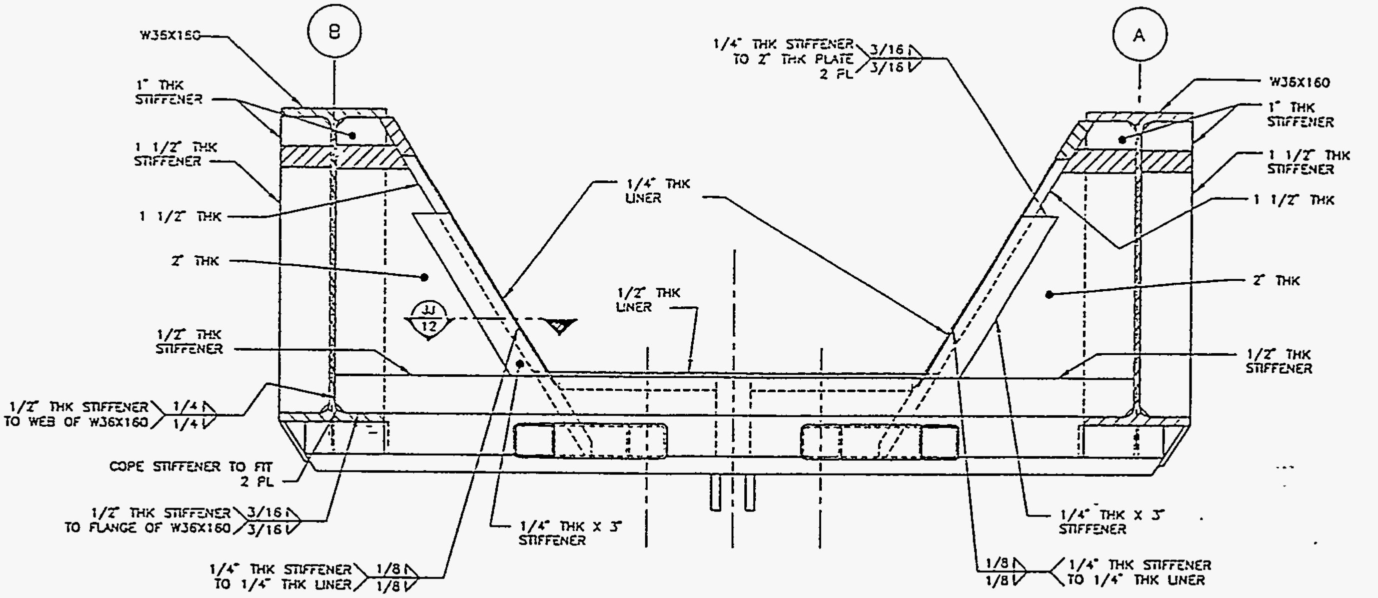
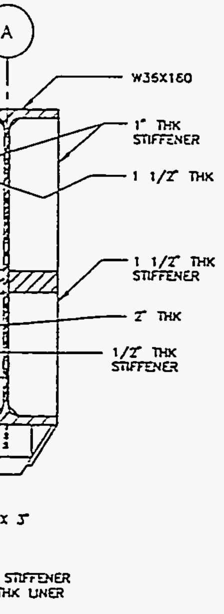
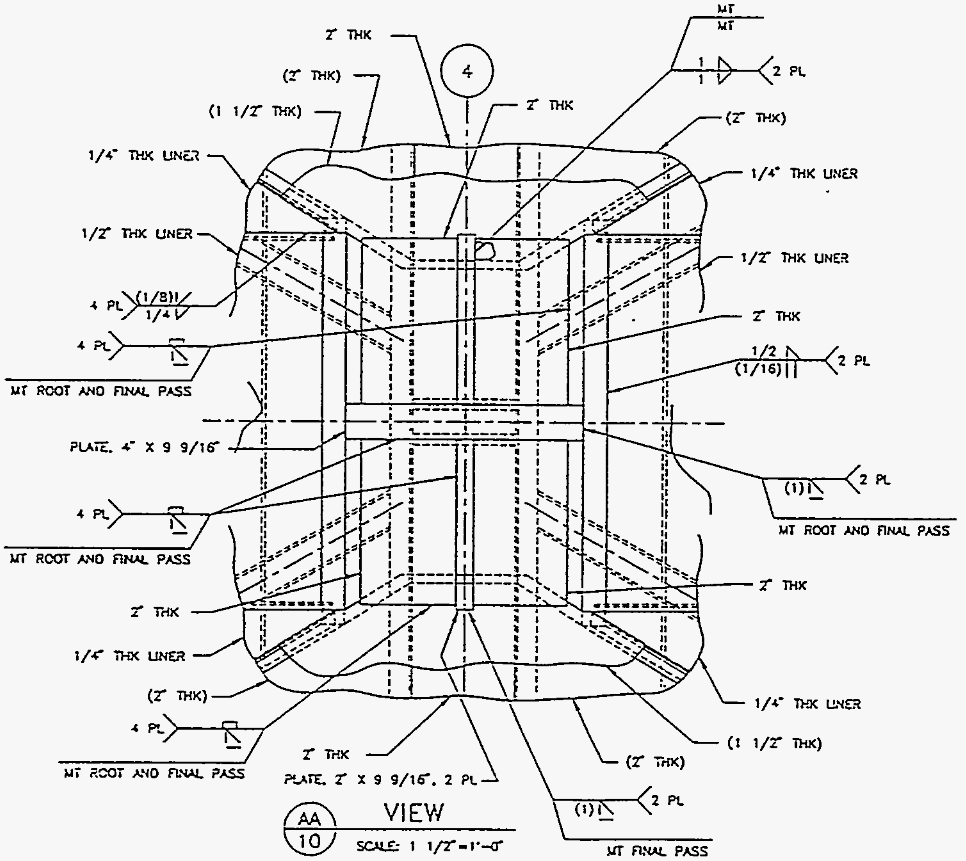




EE
8
SECTION 2 PL
SCALE: 1 1/2"=1'-0"





AA
10
VIEW
SCALE: 1 1/2"=1'-0"

FOR GENERAL NOTES SEE SHEET 1

KD JUNT	
D. HALENS	8-94
	8-94
TR BENEGAS	5-94

U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

STRONGBACK
SECTIONS AND VIEWS

F 200-C 1001 H-2-83736 0
SCALE SHOWN 700433 SHEET 11

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NEXT USED ON SHEET 1
REFERENCES
TITLE

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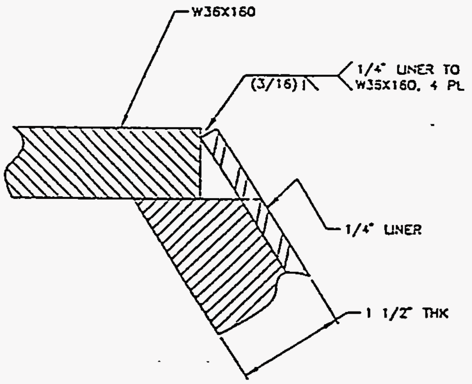
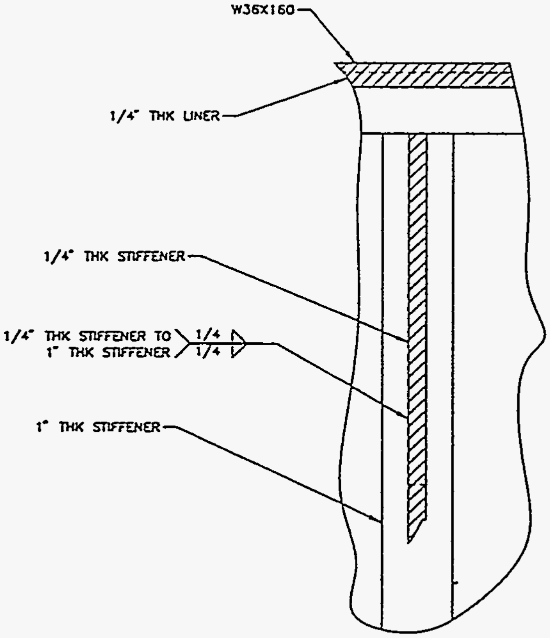


E

7/11 DETAIL

SCALE: FULL

D



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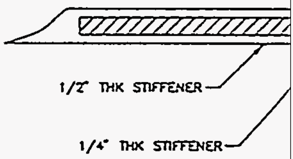
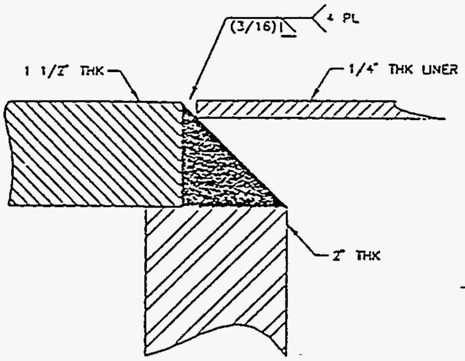


B

LL/11 SECTION

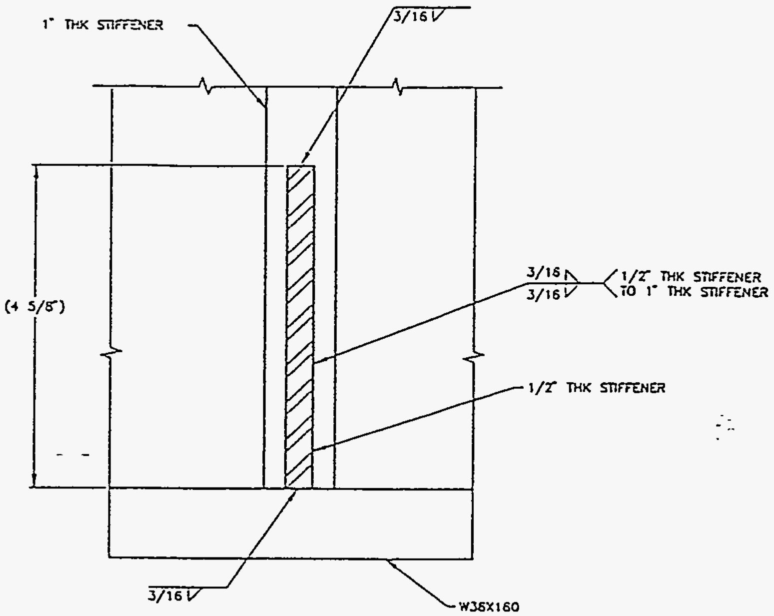
SCALE: FULL

A



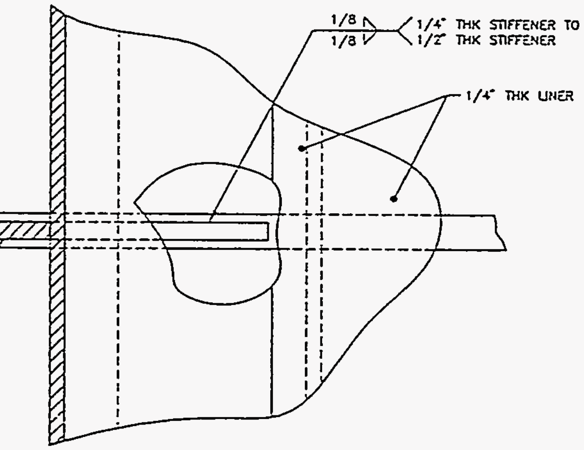
HH/11 SECTION

SCALE: FULL



KK/11 SECTION

SCALE: FULL



JJ/11 SECTION

SCALE: FULL

FOR GENERAL NOTES SEE SHEET 1

KD JUNT
D. HAVENS 8-94
TR BENEGASI 5-94

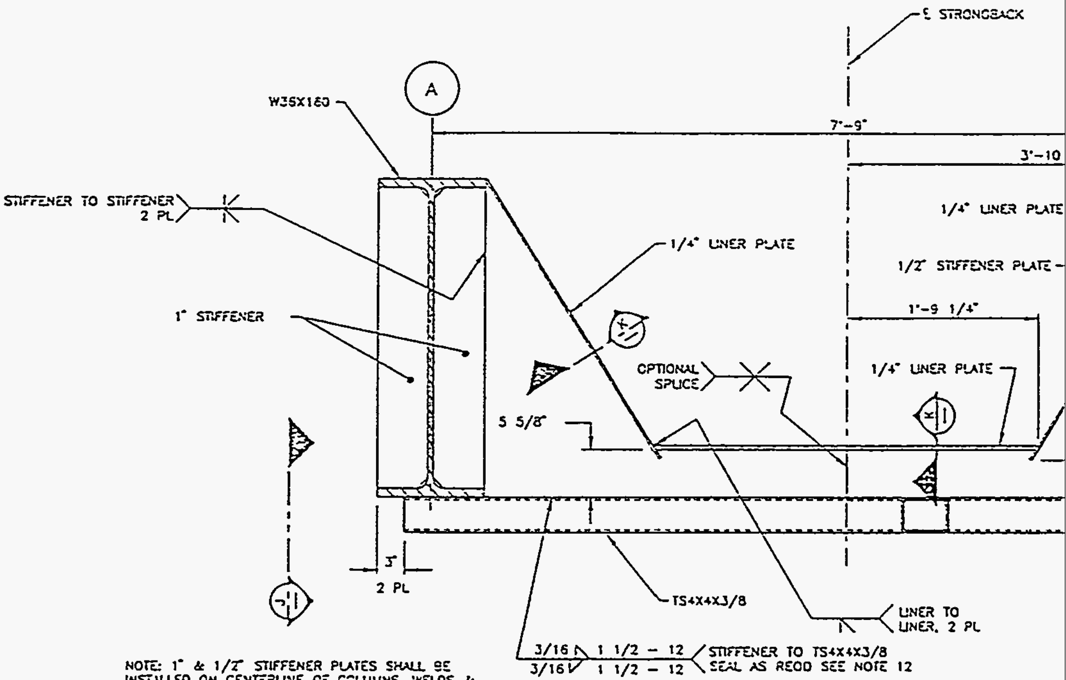
U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

STRONGBACK
SECTIONS AND DETAILS

F | 200-G | 1001 | H-2-83736 | 0

SCALE SHOWN | 700433 | SHEET 12

DRAWING TRACEABILITY LIST | NEXT USED ON SHEET 1 | CADFILE 9083736M | CADCODE C0S:3 3:ACD2:12.CO.SS

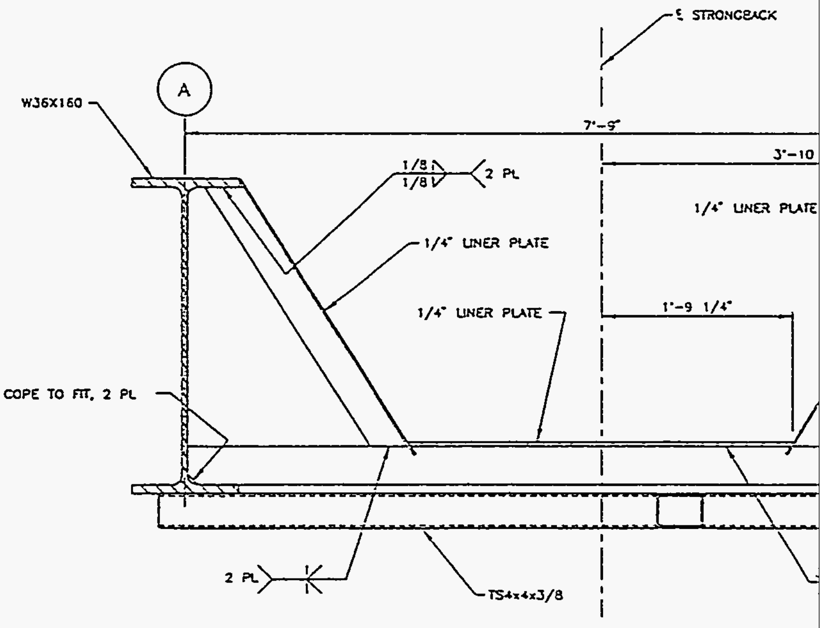


NOTE: 1" & 1/2" STIFFENER PLATES SHALL BE INSTALLED ON CENTERLINE OF COLUMNS. WELDS & DIMENSIONS SHOWN ARE TYP FOR CONNECTING STIFFENER PLATES AND LINER PLATES TO EACH OTHER & TO THE TUBE STEEL AND WIDE FLANGE

B/1 SECTION

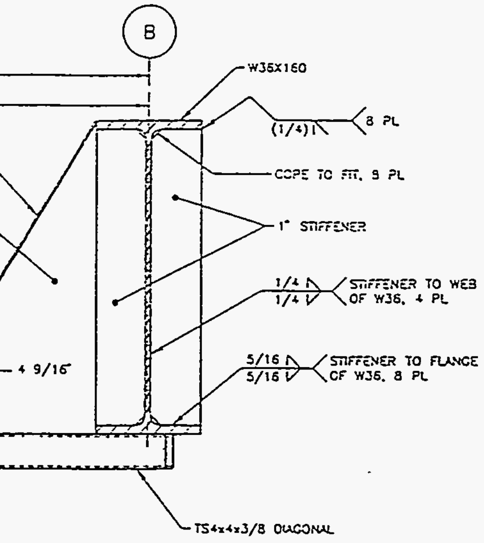
SCALE: 1 1/2" = 1'-0"

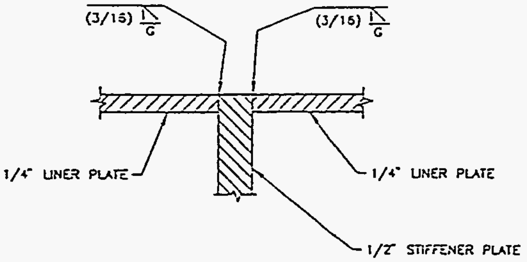
(TYP AT COL 2 & COL 3. LINER PLATE & 1/2" STIFFENER PLATE CONFIGURATION & WELDING ALSO TYP AT COL 1 & COL 5)



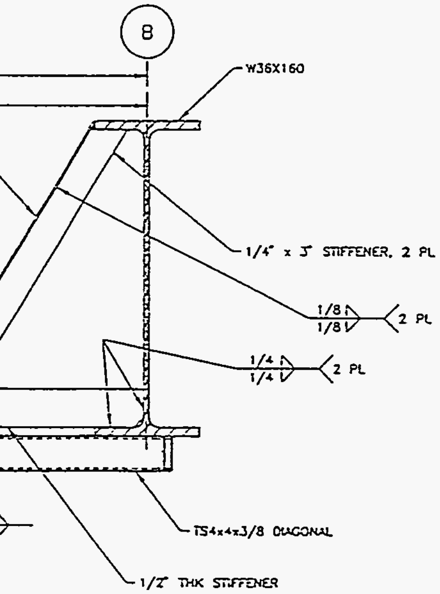
GG/1 SECTION (TYP 2 PL, MIDSPAN BE COLUMNS 1 & 2 AND

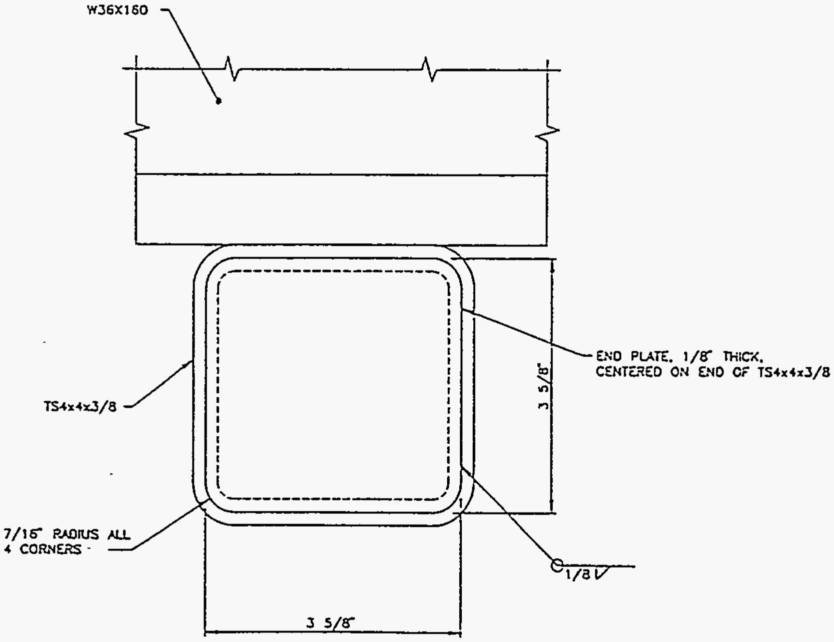
SCALE: 1 1/2" = 1'-0"





K SECTION
SCALE: FULL





J VIEW (8 PL)
SCALE: FULL

3)

FOR GENERAL NOTES SEE SHEET 1

KD JUNT	5-94	
D. RAVENS	8-94	
TR BENEGASI	5-94	

U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

STRONGBACK
SECTIONS

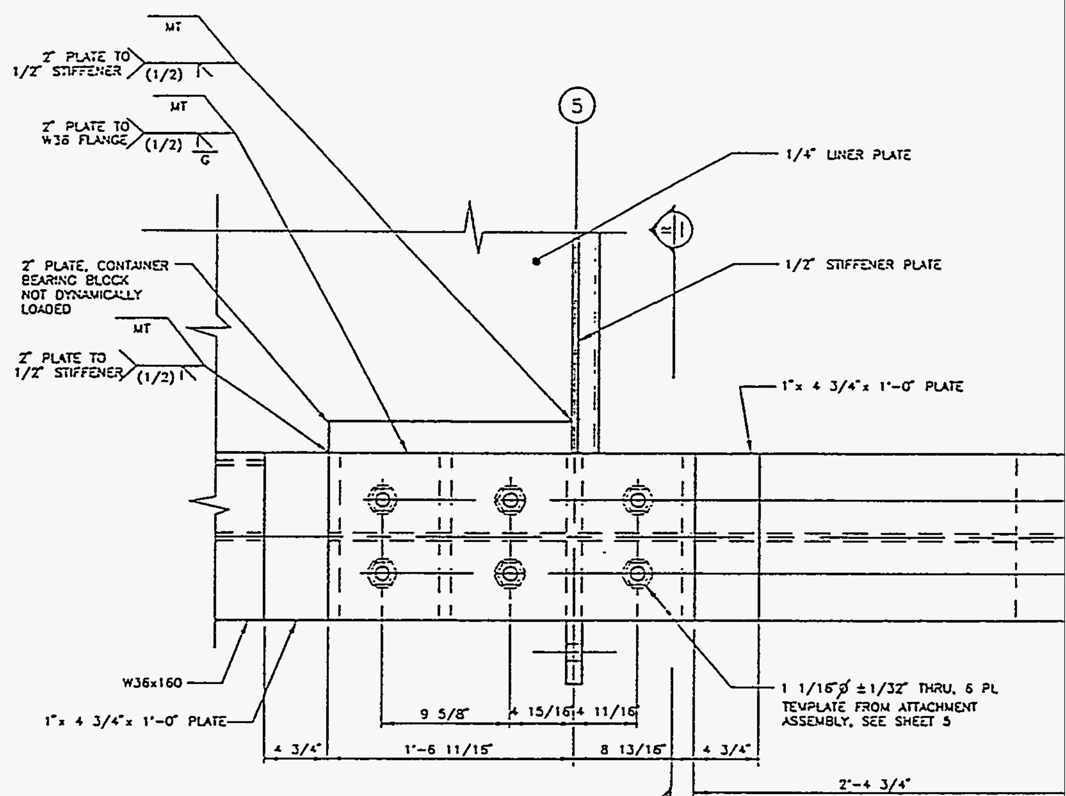
SIZE	BLDG NO	INDEX NO	DWG NO	REV
F	200-G	1001	H-2-83736	0

SCALE SHOWN 700433 SHEET 13

CADFILE E083736N
CADCODE 00S 3.3.AC02-12.C0.SS

DRAWING TRACEABILITY LIST
NEXT USED ON SHEET
REF NUMBER TITLE
REFERENCES
REVISIONS

H-2-83736 13 0



S/7 VIEW

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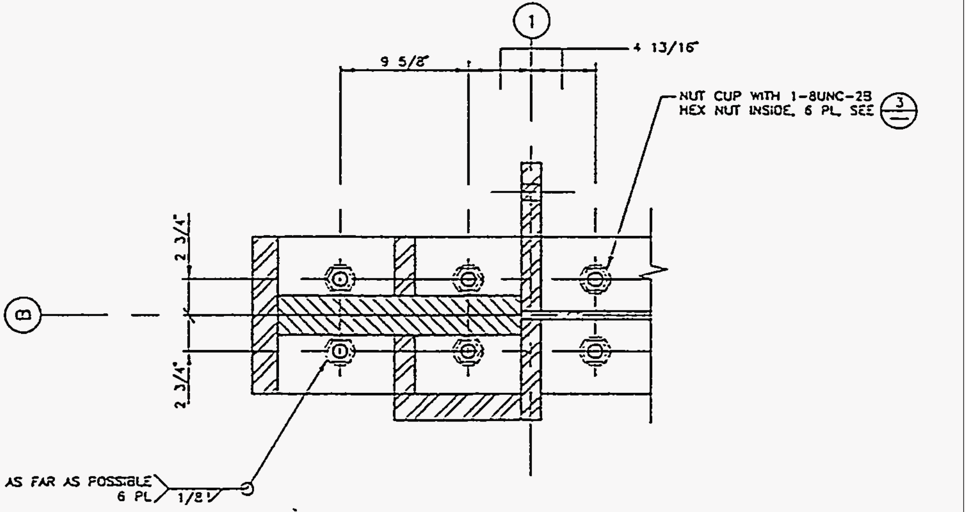

NOTE: INSTALLATION SIMILAR AT COLUMN LINE 5

M/7 M/3 SECTION

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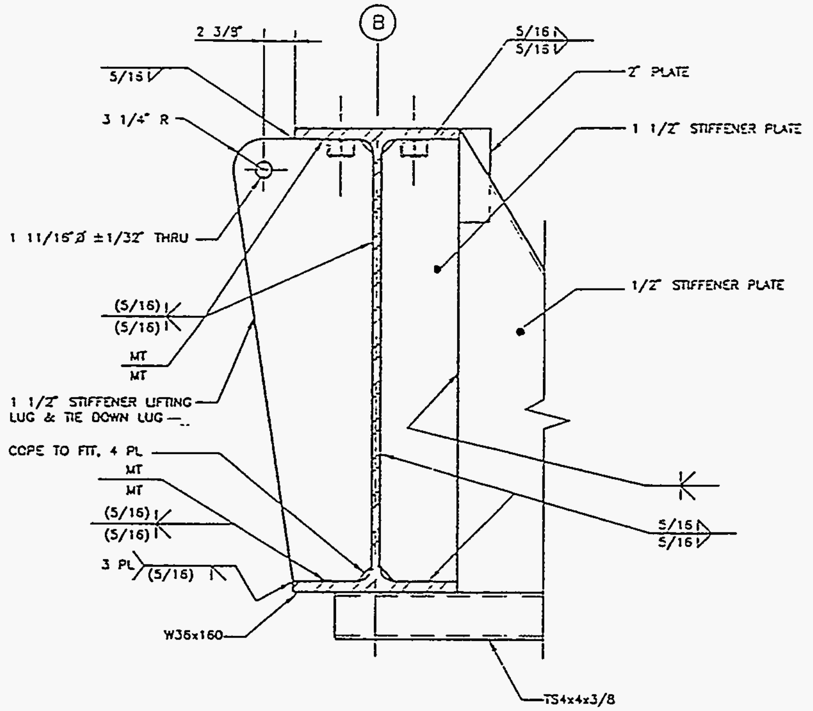

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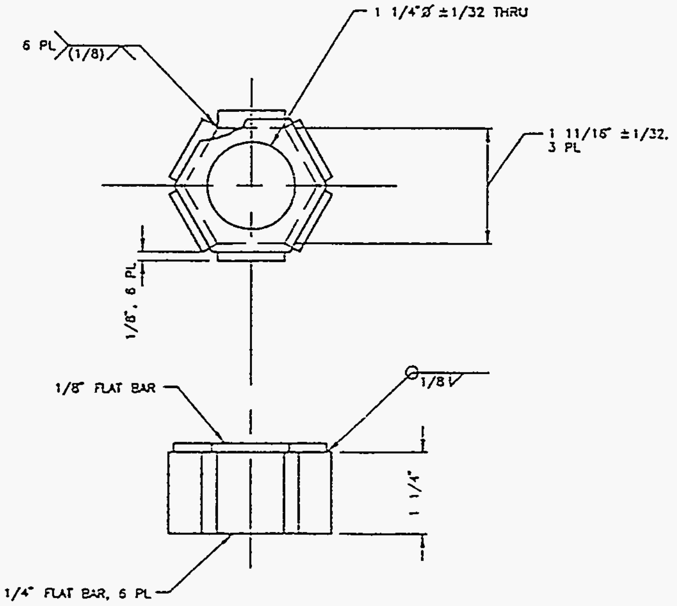

3 DETAIL (24 REQD)

SCALE: FULL

FOR GENERAL NOTES SEE SHEET 1

	AL PHILLIPS	4-94
	D. STEVENS	5-94
	TR BENEGAS	4-94

U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

STRONGBACK
SECTIONS & VIEWS

F	200-C	1001	H-2-83736	0

SHOWN 700433 14

REVISIONS

DRAWING TRACEABILITY LIST

NEXT USED ON SH 1

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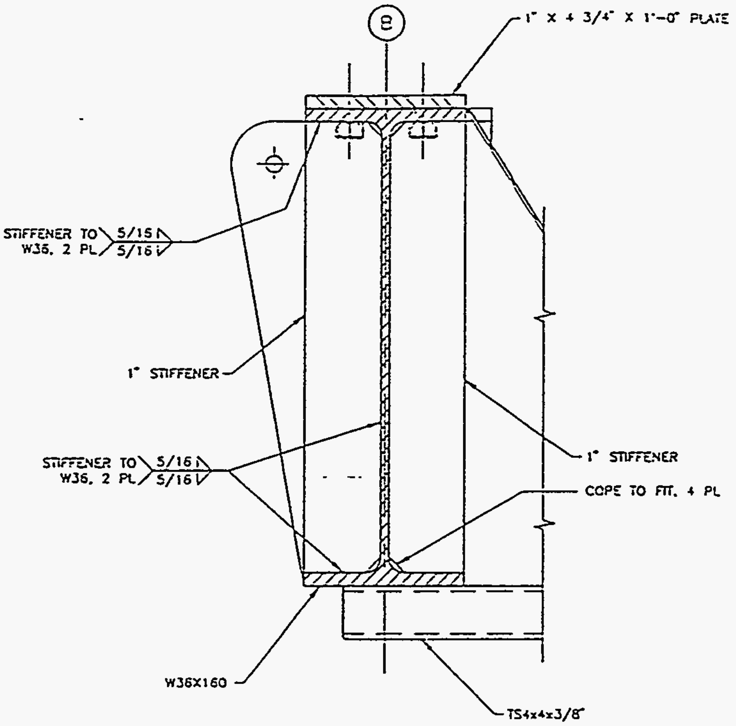

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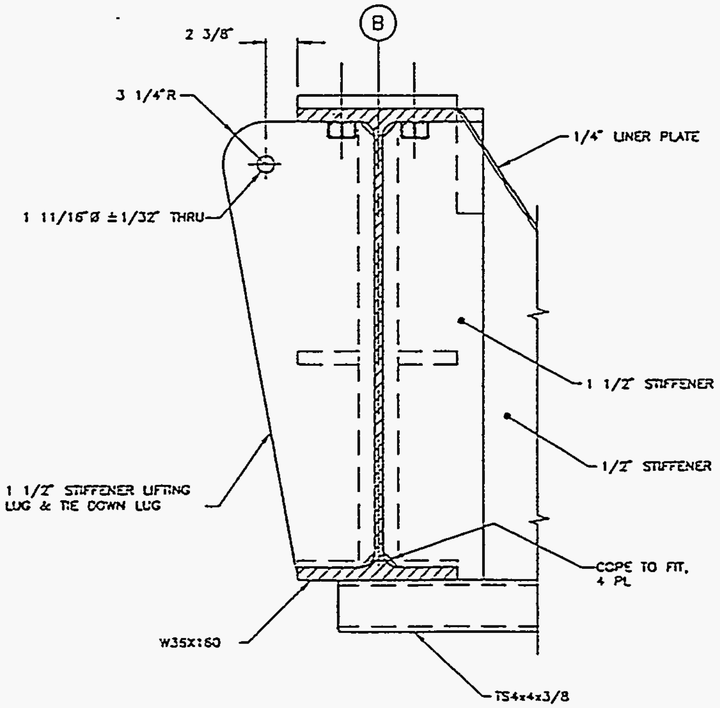

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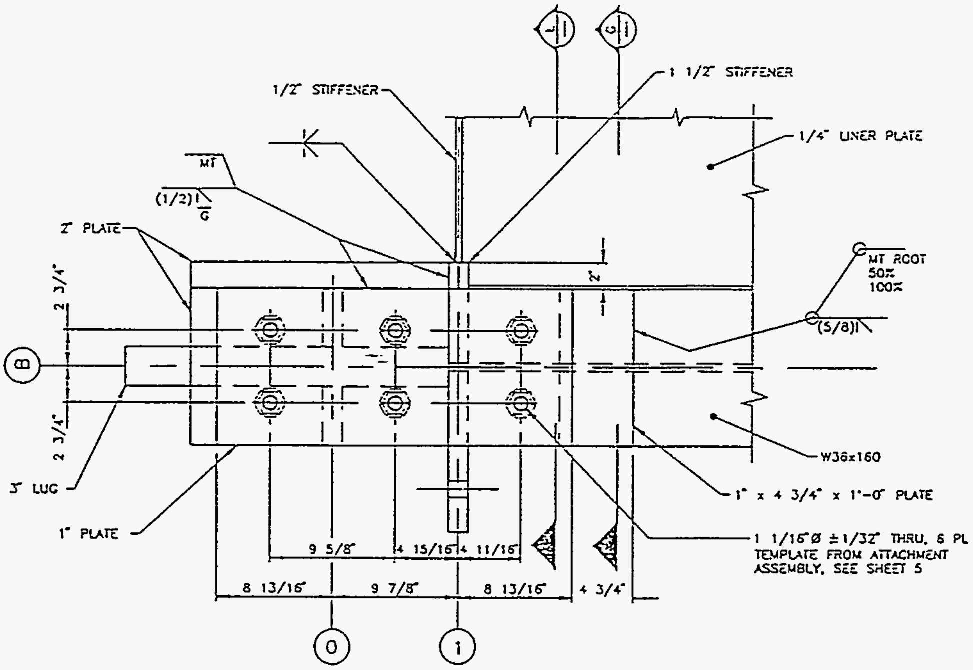

F SECTION
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FOR GENERAL NOTES SEE SHEET 1

KO JUNT
D. HALENS 8-94
TR BENECASI 5-94

U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

STRONGBACK
SECTIONS AND VIEWS

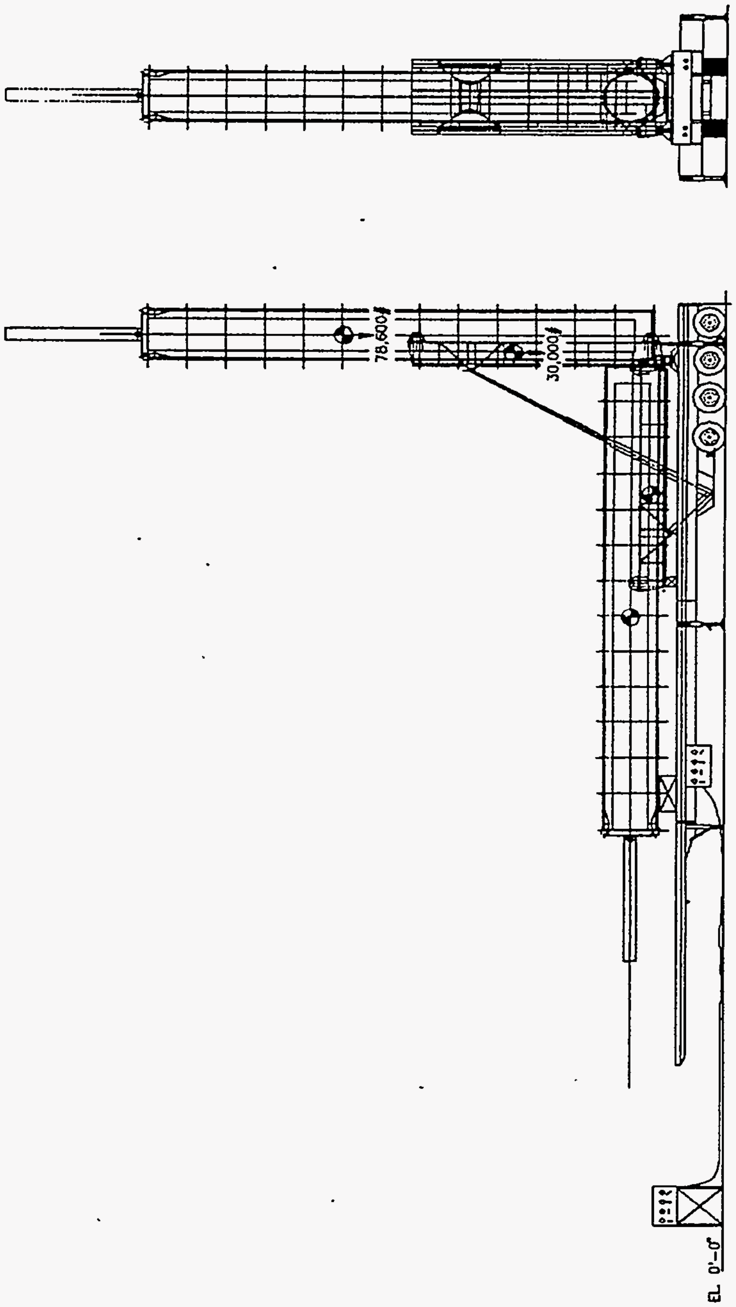
F 200-G 1001 H-2-83736 0

SCALE SHOWN 700433 SHEET 15

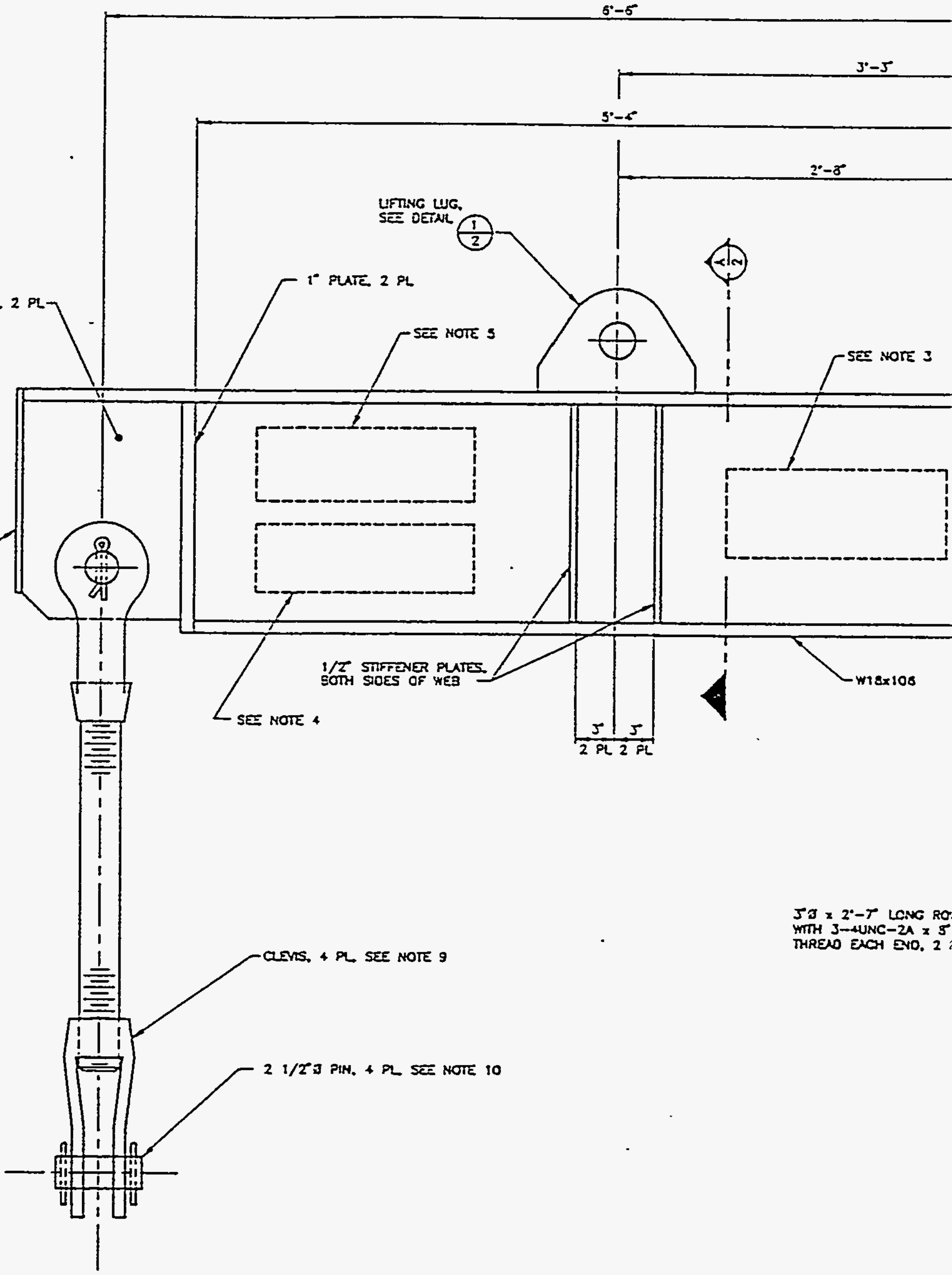
DRAWING TRACEABILITY LIST
REFERENCES
NEXT USED ON SHEET
REVISIONS
CADFILE E083736R
CADCODE DCS-3.3-ACD2-12 00-SS

9.4 TILT TRAILER SKETCH

101-SY Tilt-Trailer Configuration.



9.5 LIFTING BEAM ASSEMBLY (H-2-83744)



ASSEMBLY

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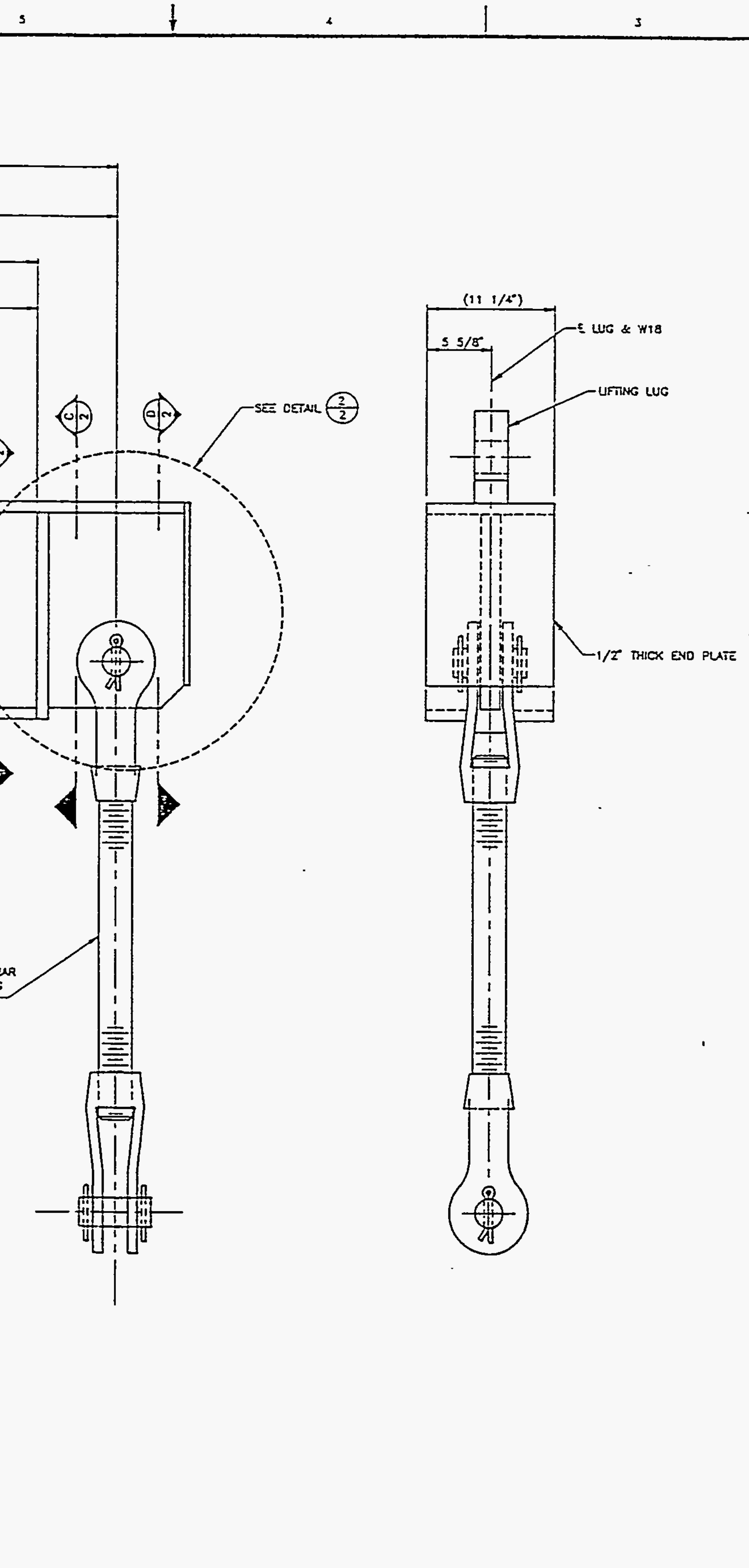


GENERAL NOTES

(UNLESS OTHERWISE NOTED)

1. REMOVE ALL BURRS AND BREAK ALL SHARP EDGES.
2. AFTER FABRICATION AND ACCEPTANCE OF LOAD TESTING, PREPARE AND PAINT ALL EXPOSED CARBON STEEL SURFACES EXCEPT PINS, NUTS, CLEVISES, THE THREAD ON THE ROUND BAR, AND THE INSIDES OF HOLES, WITH TWO COATS OF AMERLOCK #400 FOLLOWED BY ONE COAT OF AMERCOAT #450HS. COLOR SHALL BE SIEGE RT-8304. PREPARATION AND APPLICATION SHALL BE PER MANUFACTURER'S INSTRUCTIONS.
3. PAINT "LOAD CAPACITY 50 TONS" ON BOTH SIDES OF THE WIDE FLANGE BEAM IN THE LOCATION INDICATED ON THE DRAWING PER HS-BS-0015 TYPE 8. CHARACTERS SHALL BE 2" HIGH AND SHALL BE BLACK ENAMEL ON A YELLOW ENAMAL BACKGROUND.
4. PAINT DRAWING NUMBER AND DRAWING REVISION NUMBER ON BOTH SIDES OF THE WIDE FLANGE IN THE LOCATION INDICATED ON THE DRAWING PER HS-BS-0015, TYPE 8. CHARACTERS SHALL BE 1/2" HIGH AND SHALL BE BLACK ENAMEL.
5. PAINT "WEIGHT 1440 LBS" ON BOTH SIDES OF THE WIDE FLANGE BEAM IN THE LOCATION INDICATED ON THE DRAWING PER HS-BS-0015 TYPE 8. CHARACTERS SHALL BE 1" HIGH AND SHALL BE BLACK ENAMEL ON A YELLOW ENAMEL BACKGROUND.
6. WELD AND INSPECT PER AWS D1.1. VT FINAL PASS OF ALL WELDS. MT INDICATED WELDS BEFORE AND AFTER LOAD TESTING. WELD QUALIFICATIONS PER ASME SECTION IX ARE AN APPROVED SUBSTITUTION.
7. THE ASSEMBLY SHALL BE LOAD TESTED PER HANFORD SITE HOISTING AND RIGGING MANUAL DOE-RL-92-36. IF THE ASSEMBLY FAILS TO PASS THE LOAD TEST, NECESSARY REPAIRS SHALL BE MADE AND THE LOAD TEST SHALL BE REPEATED. ANY REPAIRS MADE TO THE WELDING SHALL REQUIRE RE-INSPECTION OF THE WELDS.
8. ALL PLATE AND WIDE FLANGE SHALL CONFORM TO ASTM A36 - 1992. ROUND BAR SHALL CONFORM TO 1018 COLD DRAWN.
9. CLEVISES SHALL BE CLEVIS #7 PER AISC MANUAL OF STEEL CONSTRUCTION, ASD, NINTH EDITION, PART 4, PAGE 148. THE CLEVISES THAT ATTACH TO THE 1 3/4" PLATE SHALL BE PROVIDED WITH A 2" GRIP. THE CLEVISES THAT ATTACH TO THE CONTAINER SHALL BE PROVIDED WITH A 2 1/4" GRIP. CLEVISES SHALL BE PROVIDED WITH A 2 9/16" DIAMETER HOLE FOR THE 2 1/2" DIAMETER PIN.
10. THE 4 PINS REQUIRED FOR THE CLEVISES SHALL BE 2 1/2" DIAMETER BY 6 1/2" LONG. THERE SHALL BE 2 HOLES ON 5 1/4" CENTERS PROVIDED FOR 3/8" COTTER PINS ON EACH 2 1/2" DIAMETER PIN. THE 2 1/2" DIAMETER PINS SHALL BE AISI 1035 CS. 2 1/2" DIAMETER PINS SHALL BE HELD IN PLACE WITH TWO 3/8" COTTER PINS.

OFFICIAL RELEASE
BY WHC
DATE SEP 15 1994

REF NUMBER	TITLE
H-2-83750	ASSEMBLY ARRANGEMENT
H-2-83736	STRONGBACK
H-2-83734	STORAGE CONTAINER
WHC-SD-WM-CA-1681	SUPPORTING DOC

REFERENCES

DRAWING TRACEABILITY LIST

NEXT USED ON END ITEM

REVISIONS

CADFILE F083744A

CADCODE 2OS:3.3:AC02:12.C0:SS

DRAWN RN COLE
CHECKED D HANEY 9-94
TR BENEGAS 8-94
3K 9-94

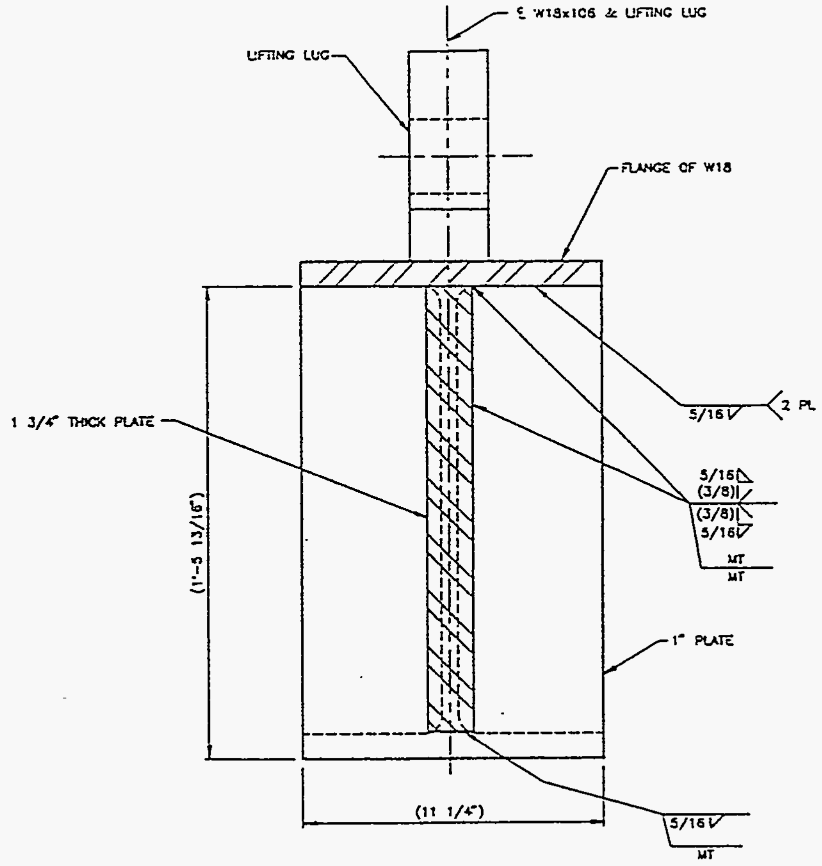
U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

LIFTING BEAM

SIZE	BLDG NO	INDEX NO	DWG NO	REV
F	200-G	1001	H-2-83744	0

SCALE SHOWN
CV 700435
SHEET 1 OF 2

H-2-83744 REV 0 SH 1 OF 2



C/1 SECTION (TYP BOTH ENDS)
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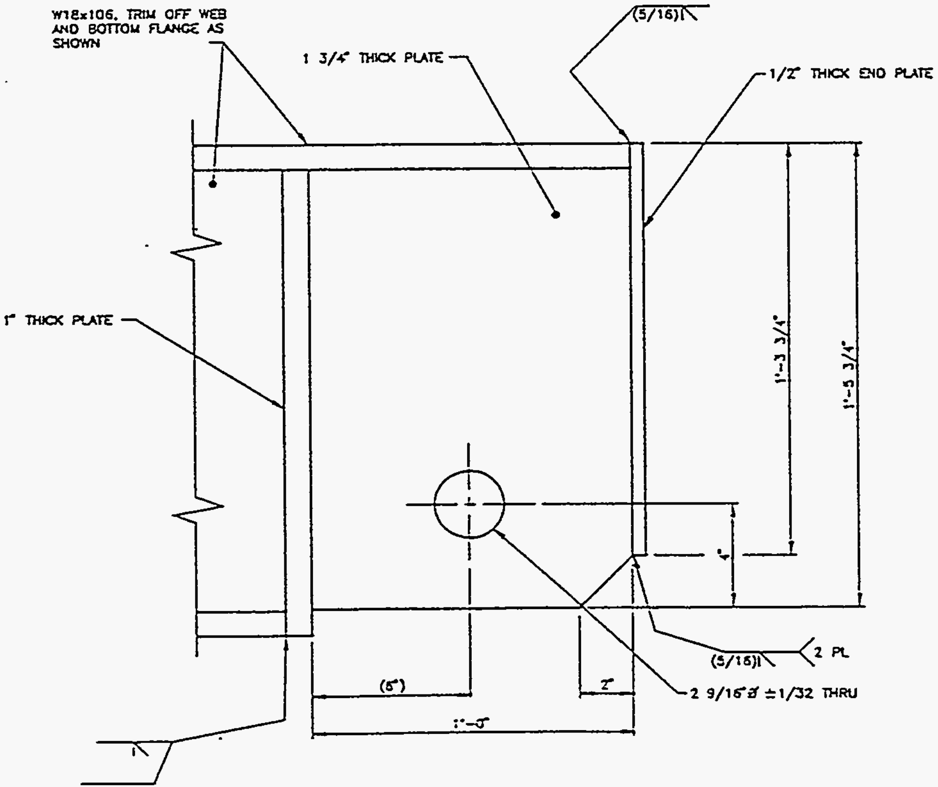
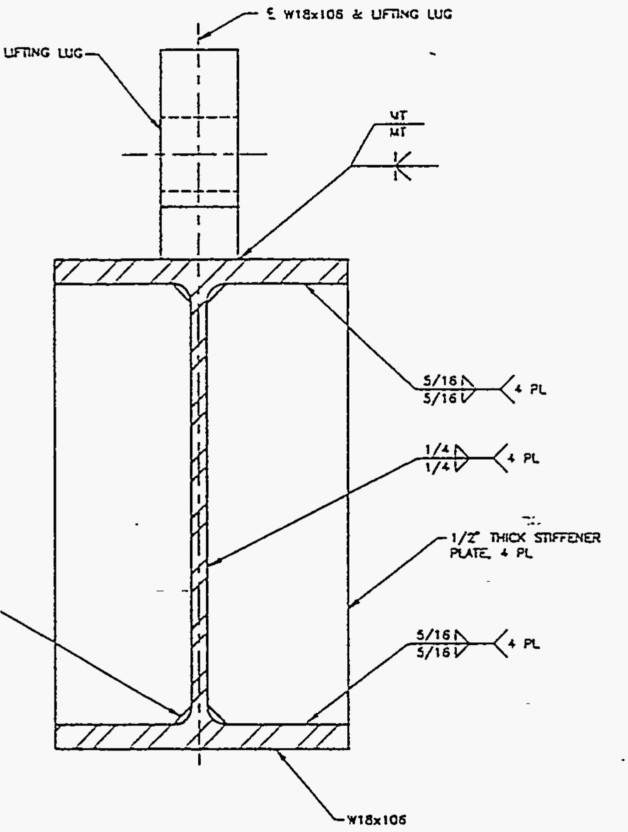


2/1 DETAIL (TYP BOTH ENDS)
SCALE: 3/8 SIZE

3/4"x45° CHAMF
8 PLACES

2 PL 5/1

(3/8
(3/8



A/1 SECTION

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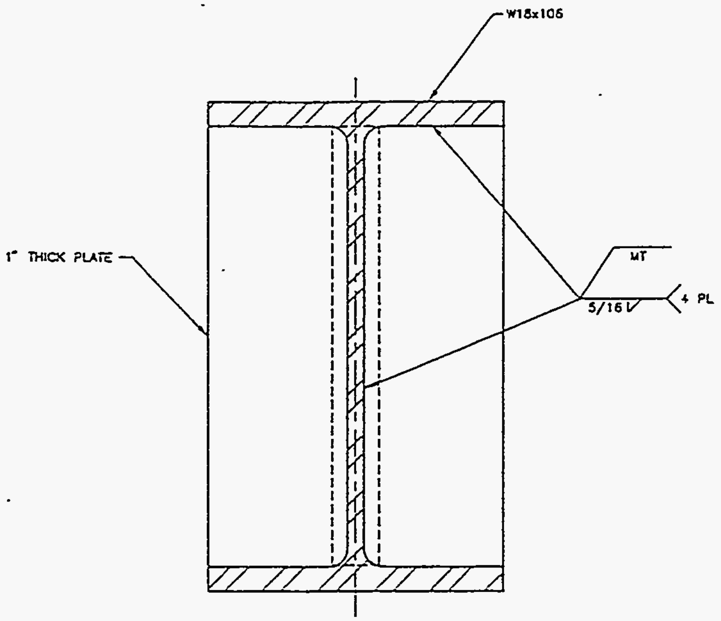

B/1 SECTION

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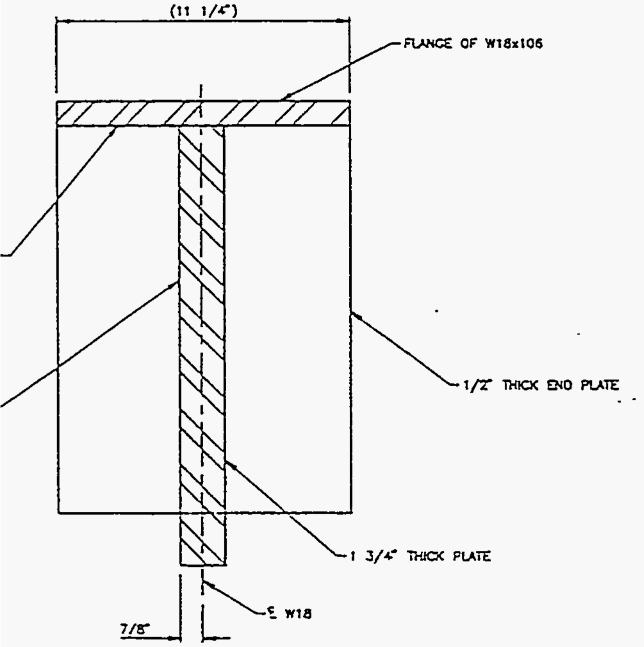

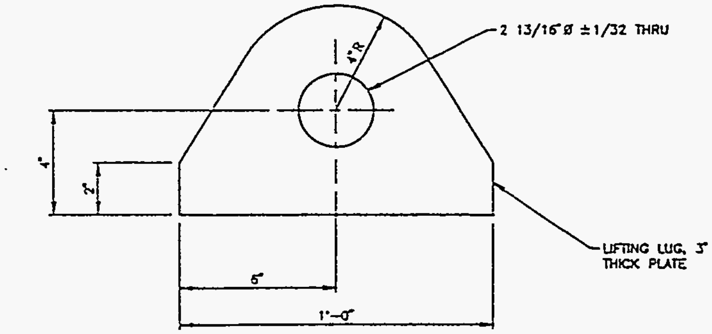

1/1 DETAIL

SCALE: 3/8 SIZE

D/1 SECTION (TYP BOTH ENDS)

SCALE: 3/8 SIZE

FOR GENERAL NOTES SEE SHEET 1

RN KYLE 5-94
D. EAVES 9-94
5-94
TR BENEGAS 5-94
7-94

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LIFTING BEAM

F 200-G 1001 H-2-83744 0

SCALE SHOWN 700436 SHEET 2

DRAWING TRACEABILITY LIST

NEXT USED ON H-2-83744 SH 1

REFERENCES

REVISIONS

CADFILE 30837448

CADCODE DOS:3.3:ACD2:12.00:SS

PART B - PACKAGE EVALUATION

1.0 INTRODUCTION

1.1 SAFETY EVALUATION METHODOLOGY

Part B of this Safety Evaluation for Packaging (SEP) identifies and evaluates the requirements considered applicable to the one-time transfer of the Hydrogen Mitigation Mixer Pump (HMMP) Package and will evaluate the adequacy and acceptability of the packaging and transfer systems described in Part A of this SEP. The SEP demonstrates that the onsite transfer meets the onsite transportation safety criteria (WHC 1994b).

A. Methodology used to evaluate the acceptability of the package for safe onsite transfer was to:

1. Determine the probability of an accident during transfer.
2. Determine the estimated release of radioactive materials following an assumed accident condition.

The results of the studies were compared to approved risk acceptance criteria for onsite transfers at the Hanford Site. This approach determines the applicable dose consequence limits listed in WHC-SD-TP-RPT-001, *Report on Equivalent Safety for Transportation and Packaging of Radioactive Materials* (WHC 1994b). Three accident probability ranges are listed in the equivalent safety document (incredible, credible, and probable). Each accident probability range has a maximum onsite and offsite dose consequence limit. For the short mileage requirements evaluated in this SEP, the probability of an accident during transfer of the package was determined to be "incredible" (less than 10^{-6}). Reference to the equivalent safety document indicated that the applicable dose consequence limits for accidents in the incredible range of events is 25 rem to an offsite person. This information was then compared to results of a dose consequence study which determined that the dose consequence following the potential accident conditions were within acceptance limits of the equivalent safety document.

B. Specific tests were selected to provide a basis for evaluation of package parameters for normal conditions of transfer and identified accident conditions. The specified tests were simulated and were evaluated by analysis. In cases where the probability of an accident was considered incredible, only testing for normal conditions of transfer were considered in this SEP.

C. Methodology used to assure that the large long-length package described in this SEP will not leak contents during normal conditions of transfer consisted of evaluating results of package drop test data. Evaluation of the drop test data consisted of assuring that the integrity of critical package containment components would not be impacted following the simulated drop tests. As noted, development of extensive leak testing criteria associated with hypothetical accident conditions was not evaluated due to the incredible probability of an accident.

1.2 EVALUATION SUMMARY AND CONCLUSIONS

Evaluation of the following safety concerns relating to the design and transfer of the HMMP Package indicated that the proposed packaging/transfer system is considered safe for the intended usage and meets the onsite transportation safety criteria.

An accident frequency assessment of the HMMP Package transferred over a specific route from the Tank Farms to the Central Waste Complex (CWC) and from the CWC to T Plant was conducted and indicated that an accident during transfer is not considered probable (incredible-less than 10^{-6}). This was based on transferring the HMMP Package a total of 4.3 miles.

A dose consequence study showed that radiation dose rates and the radionuclides that may be released in the incredible event of an accident are well below the dose consequence limits of 25 rem to an offsite person.

Conditions relating to normal handling of the package were evaluated and determined to be adequate. Simulated testing performed to evaluate normal transfer conditions include free drop, vibration, pressure, and penetration testing. Results of the drop test analysis indicated that the package would survive a drop test at the designated height(s) without unacceptable physical impairment. In addition, the drop test results indicated that the integrity of critical closure components would not be impacted.

Containment of the package contents during normal transfer conditions was evaluated based on results of the drop test and was determined to be acceptable for the stated conditions of handling and onsite transfer.

Shielding evaluations indicated that sufficient shielding (if required) can be installed on the outside of the package to limit contact dose rates to 100 mrem/h. This will meet the radiation dose rate requirements for both the transfer and storage of mixed, category 3, low-level waste.

The tiedown system design and analysis were evaluated and determined to be adequate to assure that the package will be properly secured to the vehicle during transfer.

A structural analysis of the package indicated that the lifting attachments on the package have sufficient strength to safely lift a fully loaded package in the horizontal position.

A thermal analysis of the package indicated that the fully loaded package would not exceed external surface temperature limits due to solar insolation and radioactive contents decay heat.

2.0 CONTENTS EVALUATION

2.1 CHARACTERIZATION

Certain characteristics of radioactive materials must be identified and evaluated to assure that the contents of a package can be safely transferred. Three major concerns relating to transferring radioactive materials are as follows:

1. The effective A_2 value (A_{2e}) of the material must be calculated to determine if the package must be transferred as a Type A or Type B quantity of material. If the package contents are a Type A or Type B quantity of radioactive material, a SARP or SEP is required to approve onsite transfer of the package. For a description of A_2 values of individual radionuclides and calculations of the A_{2e} of mixtures of radionuclides, see 10 CFR 71, Appendix A.

2. The quantity of fissile materials (normally in grams) must be calculated to determined if the package contents must be classified for transfer as "fissile" or "fissile excepted." If the contents are "fissile" a criticality study must be performed. See 10 CFR 71.4, 71.52, and 71.55 for definition of fissile materials.

3. The corrosive properties of the radioactive materials must be identified and evaluated to assure that the contents are compatible with the packaging materials.

Methods used in this SEP to determine if package contents are Type A or Type B consisted of developing tables to indicate the estimated curies of radioactive materials attached to the equipment and then comparing the estimated curie values to acceptable Type A limits.

Based on a waste generation study (WHC 1994a), Table B2-1 below was developed to indicate the activity of radionuclides estimated to be attached to the mixer pump. The activity in curies is shown for an estimated 3 mm thick film of waste tank material attached to specific areas of the pump and a liquid holdup of 68 gallons inside the pump. This is considered the "worst case" waste that will be attached to and contained inside the pump and will be used throughout this SEP to assure that the package is properly evaluated for the intended use.

Table B2-2 was developed to determine the A_{2e} values for the mixture of radionuclides attached to and contained inside the mixer pump. As noted above, if the total curies of waste material attached to the mixer pump is greater than the A_{2e} value of the mixture, the waste equipment must be transferred as a Type B quantity of waste.

Table B2-1. Radionuclide Activity for the HMMP Package.

Radionuclide	Pump Holdup (Ci)*	Pump Film (Ci)**	Total Curies
^{241}Am	1.02 E-01	6.03 E-02	1.63 E-01
^{238}Pu	2.82 E-04	1.66 E-04	4.48 E-04
^{239}Pu	5.65 E-03	3.33 E-03	8.97 E-03
^{240}Pu	1.33 E-03	7.86 E-04	2.12 E-03
^{241}Pu	1.12 E-02	6.61 E-03	1.78 E-02
^{242}Pu	6.24 E-08	3.68 E-08	9.92 E-08
^{243}Cm	1.16 E-04	6.86 E-05	1.85 E-04
^{244}Cm	2.03 E-03	1.20 E-03	3.22 E-03
^{242}Cm	5.05 E-05	2.97 E-05	8.02 E-05
^{137}Cs	1.61 E+02	9.50 E+01	2.56 E+02
^{137}Ba	1.52 E+02	8.98 E+01	2.42 E+02
^{14}C	3.88 E-04	2.29 E-04	6.17 E-04
^{90}Sr	1.88 E+01	1.11 E+01	2.99 E+01
^{90}Y	1.88 E+01	1.11 E+01	2.99 E+01
^{99}Tc	1.51 E-01	8.90 E-02	2.40 E-01
^{129}I	5.93 E-03	3.49 E-03	9.42 E-03
^{237}Np	1.68 E-02	9.87 E-03	2.66 E-02
^{238}U	2.14 E-05	1.26 E-05	3.40 E-05
^{235}U	2.35 E-06	1.39 E-06	3.74 E-06
^{79}Se	1.35 E-04	7.94.E-05	2.14 E-04
^{94}Nb	1.88 E-05	1.11 E-05	2.99 E-05
^{93m}Nb	1.61 E-03	9.50 E-04	2.56 E-03
^{60}Co	2.10 E-01	1.23 E-01	3.33 E-01
^{154}Eu	1.50 E+00	8.83 E-01	2.38 E+00
^{59}Ni	5.40 E-05	3.18 E-05	8.58 E-05
^{63}Ni	8.61 E-03	5.07 E-03	1.37 E-02
^{236}U	1.59 E-06	9.40 E-07	2.53 E-06

* Based on 68 gallon waste holdup in pump legs (987 lb)
** Based on 3 mm film thickness of waste (582 lb)

Table B2-2. Effective A_2 -- HMMP Package.

Radionuclide	A_2 Limit (Ci)	HMMP (Ci)	f_i	f_i/A_2
^{241}Am	0.008	1.63 E-01	2.91 E-04	0.0364
^{238}Pu	0.003	4.48 E-04	7.99 E-07	0.003
^{239}Pu	0.002	8.97 E-03	1.60 E-05	0.008
^{240}Pu	0.002	2.12 E-03	3.78 E-06	0.0019
^{241}Pu	0.1	1.78 E-02	3.17 E-05	0.0003
^{242}Pu	0.003	9.92 E-08	1.77 E-10	0
^{243}Cm	0.009	1.85 E-04	3.30 E-07	0
^{244}Cm	0.01	3.22 E-03	5.74 E-06	0.0006
^{242}Cm	0.2	8.02 E-05	1.07 E-06	0
^{137}Cs	10	2.56 E+02	4.564 E-01	0.0456
^{137}Ba	10	2.42 E+02	4.314 E-01	0.0431
^{14}C	60	6.17 E-04	1.10 E-06	0
^{90}Sr	0.4	2.99 E+01	5.33 E-02	0.1333
^{90}Y	0.4	2.99 E+01	5.33 E-02	0.1333
^{99}Tc	25	2.40 E-01	4.28 E-04	0
^{129}I	2	9.42 E-02	1.68 E-05	0
^{237}Np	0.005	2.66 E-02	4.74 E-05	0.0948
^{238}U	U	3.40 E-05	6.06 E-08	0
^{235}U	0.2	3.74 E-06	6.67 E-09	0
^{79}Se	NA	2.14 E-04	0	0
^{94}Nb	NA	2.99 E-05	0	0
^{93m}Nb	NA	2.56 E-03	0	0
^{60}Co	7	3.33 E-01	5.94 E-04	0.0001
^{154}Eu	5	2.38 E+00	4.24 E-03	0.0008
^{59}Ni	900	8.58 E-05	1.53 E-07	0
^{63}Ni	100	1.37 E-02	2.44 E-05	0
^{236}U	0.2	2.53 E-06	4.51 E-09	0
TOTALS		561	1.00	0.4985
Effective A_2				2.01

Note: The effective A_2 value is 1.00/0.4985 = 2.006 Ci. The total curies are greater than the effective A_2 value, therefore, the mixer pump must be transferred as a Type B quantity of waste. The total activity in terms of A_2 is 560.79/2.01 = 280 A_2s

The total estimated curies of material in the package contents (561 Ci) is 281 times greater than the A_{2e} value of the mixture of radionuclides indicating that the mixer pump must be transferred as a Type B quantity of waste. The A_{2e} value for a mixture is equal to $1/\Sigma\ f_i/A_2$ where f_i is a fraction of activity for each radionuclide in the mixture and A_2 is the appropriate Type A curie limit for each radionuclide.

Fissile materials present in the waste are ^{238}Pu, ^{239}Pu, ^{241}Pu, and ^{235}U. The quantity (grams) of each component of fissile material is based on the total curies of each component divided by the specific activity of each component. Table B2-3 was developed to determine the total grams of fissile materials in the HMMP Package evaluated in this SEP.

Table B2-3. Fissile Content.

	Activity (Ci/g)	Curies	Grams
^{238}Pu	17	4.48 E-04	2.63 E-05
^{239}Pu	0.62	8.97 E-03	1.45 E-02
^{241}Pu	110	1.78 E-02	1.62 E-04
^{235}U	2.10 E-06	3.74 E-06	1.78 E+00
TOTAL GRAMS			1.7947

As shown in Table B2-3, the total quantity of the fissile radionuclides estimated to be attached to and contained inside the mixer pump is 1.7947 g. Radioactive waste is excepted from fissile classification if the total quantity of fissile components are less than 15 g (DOT 1992) in each package. Under the conditions stated above, the package containing the mixer pump will be considered as "Fissile Excepted." Based on the "Fissile Excepted" classification, a criticality study will not be performed as part of this SEP evaluation.

The corrosive components are considered to be the non-radioactive chemicals in the waste contents. These chemicals are the hazardous components that resulted in classification of the materials as "mixed waste." Two conditions should be considered with reference to the potential corrosive properties of these chemicals:

1. Materials in underground radioactive waste storage tanks are neutralized to a 10 pH or higher to prevent corrosive reactions with the carbon steel tank materials.

2. The chemicals are normally in a liquid phase in the tank and will normally be washed off by spraying the equipment with water during removal.

For purposes of evaluating the package for transfer, the potential corrosion of packaging materials from the estimated minute quantity of non-radioactive chemicals that may remain attached to the solid waste material is considered insignificant. It should also be noted that absorbent material will be included in the package to absorb any free liquids. This will prevent direct contact of liquids with the packaging materials and will tend to prevent or delay any potential corrosive reactions that may impact the package during the specified service life.

2.2 CONTENT RESTRICTIONS

Since this SEP approves the transfer of specific package contents, generic restrictions of the contents are not considered applicable. However, by definition of the SEP document, contents that exceed estimated weights and/or radionuclide limits cannot be transferred under the SEP unless an Engineering Change Notice (ECN) is issued. The maximum amount of curies for each radionuclide estimated to be attached to the hydrogen mitigation mixer pump is shown in Table B2-1. The estimated maximum quantities of fissile radionuclides attached to the pump is shown in Table B2-3.

2.3 CONCLUSIONS

Package contents as characterized in the waste generation study (WHC 1994a) shown in Part A, Section 3.0, and evaluated in this section of the SEP are considered to be properly identified and sufficiently analyzed to be considered acceptable for transfer in the HMMP Package.

3.0 RADIOLOGICAL RISK EVALUATION

3.1 INTRODUCTION

Packaging and transportation systems were evaluated to determine if calculated radiological releases that may occur during transfer of the package are considered to be within acceptable radiological limits listed in WHC-SD-TP-RPT-001, *Report on Equivalent Safety for Transportation and Packaging of Radioactive Materials* (WHC 1994b). Results of an accident frequency assessment and dose consequence study were used as the basis for analyzing and comparing identified risks to the approved risk acceptance criteria.

3.2 RISK ACCEPTANCE CRITERIA

Specific risk acceptance criteria for onsite transfers of material at the Hanford Site are shown in the *Report on Equivalent Safety for Transportation and Packaging of Radioactive Materials* (WHC 1994b); however, for purposes of evaluations in this SEP, specific criteria data from the referenced document are shown in Table B3-1.

Table B3-1. Risk Acceptance Criteria.

Accident Condition	Annual Accident Frequency	Dose Limits Onsite Worker (rem)	Dose Limits Offsite Farmer (rem)
Incredible	$< 10^{-7}$	N/A	N/A
Incredible	10^{-7} to $< 10^{-6}$	N/A	25 (EDE)
Credible	10^{-6} to $< 10^{-3}$	5/15/50	0.5/1.5/0.5
Probable	10^{-3} to 1	0.2/0.6/2	0.01/0.03/0.1

3.3 ACCIDENT FREQUENCY ASSESSMENT

An accident frequency assessment (see Part B, Section 3.6) was performed to determine the probability of an accident for the one-time shipment described in this SEP. Results of the accident frequency assessment indicated that the short-term mileage of this campaign precludes the activity from falling within the credible or probable frequency range for accidents. The accident frequency was calculated to be 4.97×10^{-8} indicating that accidents are considered incredible for the onsite transfer of the HMMP Package described in this SEP. As noted in Table B3-1, no radiation release limits to an offsite farmer are required for a calculated accident frequency of below 10^{-7}. However, the predicted effect to an offsite individual was evaluated based on the 10^{-6} to 10^{-7} accident frequency for added conservatism.

3.4 DOSE CONSEQUENCE ANALYSIS

A dose consequence analysis (see data sheets - Part B, Section 3.7) was performed to assess the results of a radiological release of material to an offsite farmer for the HMMP Package in the unlikely event of an accident. The analysis assumed in the worst case that 30% of the radionuclide inventory is released to the environment in less than one hour, 50% of the released inventory is dispersed to the atmosphere, and that decay of the radionuclides began at the time of release. The analysis indicated that an offsite farmer at the nearest site boundary would be subjected to a 50 year committed effective dose equivalent (EDE) of 4.1 rem for an accident with an estimated 15% dispersement of the radionuclide inventory to the atmosphere.

3.5 RISK EVALUATION AND CONCLUSIONS

For incredible accident conditions for acceptable release limits at the Hanford Site, the calculated 4.1 rem EDE to an offsite farmer is well below the 25 rem limit shown in Table B3-1. The conclusions of this evaluation are that the identified radiological risks associated with the one-time transfer of the HMMP Package described in this SEP are acceptable.

3.6 ACCIDENT FREQUENCY ASSESSMENT

HYDROGEN MITIGATOR MIXER PUMP TRANSPORT FROM 101-SY TANK FARM TO CENTRAL WASTE COMPLEX AND T PLANT

J. E. Kelly/ S. E. Lindberg
Risk Assessment Technology

June 1994

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HYDROGEN MITIGATION MIXER PUMP TRANSPORT FROM 101-SY TANK FARM TO CENTRAL WASTE COMPLEX AND T PLANT

1.0 INTRODUCTION

This report contains an accident frequency assessment for transferring the Hydrogen Mitigation Mixing Pump (HMMP) package containing contamination removed from Tank 101-SY to the Central Waste Complex (CWC) and eventually to T Plant for treatment/processing. To perform the analysis, an estimate must be made of the distance that will be travelled and then apply the site data for vehicle accident frequencies which are based on this distance.

2.0 APPROACH

The approach that will be used in this analysis is to develop an event tree that defines all of the events required for an accident leading to a possible release of radioactive material in the transport of the HMMP package by truck. The event tree (Figure 2-1) maps transportation accident sequences resulting in radioactive releases by considering a series of questions. These questions, also called top events, appear across the top of the tree. The decisions or "branch" points under these top events are described and discussed in the paragraphs that follow.

3.0 TRAVEL DISTANCE

The pathway selected for this analysis has the vehicle leaving the SY tank farm and going South on Camden Avenue to 10th Street. Turn West on 10th Street and go to Cooper Avenue. Turn North on Cooper to 13th Street. Turn West on 13th Street to Dayton Avenue. Turn North on Dayton Avenue and drive to the CWC. The distance from SY Tank Farm to the CWC is less than three miles. The additional trip from the CWC to T Plant is 1.3 miles. Go North on Dayton and East on 23rd Street to accomplish this trip. Therefore, the total mileage for this trip is less than 4.3 miles. This is the distance that will be used in this study. It will not be used directly in the event tree development, but the results of the generic event tree (see Figure 2-1) will be multiplied by this mileage to determine the frequency of the potential accidents. The first event of the event tree, **SHIPPING ACTIVITY**, will be assigned a frequency of one (see Figure 3-1 for pathway driven).

Figure 2-1. Transportation Event Tree.

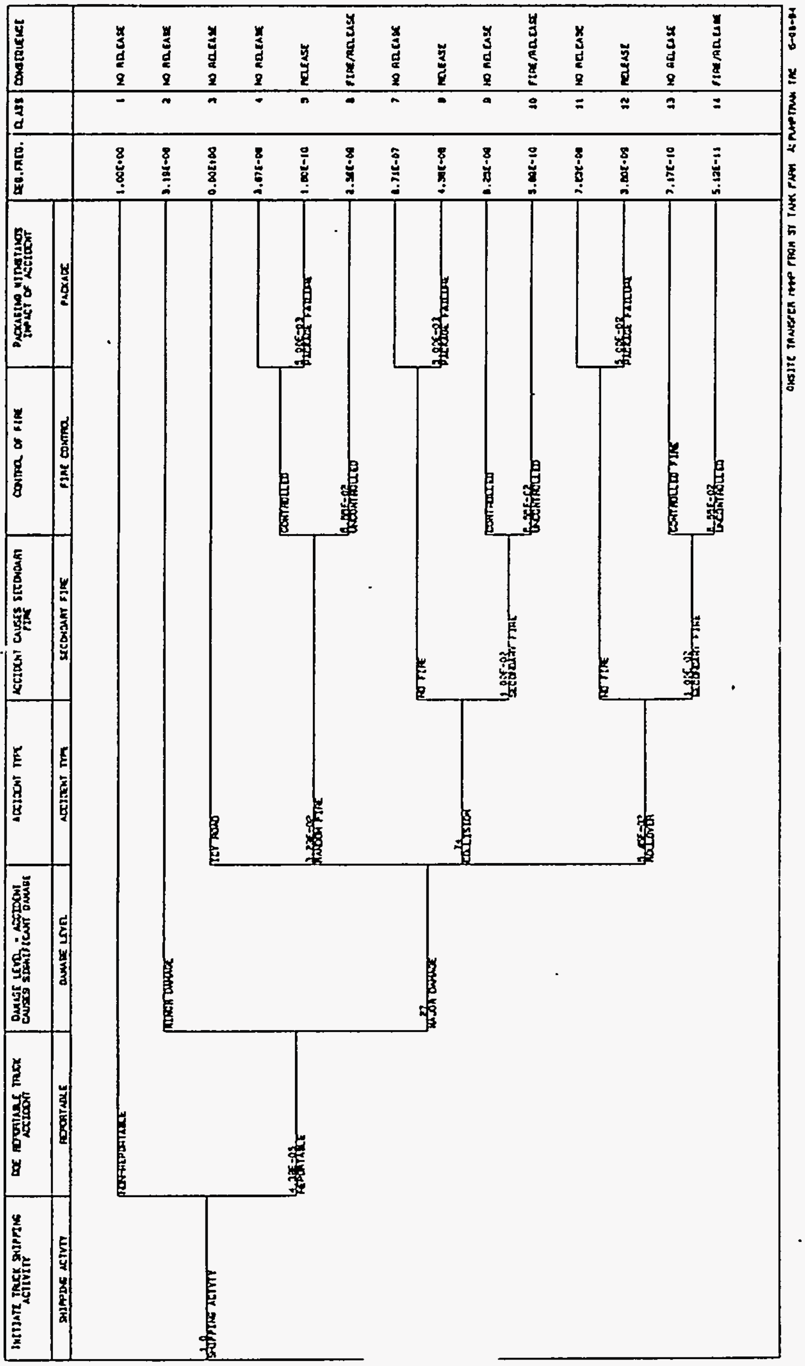
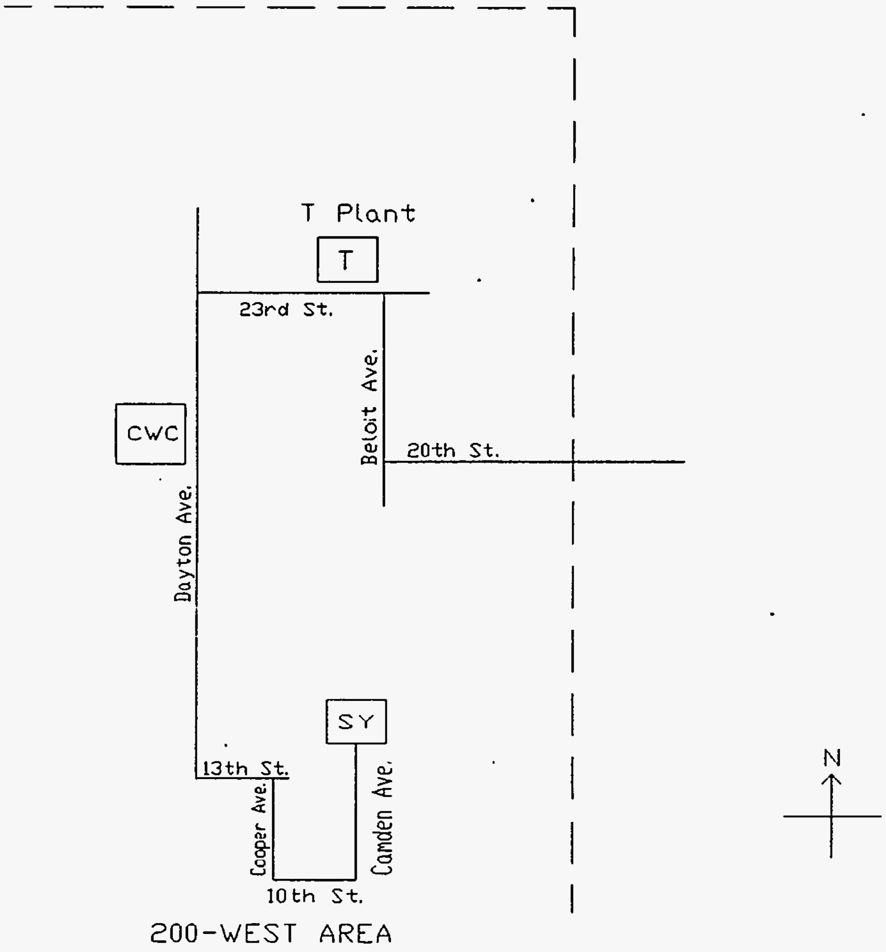


Figure 3-1. Transportation of Pump from SY Tank Farm to CWC.



4.0 HANFORD VEHICLE ACCIDENT STATISTICS

Hanford Site specific data, rather than Washington State statistics, were used to develop accident frequencies and probabilities. Washington State statistics represent a significantly different transportation environment than the Hanford Site because commercial transportation has little influence on its operating conditions while Hanford on-site shipping is highly controlled.

Due to a computer system upgrade, it is not possible to separate mileage by vehicle class prior to 1992. Therefore, a single accident rate for all classes is developed by dividing the number of truck accidents by the total truck miles. The occurrence of 114 reportable accidents over 26.0 million miles results in an accident rate of 4.38E-06 accidents per mile. See WHC-SD-TP-RPT-007 for a list of the accidents and the mileage. This frequency will be assigned to the second event, **REPORTABLE**, on the event tree.

The Hanford Site had 114 reportable truck accidents (Gross Vehicle Weight over 8500 pounds) over a period in which 26.0 million miles were driven. The U.S. Department of Energy requires accidents with $500 or more damage be reported. A proposed change to WHC-CM-1-13 may increase the amount to $5,000. Of these accidents only thirty-one (27.2 percent) resulted in major damage in which an undesired radioactive release could occur. This probability or percentage will be applied to event three, **DAMAGE LEVEL**, on the event tree. (Two were rollovers, twenty-three were collisions, one was a random fire, and five occurred on icy roads). Ratios will be used on the fourth event, **ACCIDENT TYPE**, to divide the 31 major accidents on the event tree. The remaining eighty-three were minor "fender benders" or accidents involving special vehicles such as fire trucks and cranes.

Commercial truck transportation data shows that secondary fires occur in approximately one percent of all truck accidents (Clark, 1976). Vehicle fires can damage the cargo and allow radioactive releases. Cargo environments can range from minor thermal exposure to severe thermal exposure. The fifth event, **SECONDARY FIRE**, is evaluated based on the one percent fire occurrence data.

Few vehicle fires seriously threaten the cargo because fires are usually confined to small areas or are of short duration. Because fires typically start in the engine compartment, cargo will not be significantly damaged if a fire is controlled within ten minutes. Based on the response time of the fire department, ninety percent of all truck fires can be extinguished during the initiating phase. One-third of the remaining ten percent can be controlled by the fire department before the cargo is damaged.

Two facts justify these assumptions. First, hand-held fire extinguishers are effective on vehicle fires if less than seventy-five gallons of fuel or less than one thousand pounds of solid combustible cargo are involved. Second, the locations of the three fire stations on the Hanford Site allow fire trucks to get to one-third of the site within five minutes, two-thirds of the site within ten minutes, and to the entire site within fifteen minutes (Reference 4). From this information a probability of 6.66e-02 was formulated and used for event six, **FIRE CONTROL**, on the event tree.

The final event, **PACKAGE**, on the event tree evaluates the proposed packaging. Based on the packaging design criteria, WHC-SD-TP-PDC-019, Draft, the transfer pump located in tank 241-SY-101 weighs 20,906 lbs.with total weight waste matrix, is 41 inches in diameter, and 60 feet long. The package for this pump will be analyzed for a drop of three feet. The packages will be tied down to the vehicle. The tiedown devices used to secure the package to the transport vehicle shall be designed and evaluated to assure the tie-down assemblies used to secure the packaging can withstand sudden stops or cornering at 15 MPH. Attachments shall be provided on the package container as required to safely lift the waste package and secure the package during transfer. Any lifting attachment that is a structural part of the package shall be designed with one of the following (whichever is more conservative):

- A minimum safety factor of three against yielding.
- A safety factor of five based on the ultimate strength of material. When the lifting attachment is used as intended, it must be designed so that the lifting device failure caused by an excessive load will not impair the package from meeting other criteria. Any structural part of the package not approved for lifting the package shall be rendered inoperable for lifting the package during transfer or shall be designed with strength equivalent to that required for the approved lifting attachments.

The speed of the transport trailer shall not exceed 35 mph on straight sections of the road and 15 mph on curved sections of the road during waste transfers. This information was used to estimate the package failure due to a random fire or collision at 5.0E-03, and 5.0E-02 due to a rollover. Included in the package failure probability is a factor to account for the percentage of radioactive release. For a complete release, not only would the packaging have to fail, but the pump itself would have to open to result in a complete inventory release. These values appear on the event tree.

4.1 EVENT TREE EVALUATION

Fourteen accident sequences are defined by the event tree. Eight of these result in no release. It should be noted that it was assumed that the transfer would not be allowed to occur during icy road conditions. Three sequences result in a release, and three more result in a fire release. One of the combinations of releases is caused by a random fire where the fire is controlled but the packaging fails or the fire is not controlled. The frequencies for these accidents are 1.80E-10 and 2.56E-09 per mile. The next set of two sequences resulting in a release is initiated by a collision. The collision with no fire but with a packaging failure has a frequency of

4.38e-09 accidents per mile, and the collision with an uncontrolled fire has a frequency of 5.89E-10 per mile. The final series is initiated by a rollover accident. When there is no fire the frequency is 3.80E-09 per mile and 5.12E-11 per mile with an uncontrolled fire. Summing the three accidents without a fire results in a frequency of 8.36E-09 accidents per mile. When this is multiplied by the distance of 4.3 miles results in an accident frequency of 3.59E-08 per transfer. The three accidents with a fire release sum to 3.20E-09 accidents per mile. Again using 4.3 miles, results in a frequency of 1.38E-08 per transfer.

5.0 SUMMARY

The sum for the worst case accidents as defined by the maximum mileage for both with and without a fire are less than the annual criteria frequency of 1.0E-06 per transport and therefore no further restrictions are required.

6.0 REFERENCES

1. Clarke, R. K., 1976, "*Severities of Transportation Accidents*", SLA-740001, Sandia Laboratories, Albuquerque, New Mexico, September, 1976.

2. WHC-SD-TP-PDC-019, (Draft), "*Package Design Criteria Transfer and Disposal of Hydrogen Mitigation Mixer Pump*",

3. WHC-SD-TP-RPT-001, Rev. 0, "*Report on Equivalent Safety for Transportation and Packaging of Radioactive Material*", December, 1993.

4. WHC-SD-TP-RPT-007, Rev. 0, "*Standard Transportation Risk Assessment Methodology*", December, 1993.

3.7 DOSE CONSEQUENCE ANALYSIS

Westinghouse Hanford Company

Internal Memo

From: Radiation Physics and Shielding
Phone: 376-8244 HO-35
8D530-RLS-94-007
Date: May 5, 1994
Subject: DOSE CONSEQUENCE ANALYSIS FOR THE HYDROGEN MITIGATION MIXER PUMP SHIPPING CONTAINER

To:	R. F. Carlstrom	G2-02		
cc:	J. G. Field	G2-02	H. J. Goldberg	HO-35
	J. Greenborg	HO-35	P. D. Rittmann	HO-36
	A. E. Waltar	HO-32	RLS File/LB	

REFERENCES:

1. Internal Memorandum R. L. Simons to R. F. Carlstrom, "Estimated Activity on the Mixer Pump Removed from Tank 101 SY," 22570-RLS-93-010, December 14, 1993.
2. B. E. Hey, "GXQ 3.1 User's Guide," WHC-SD-GN-SWD-30002, Rev 0, Westinghouse Hanford Company, Richland, WA, June 8, 1993.
3. B. A. Napier, et al., "GENII - The Hanford Environmental Radiation Dosimetry Software System Volume 2: Users' Manual," PNL-6584 vol. 2, Pacific Northwest Laboratory, Richland WA, November 1988.

This memorandum reports the calculated dose consequences for the accidental release of radioactive material from the hydrogen mitigation mixer pump that will be shipped from the 200 West area to interim storage and processing facilities. The results of this analysis will be used by Transportation and Packaging to determine the dose consequence off-site. The analysis assumed in the worst case that 30 percent of the radionuclide inventory is released to the environment in less than one hour, 50 percent of the released inventory is dispersed to the atmosphere, and that decay of the radionuclides began at the time of release.

The radionuclide source was reported in reference [1]. The atmospheric dispersion of radionuclides (X/Q) was calculated with the GXQ computer code [2] using Hanford Site specific meteorological data. The Gaussian straight line plume model was used for the analysis. The 50 year committed effective dose equivalent (EDE) to a farmer at the site boundary included direct irradiation from the passing cloud, and uptake by inhalation, terrestrial, and animal pathways. The off-site EDE was calculated with version 1.485 of GENII [3]. The release site was located at the site of the tank 101 SY in the 200 West area. Plume meander was not considered in this analysis.

The EDE calculated by GENII for a net 15 percent release to the atmosphere is 4.1 Rem to a farmer at the nearest site boundary (near the Yakima barricade).

Attachment A gives GXQ input data and Attachment B gives GENII input data for future reference and for review of this work.

If you have any questions regarding this analysis, please contact me.

R L Simons

R.L. Simons, Principal Scientist
Physics and Radiation Shielding

Concurrence: ______________________
J. Greenborg, Manager

Paul Rittmann

Reviewed by: ______________________
P. D. Rittmann, Principal Engineer
Environmental Risk and Performance Assessment

HEDOP REVIEW CHECKLIST
for
Radiological and Nonradiological Release Calculations

Document Reviewed: Internal Memorandum: 8D530-RLS-94-007

Dose Consequence Analysis for the Hydrogen Mitigation Mixer Pump Shipping Container

Submitted by: R. L. Simons Date Submitted: May 5, 1994

Scope of Review: Entire Document

YES	NO*	N/A		
☒	☐	☐	1.	A detailed technical review and approval of the environmental transport and dose calculation portion of the analysis has been performed and documented.
☒	☐	☐	2.	Detailed technical review(s) and approval(s) of scenario and release determinations have been performed and documented.
☒	☐	☐	3.	HEDOP-approved code(s) were used.
☒	☐	☐	4.	Receptor locations were selected according to HEDOP recommendations.
☒	☐	☐	5.	All applicable environmental pathways and code options were included and are appropriate for the calculations.
☒	☐	☐	6.	Hanford site data were used.
☒	☐	☐	7.	Model adjustments external to the computer program were justified and performed correctly.
☒	☐	☐	8.	The analysis is consistent with HEDOP recommendations.
☐		☒	9.	Supporting notes, calculations, comments, comment resolutions, or other information is attached. (Use the "Page 1 of X" page numbering format and sign and date each added page.)
☒	☐		10.	**Approval is granted on behalf of the Hanford Environmental Dose Overview Panel.**

* All "No" responses must be explained and use of nonstandard methods justified.

Reviewer Name: Paul D. Rittmann, PhD CHP
(print or type)

Paul Rittmann 5-5-94
HEDOP-Approved Reviewer (Signature) Date

ATTACHMENT A

GXQ INPUT DATA

```
Calc of GXQ for tank SY101 pump in 200 west area.
c GXQ Ver. 3.1 Input File
c   mode
    1
c
c MODE CHOICE:
c mode = 1 then X/Q based on Hanford site specific meteorology
c mode = 2 then X/Q based on atmospheric stability class and wind speed
c mode = 3 then X/Q plot file is created
c
c LOGICAL CHOICES:
c   ifox  inorm icdf  ichk  isite ipop  icon
    t     f     f     f     f     f     f
c ifox  = t then joint frequency used to compute frequency to exceed X/Q
c       = f then joint frequency used to compute annual average X/Q
c inorm = t then joint frequency data is normalized (as in GENII)
c       = f then joint frequency data is un-normalized
c icdf  = t then cumulative distribution file created (CDF.OUT)
c       = f then no cumulative distribution file created
c ichk  = t then X/Q parameter print option turned on
c       = f then no parameter print
c isite = t then X/Q based on joint frequency data for all 16 sectors
c       = f then X/Q based on joint frequency data of individual sectors
c ipop  = t then X/Q is population weighted
c       = f then no population weighting
c icon  = t then X/Q is air concentration
c       = f then X/Q is integrated exposure
c
c MODEL CHOICES:
c   idep  iwake ipm   irise igrav iwash iflow iwind
    0     0     0     0     0     0     0     0
c idep  = 1 then plume depletion model turned on (Chamberlain model)
c iwake = 1 then NRC RG 1.145 building wake model turned on
c       = 2 then MACCS virtual distance building wake model turned on
c ipm   = 1 then NRC RG 1.145 plume meander model turned on
c       = 2 then 5th Power Law plume meander model turned on
c       = 3 then sector average model turned on
c irise = 1 then momentum/buoyancy plume rise model turned on, buoyancy
c          rise based on sensible heat emission
c       = 2 then momentum/buoyancy plume rise model turned on, buoyancy
c          rise based on initial plume density
c igrav = 1 then gravitational settling model turned on
c iwash = 1 then stack downwash model turned on
c iflow = 1 then sigmas adjusted for volume flow rate
c iwind = 1 then wind speed corrected for plume height
c       = 0 to turn any of the above models off
c
c PARAMETER INPUT:
c   stack          wind                          frequency
c   release        speed          mixing         to             scaling
c   height         height         height         exceed         factor
c   (m)            (m)            (m)            (%)            (?)
    0              10             1000          0.5             1
c
c                                                               gravitational
c   building       building       release        deposition     settling
c   width          height         duration       velocity       velocity
c   (m)            (m)            (hr)           (m/s)          (m/s)
    5              5              1              0.001          0.001
c
c                  initial                       sensible
c   initial        plume                         heat
c   plume          flow           stack          emission
c   density        rate           diameter       rate
c   (g/cc)         (m3/s)         (m)            (cal/s)
    0.00122        0              1              4.18000E+05
c
c RECEPTOR DEPENDENT DATA
c FOR MODE     make         RECEPTOR DEPENDENT DATA
c 1 (site specific)         sector distance z-height
c 2 (by class & wind speed) class windspeed distance offset z-height
c 3 (create plot file)      class windspeed xmax imax ymax jmax xqmin power
c
c RECEPTOR PARAMETER DESCRIPTION:
c sector = 0, 1, 2... (all, S, SSW, etc.)
c distance = meters
```

```
c class = 1, 2, 3, 4, 5, 6, 7 (P-G stability class A, B, C, D, E, F, G)
c windspeed = m/s
c offset = meters offset from plume centerline
c xmax = maximum distance to plot or calculate to (m)
c imax = distance intervals
c ymax = maximum offset to plot (m)
c jmax = offset intervals
c xqmin = minimum scaled X/Q to calculate
c power = exponent in power function step size
1    13160   0
2    13430   0
3    14860   0
4    12710   0
5    12460   0
6    12680   0
7    16430   0
8    17290   0
9    18960   0
10   27280   0
11   26890   0
12   23640   0
13   23270   0
14   28110   0
15   22790   0
16   18380   0
```

ATTACHMENT B

INPUT DATA FOR GENII CALCULATION OF DOSE CONSEQUENCES

```
######################### Program GENII Input File ########### 8 Jul 88 ####
Title: Site boundary dose consequences for SY101 Pump
       \GENII\pump_sb.in                        Created on 05-02-1994 at 10:38
OPTIONS======================== Default ====================================
F    Near-field scenario?      (Far-field)    NEAR-FIELD: narrowly-focused
F    Population dose?         (Individual)                release, single site
T    Acute release?             (Chronic)     FAR-FIELD:  wide-scale release,
     Maximum Individual data set used                     multiple sites
                                 Complete                               Complete
TRANSPORT OPTIONS============ Section   EXPOSURE PATHWAY OPTIONS===== Section
T  Air Transport                 1     F  Finite plume, external       5
F  Surface Water Transport       2     T  Infinite plume, external     5
F  Biotic Transport (near-field) 3,4   F  Ground, external             5
F  Waste Form Degradation (near) 3,4   F  Recreation, external         5
                                       T  Inhalation uptake            5,6
REPORT OPTIONS=======================  F  Drinking water ingestion     7,8
F  Report AEDE only                    F  Aquatic foods ingestion      7,8
F  Report by radionuclide              T  Terrestrial foods ingestion  7,9
F  Report by exposure pathway          T  Animal product ingestion     7,10
F  Debug report on screen              F  Inadvertent soil ingestion

INVENTORY ##################################################################

 4   Inventory input activity units: (1-pCi  2-uCi  3-mCi  4-Ci  5-Bq)
 0   Surface soil source units (1- m2  2- m3  3- kg)
     Equilibrium question goes here

     --------¦----Release Terms------¦----------Basic Concentrations---------¦
     Use when¦  transport selected   ¦  near-field scenario, optionally      ¦
     --------¦-----------------------¦---------------------------------------¦
     Release ¦        Surface Buried ¦        Surface Deep    Ground  Surface¦
     Radio-  ¦Air     Water   Waste  ¦Air     Soil    Soil    Water   Water  ¦
     nuclide ¦/yr     /yr     /m3    ¦/m3     /unit   /m3     /L      /L     ¦
     --------¦------- ------- -------¦------- ------- ------- ------- -------¦
     C 14    6.2E-04
     CO60    3.3E-01
     NI59    8.6E-05
     NI63    1.4E-02
     SE79    2.1E-04
     SR90    3.0E+01
     Y 90    3.0E+01
     NB93M   2.6E-03
     NB94    3.0E-05
     TC99    2.4E-01
     I 129   9.4E-03
     CS137   2.6E+02
     EU154   2.4E+00
     U 235   3.7E-06
     U 236   2.5E-06
     U 238   3.4e-05
     NP237   2.7E-02
     PU238   4.5e-04
     PU239   9.0e-03
     PU240   2.1e-03
     PU241   1.8e-02
     PU242   9.9e-08
     AM241   1.6e-01
     CM242   8.0e-05
     CM243   1.9e-04
     CM244   3.2e-03

     --------¦----Derived Concentrations-----¦
     Use when¦   measured values are known   ¦
     --------¦-------------------------------¦
     Release ¦Terres. Animal  Drink   Aquatic¦
     Radio-  ¦Plant   Product Water   Food   ¦
     nuclide ¦/kg     /kg     /L      /kg    ¦
     --------¦------- ------- ------- -------¦

TIME #######################################################################

1    Intake ends after (yr)
50   Dose calc. ends after (yr)
0    Release ends after (yr)
0    No. of years of air deposition prior to the intake period
0    No. of years of irrigation water deposition prior to the intake period
```

```
FAR-FIELD SCENARIOS (IF POPULATION DOSE) ####################################

0          Definition option: 1-Use population grid in file POP.IN
0                             2-Use total entered on this line

NEAR-FIELD SCENARIOS ########################################################

           Prior to the beginning of the intake period: (yr)
0            When was the inventory disposed?  (Package degradation starts)
0            When was LOIC?  (Biotic transport starts)
1.0        Fraction of roots in upper soil (top 15 cm)
0          Fraction of roots in deep soil
0          Manual redistribution: deep soil/surface soil dilution factor
1250       Source area for external dose modification factor (m2)
TRANSPORT ###################################################################
           ====AIR TRANSPORT===================================SECTION 1=====
                   0-Calculate PM           ¦0       Release type (0-3)
1          Option: 1-Use chi/Q or PM value  ¦F       Stack release (T/F)
                   2-Select MI dist & dir   ¦0       Stack height (m)
                   3-Specify MI dist & dir  ¦0       Stack flow (m3/sec)
1.62E-05   Chi/Q or PM value                ¦0       Stack radius (m)
0          MI sector index (1=S)            ¦0       Effluent temp. (C)
0          MI distance from release point (m)¦0      Building x-section (m2)
F          Use jf data, (T/F) else chi/Q grid¦0      Building height (m)

           ====SURFACE WATER TRANSPORT=========================SECTION 2=====
0          Mixing ratio model: 0-use value, 1-river, 2-lake
0          Mixing ratio, dimensionless
0          Average river flow rate for: MIXFLG=0 (m3/s), MIXFLG=1,2 (m/s),
0          Transit time to irrigation withdrawl location (hr)
           If mixing ratio model > 0:
0            Rate of effluent discharge to receiving water body (m3/s)
0            Longshore distance from release point to usage location (m)
0            Offshore distance to the water intake (m)
0            Average water depth in surface water body (m)
0            Average river width (m), MIXFLG=1 only
0            Depth of effluent discharge point to surface water (m), lake only

           ====WASTE FORM AVAILABILITY=========================SECTION 3=====
0          Waste form/package half life, (yr)
0          Waste thickness, (m)
0          Depth of soil overburden, m

           ====BIOTIC TRANSPORT OF BURIED SOURCE================SECTION 4=====
T          Consider during inventory decay/buildup period (T/F)?
T          Consider during intake period (T/F)?  ¦ 1-Arid non agricultural
0          Pre-Intake site condition.............¦ 2-Humid non agricultural
                                                 ¦ 3-Agricultural

EXPOSURE ####################################################################

           ====EXTERNAL EXPOSURE===============================SECTION 5=====
           Exposure time:              ¦  Residential irrigation:
0            Plume (hr)                ¦ T       Consider: (T/F)
0            Soil contamination (hr)   ¦ 0       Source: 1-ground water
0            Swimming (hr)             ¦                 2-surface water
0            Boating (hr)              ¦ 0       Application rate (in/yr)
0            Shoreline activities (hr) ¦ 0       Duration (mo/yr)
0          Shoreline type: (1-river, 2-lake, 3-ocean, 4-tidal basin)
0          Transit time for release to reach aquatic recreation (hr)
1.0        Average fraction of time submersed in acute cloud (hr/person hr)

           ====INHALATION======================================SECTION 6=====
8766.0     Hours of exposure to contamination per year
0          0-No resus-  1-Use Mass Loading         2-Use Anspaugh model
0            pension      Mass loading factor (g/m3)   Top soil available (cm)

           ====INGESTION POPULATION============================SECTION 7=====
 1         Atmospheric production definition (select option):
0            0-Use food-weighted chi/Q, (food-sec/m3), enter value on this line
             1-Use population-weighted chi/Q
             2-Use uniform production
             3-Use chi/Q and production grids (PRODUCTION will be overridden)
0          Population ingesting aquatic foods, 0 defaults to total (person)
0.0        Population ingesting drinking water, 0 defaults to total (person)
F          Consider dose from food exported out of region (default=F)
```

```
            Note below: S* or Source: 0-none, 1-ground water, 2-surface water
                                      3-Derived concentration entered above
            ==== AQUATIC FOODS / DRINKING WATER INGESTION=========SECTION 8====

F           Salt water? (default is fresh)

            USE         TRAN-  PROD-    -CONSUMPTION- |
            ?   FOOD    SIT    UCTION   HOLDUP   RATE |
            T/F TYPE    hr     kg/yr    da      kg/yr |      DRINKING WATER
            --- ------ -----  -------  ------   ----- |------------------------
            F   FISH    0.00  0.0E+00    1.00    40.0 | 0      Source (see above)
            F   MOLLUS  0.00  0.0E+00    0.00     0.0 | T      Treatment? T/F
            F   CRUSTA  0.00  0.0E+00    0.00     0.0 | 1.0    Holdup/transit(da)
            F   PLANTS  0.00  0.0E+00    0.00     0.0 | 730.0  Consumption (L/yr)

            ====TERRESTRIAL FOOD INGESTION======================SECTION 9=====

            USE         GROW   --IRRIGATION--          PROD-    --CONSUMPTION--
            ?   FOOD    TIME   S RATE   TIME   YIELD   UCTION   HOLDUP   RATE
            T/F TYPE    da     * in/yr  mo/yr  kg/m2   kg/yr    da       kg/yr
            --- ------ -----  - -----  -----  -----  -------  ------   ------
            T   LEAF V 90.00  0   0.0    0.0    1.5   0.0E+00    1.0     30.0
            T   ROOT V 90.00  0   0.0    0.0    4.0   0.0E+00    5.0    220.0
            T   FRUIT  90.00  0   0.0    0.0    2.0   0.0E+00    5.0    330.0
            T   GRAIN  90.00  0   0.0    0.0    0.8   0.0E+00  180.0     80.0

            ====ANIMAL PRODUCTION CONSUMPTION===================SECTION 10====

            ---HUMAN---- TOTAL   DRINK    ------------STORED FEED-------------
USE         CONSUMPTION  PROD-   WATER    DIET  GROW  -IRRIGATION--       STOR-
?   FOOD    RATE  HOLDUP UCTION  CONTAM   FRAC- TIME  S RATE  TIME  YIELD AGE
T/F TYPE    kg/yr   da    kg/yr  FRACT.   TION  da    * in/yr mo/yr kg/m3 da
--- ------ ------ -----  ------ -------   ----  ----  - ----- ----- ----- -----
T   BEEF     80.0  15.0   0.00    0.00    0.00  90.0  0   0.0  0.00  0.80   0.0
T   POULTR   18.0   1.0   0.00    0.00    0.00  90.0  0   0.0  0.00  0.80   0.0
T   MILK    270.0   1.0   0.00    0.00    0.00  45.0  0   0.0  0.00  2.00   0.0
T   EGG      30.0   1.0   0.00    0.00    0.00  90.0  0   0.0  0.00  0.80   0.0
                                           ------------FRESH FORAGE-----------
    BEEF                                  0.00  45.0  0   0.0  0.00  2.00 100.0
    MILK                                  0.00  30.0  0   0.0  0.00  1.50   0.0

##############################################################################
```

4.0 CONTAINMENT EVALUATION

4.1 INTRODUCTION

Evaluations in this section are provided to assure that the packaging containment system is acceptable to withstand designated conditions during normal onsite transfers of the package. The packaging containment system is described in Part A, Section 2.5.

4.2 NORMAL TRANSFER CONDITIONS

For normal conditions of transfer, the containment system shall withstand a simulated 1 ft drop of the packaging from a horizontal position onto a 12 in. thick reinforced concrete slab with #9 rebar at 12 in. spacings for reinforcement. Evaluation of the simulated drop will verify that material stresses will not exceed yield stresses at critical structural or closure locations.

Normal vibration of the package during transfer will be evaluated to assure that the package is capable of withstanding the expected movements.

The package shall be evaluated to determine the effects of a reduction in external pressure of 3.5 psi absolute and an increase in external pressure of 20 psi absolute.

A penetration test shall be performed on the package to determine the effects of the hemispherical end of a vertical steel cylinder of 3.2 cm diameter and 6 kg mass dropped from a height of 1 m. The steel cylinder shall be dropped onto the exposed surface of the package which is expected to be most vulnerable to penetration. The long axis of the axis of the cylinder must be perpendicular to the package surface.

Testing and evaluations for normal conditions of onsite transfers shall consider the effects of transferring a package at ambient temperatures between 0 °F and 115 °F.

4.3 CONTAINMENT EVALUATION AND CONCLUSIONS

Evaluations to assure that the packaging containment system is acceptable for safe transfer of the pump package was based on results of Normal Transfer Condition testing analyses (Part B, Section 6.4), a radiological risk evaluation (Part B, Section 3.6), dose consequence evaluation (Part B, Section 3.7), and a gas generation study (Part B, Section 8.3).

Results of the simulated free drop, vibration, penetration, and pressure tests indicated that the package will not lose integrity of the containment barrier during normal transfer operations.

Results of the risk evaluation (as shown in Part B, Section 3.6) indicated that a release of the package contents is extremely unlikely, and if a release was made, the dose consequence (as shown in Part B, Section 3.7) would not exceed acceptable Hanford Site limits for an incredible accident assessment.

Results of a gas generation study indicated that hydrogen gas build-up in a package would not exceed 5% (for "worst case" waste material attached to a pump) within the twenty year service life of the package. To prevent the possibility of hydrogen build-up in excess of 5%, the package is fitted with an approved filter when placed into storage.

Conclusions of this evaluation are that the packaging containment system is considered acceptable to safely contain radioactive materials for normal conditions of transfer identified in this SEP.

5.0 SHIELDING EVALUATION

5.1 INTRODUCTION

Evaluations in this section are provided to assure that the packaging shielding system is adequate to provide sufficient shielding of the package during designated normal conditions of transfer. Since the package will be transferred to the CWC for storage, the lowest acceptable dose rate at the surface of the package for either transfer or storage of the package will be considered the controlling dose rate for evaluations in this SEP. A shielding analysis was completed to support evaluations in this SEP and is shown in Part B, Section 5.4

5.2 SHIELDING REQUIREMENTS

Shielding shall limit the dose rate on the surface of the package to 200 mrem/h and 10 mrem/h at 2 m from the vehicle for transfer of the package. For storage of **mixed low-level waste**, the dose rate on the surface of the package shall be limited to 100 mrem/h (WHC 1993). Shielding material shall be added to the package annulus or secured to the outside of the package as required to withstand normal conditions of transfer. The dose rate at the vehicle driver location shall not exceed 2 mrem/h during transfer of the package.

To assure that the lowest identified shielding requirements of 100 mrem/h can be met at the surface of the package, the packaging design shall include provisions to install sufficient shielding material in the annulus of the package and on the outside of the package to limit dose rates to 100 mrem/h or less. The design shall also include provisions for remote installation of the shielding material.

5.3 SHIELDING EVALUATION AND CONCLUSIONS

A shielding analysis (Part B, Section 5.4) was performed for addition of lead shot or steel shot in the 2 in. annulus space of the shipping container to reduce dose rates to less than 100 mrem/h at the surface of the package. The analysis was based on "worst case" waste material attached and contained inside the hydrogen mitigation mixer pump. A film thickness of 3 mm and waste material holdup of 68 gallons was assumed (Part B, Section 2.0). Considerations were made for the approximate location of the mixer pump with respect to the ends of the package to assure that the dose rate limits were not exceeded for the total length of the package.

Results of the shielding analysis indicated that the package containing the 101-SY HMMP must require addition of lead shot into the 2 in. annulus space for the "worst case" waste for a minimum length of 800 cm on the "hot" end of the package. Considering that the annulus for shielding addition is 2 in. thick and that the pump will be rinsed with a high pressure water spray (3000 psi at 160 °F) during removal from the tank, the packaging design is more than adequate to assure that the dose rates on the surface of the package can be limited to 100 mrem/h.

Based on evaluation of the high pressure spray operation for radioactive waste removal and evaluation of the package surface dose rates taken prior to transport, use of steel shot or no shielding may be considered for specific sections of the package. This will satisfy all requirements for transfer and storage of the package except for dose limits at the driver location. Dose limits at the driver location based on the estimated location of the package on the transport vehicle tractor require evaluation and the actual dose rates shall be less than 2 mrem/h. This will be verified in the field prior to transfer of the package.

5.4 SHIELDING ANALYSIS

**Westinghouse
Hanford Company**

**Internal
Memo**

From: Radiation Physics and Shielding
Phone: 376-9892 H0-35
Date: July 22, 1994
Subject: ESTIMATED DOSE RATES OF THE SURFACE OF THE 101-SY MIXER PUMP SHIPPING CONTAINER

8D530-SRG-94-007

To:	R. F. Carlstrom	G2-02		
cc:	H. E. Adkins, Jr.	G2-03	S. R. Crow	G2-03
	J. Greenborg	H0-35	J. P. Hauptman	S2-03
	A. E. Waltar	H0-32	SRG File/LB	

References:

1) Internal Memorandum from E. R. Selle to D. C. Hetzer, "*Cesium Inventory Remaining on Air Lances Removed from Tank 101-SY*,: December 16, 1992, 29250-ERS-92014.

2) Briesmeister, J. F., Editor, *MCNP -- A General Monte Carlo N-Particle Transport Code*. Version 4A, LA-12625, Los Alamos National Laboratory, Los Alamos, New Mexico, 1993.

3) Carter, L. L. and R. A. Schwarz, *Certification of MCNP Version 4A for WHC Computer Platforms*, ECN 186710, January 4, 1994.

This analysis provides radiological dose rate estimates for a contaminated 101-SY hydrogen mitigation mixing pump (HMMP) in various configurations of a shielded shipping container. Dose rates were also calculated at the 51 foot elevation, where it is anticipated the pump would be cut after placement in the shipping container.

The shipping container is modelled as two concentric cylinders with an annulus region filled with lead or steel shot. The inner cylinder is 0.5" steel, the outer was modelled as either 0.25" or 0.5" steel. The annulus region between was either 1.5" or 2.0" and modelled with steel shot, lead shot or air. A packing factor of 60% was assumed when calculating the average density of regions filled with shot. The bottom of the shipping container was modelled as two steel plates separated by a 0.5" air gap. The inner plate was placed 21.25" below the bottom of the pump.

The HMMP was modelled as a combination of simple geometrical shapes representing the 6" pump discharge legs, 16" pump support column, riser seal discs and pump casting. These structures comprise the majority of the wetted surface areas and are the basis for a source term of approximately 13 gallons of slurry. Additionally, it was assumed that the 6" discharge legs and the impeller casing are completely filled with slurry. This represents a worst anticipated interior contamination of the mixer pump, and adds 68 gallons of slurry to the source term. The actual MCNP model is shown in Figure 1; the yellow regions show the source regions. Reference 1 indicates that 101-SY slurry has a density of 1.74 g/cc and a ^{137}Cs specific activity of 360 μCi/g.

Results of this analysis are given in the attached Tables. Note that pump column internals (i.e. conduit/pipe/guide plates), riser seal discs, and other components above the wetted zone are not modelled, and that the calculated dose rates at the top end of the model are undoubtably high. Specifically, the dose rate on the top centerline of the support column is probably high by an order of magnitude.

S. R. Gedeon, Advanced Engineer
Radiation Physics and Shielding

R J Morford

Reviewed by: ______________________________
R. J. Morford, Principal Scientist
Radiation Physics and Shielding

sam

Attachments

7/22/94

Concurrence: ________________________ Date: ________
J. Greenborg, Manager
Radiation Physics and Shielding

elev above HMMP bottom (cm)	Dose Rate (mrem/hr)						
	air		lead shot			steel shot	
	annulus thickness / outer cover thickness (inches)						
	1.5/.25	2./.5	1.5/.25	2/.25	2/.5	1.5/.25	2./.5
12.55	2242	1685	116	44	35	901	481
38.05	2951	2228	159	61	49	1194	640
338.05	3745	2795	181	69	55	1448	756
487.6	6131	4489	280	104	83	2275	1175
566.	6785	4937	295	107	84	2502	1277
600.	6348	4637	298	109	87	2386	1227
650.	4044	2923	183	67	53	1472	754
700.	1259	880	30	10	8	346	159
750.	668	469	22	8	7	196	95
800.	530	383	20	7		177	87
850.	444	328	20	7		158	82
900.	385	289	18	7		149	76
950.	269	200	13	5		105	54
1000.	182	132	8	3		71	36
1050.	91	63					
1100.	38						
1500.	<1						
1550.	<1						

Table 1. Maximum Radial Dose Rate as a Function of Distance from the Bottom of the Hydrogen Mitigation Mixing Pump.

Bottom	Dose Rate mrem/hr	Top	Dose Rate mrem/hr
2" and 1.25" endplates	189	centerline	94
2" and 2" endplates	79	10 cm off centerline	10

Table 2. Dose Rates at Ends of Shipping Container

Attachment

MCNP Input File

```
Gamma Dose Rate Tank 101-SY Mixer Pump 1.5 inch annulus shipping asby
c    no Pb, air in annulus
c    mat#  mat.den   surfaces
1    2    -.0012   -1  -200 100          $air inside 6" pipe
2    2    -.0012   -2  1  -200 100      $no cont. inside pipe
3    3    -7.8     -3  2  -200 100      $6" steel pipe
4    1    -1.5     -4  3  -200 100      $ cont. outside of pipe
10   2    -.0012   -10  -200 100        $air inside 6" pipe
11   1    -1.5     -11  10 -200 100     $1mm cont. inside pipe 2
12   3    -7.8     -12  11 -200 100     $6" steel pipe 2
13   1    -1.5     -13  12 -200 100     $1mm cont. outside pipe 2
20   2    -.0012   -20  -200 100        $air inside pipe 3
21   2    -.0012   -21  20 -200 100     $no  cont. inside pipe 3
22   3    -7.8     -22  21 -200 100     $6" steel pipe 3
23   1    -1.5     -23  22 -200 100     $1mm cont. outsid pipe 3
30   2    -.0012   -30  -200 100        $air inside pipe 4
31   1    -1.5     -31  30 -200 100     $1mm cont. outside pipe 4
32   3    -7.8     -32  31 -200 100     $6" steel pipe 4
33   1    -1.5     -33  32 -200 100     $1mm cont. outside pipe 4
41   2    -.0012   -41  200 -420        $air inside pipe 1b
42   2    -.0012   41  -42  200  -420   $1mm cont. inside pipe 1b NOT
43   3    -7.8     42  -43  200  -420   $6" steel pipe 1b
44   1    -1.5     43  -44  200  -420   $cont. outside pipe 1b
51   2    -.0012   -51  200  -420       $air inside pipe 2b
52   1    -1.5     51  -52  200  -420   $cont. inside pipe 2b
53   3    -7.8     52  -53  200  -420   $steel pipe 2b
54   1    -1.5     53  -54  200  -420   $cont. outside pipe 2b
61   2    -.0012   -61  200  -420       $air inside pipe 3b
62   2    -.0012   61  -62  200  -420   $cont inside pipe 3b  NOT
63   3    -7.8     62  -63  200  -420   $steel pipe 3b
64   1    -1.5     63  -64  200  -420   $cont. outside pipe 3b
71   2    -.0012   -71  200  -420       $air inside pipe 4b
72   1    -1.5     71  -72  200  -420   $cont. inside pipe 4b
73   3    -7.8     72  -73  200  -420   $steel pipe 4b
74   1    -1.5     73  -74  200  -420   $cont. outside pipe 4b
90   2    -.0012   -90  209  -400       $air inside support column
91   3    -7.8      90 -91 200 -400     $1/8" steel support column
92   1    -1.5      91 -92 200 -400     $cont. on column
93   1    -1.5     -90      200 -209    $volute, impeller filled w/ waste
110  3    -7.8     -101 4 13 23 33 109 -110   $disc 1
111  1    -1.5     -101 4 13 23 33 111 -109   $1mm cont. under disc 1
112  1    -1.5     -101 4 13 23 33 110 -112   $1mm cont. on top of disc 1
120  3    -7.8     -101 4 13 23 33 120 -121   $disc 2
121  1    -1.5     -101 4 13 23 33 122 -120   $cont. on bottom disc 2
122  1    -1.5     -101 4 13 23 33 121 -123   $cont. on top disc 2
130  3    -7.8     -101 4 13 23 33 130 -131   $disc 3
131  1    -1.5     -101 4 13 23 33 132 -130   $cont. on bottom disc 3
132  1    -1.5     -101 4 13 23 33 131 -133   $cont. on top disc 3
140  3    -7.8     -101 4 13 23 33 140 -141   $disc 4
141  1    -1.5     -101 4 13 23 33 142 -140   $cont. on bottom disc 4
142  1    -1.5     -101 4 13 23 33 141 -143   $cont. on top disc 4
150  3    -7.8     -101 4 13 23 33 150 -151   $disc 5
151  1    -1.5     -101 4 13 23 33 152 -150   $cont. on bottom disc 5
152  1    -1.5     -101 4 13 23 33 151 -153   $cont. on top disc 5
160  3    -7.8     -101 4 13 23 33 160 -161   $disc 6
161  1    -1.5     -101 4 13 23 33 162 -160   $cont. on bottom disc 6
162  1    -1.5     -101 4 13 23 33 161 -163   $cont. on top disc 6
170  3    -7.8     -101 4 13 23 33 170 -171   $disc 7
171  1    -1.5     -101 4 13 23 33 172 -170   $cont. on bottom disc 7
172  1    -1.5     -101 4 13 23 33 171 -173   $cont. on top disc 7
180  3    -7.8     -101 4 13 23 33 180 -181   $disc 8
181  1    -1.5     -101 4 13 23 33 182 -180   $cont. on bottom disc 8
182  1    -1.5     -101 4 13 23 33 181 -183   $cont. on top disc 8
210  3    -7.8     -101 92 44 54 64 74 210 -211  $disc 9
211  1    -1.5     -101 92 44 54 64 74 212 -210  $cont. on bot. of 9
212  1    -1.5     -101 92 44 54 64 74 211 -213  $cont. on top of 9
220  3    -7.8     -101 92  220 -221  $disc 10
221  1    -1.5     -101 92  222 -220  $cont.on bot. of 10
222  1    -1.5     -101 92  221 -223  $cont. on top of 10
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```
230  3   -7.8      -101 92  230 -231  $disc 11
231  1   -1.5      -101 92  232 -230  $cont. on bot of 11
232  1   -1.5      -101 92  231 -233  $cont. on top of 11
240  3   -7.8      -101 92  240 -241  $disc 12
241  1   -1.5      -101 92  242 -240  $cont. on bot of 12
242  1   -1.5      -101 92  241 -243  $cont. on top 12
300  2   -.0012    -101 4 13 23 33 100 -111   $air space b/n datum & dsc1
301  2   -.0012    -101 4 13 23 33 112 -122   $air space b/n disc 1&2
302  2   -.0012    -101 4 13 23 33 123 -132   $  "  "    "    "   2&3
304  2   -.0012    -101 4 13 23 33 133 -142   $  "  "    "    "   3&4
306  2   -.0012    -101 4 13 23 33 143 -152   $  "  "    "    "   4&5
308  2   -.0012    -101 4 13 23 33 153 -162   $  "  "    "    "   5&6
310  2   -.0012    -101 4 13 23 33 163 -172   $  "  "    "    "   6&7
312  2   -.0012    -101 4 13 23 33 173 -182   $  "  "    "    "   7&8
314  2   -.0012    -101 4 13 23 33 183 -200   $  "  "    "    "8 and top
320  2   -.0012    -101 92 44 54 64 74 200 -212  $air b/n sec 1 and dsc 9
322  2   -.0012    -101 92 44 54 64 74 213 -420  $air b/n dsc 9&top of pipes
324  2   -.0012    -101 92 420 -222        $air b/n top pipes & dsc 10
326  2   -.0012    -101 92 223 -232        $air b/n dsc10 & 11
328  2   -.0012    -101 92 233 -242        $air b/n dsc11 & 12
330  2   -.0012    -101 92 243 -400        $air b/n dsc12 & top
601  2  -0.0012     101 -93     100  -400  $air b/n pump & shipping assembly
602  3  -7.8         93 -94     100  -400  $shipping asby--structural steel
603  2  -0.00122     94 -95     100  -400  $Pb annulus
604  3  -7.8         95 -96     100  -400  $steel cover on Pb annulus
605  2  -0.0012     ( 97 : -455  : 440 )  -1000  $ air outside shipping asby
651  2  -0.0012     -96         -100   451  $ air
652  3  -7.8        -96         -451   452  $ inner end plate
653  2  -0.0012     -96         -452   453  $ half inch air gap btwn end plts
654  3  -7.8        -96         -453   454  $ outer 2" end plate
661  2  -0.0012     -90          400  -440  $ air inside support column
662  3  -7.8         90  -91     400  -440  $ support column
663  2  -0.0012      91  -93     400  -440  $ air btwn sup col & ship asby
664  3  -7.8         93  -94     400  -440  $ inner ship container
665  2  -0.0012      94  -95     400  -440  $ annulus btwn inner & outer
666  3  -7.8         95  -96     400  -440  $ outer cover
667  2  -0.0012     -97 (96 : -454) 455 -440 $ 2 in airgap btwn asbly & dose plane
1001 0              1000                           $universe

1      c/z   0 -20.0 7.52         $1mm thick cont. inside 6" pipe
2      c/z   0 -20.0 7.62         $inside pipe dia.
3      c/z   0 -20.0 8.414        $outside pipe dia.
4      c/z   0 -20.0 8.514        $1mm thick cont. outside 6" pipe
10     c/z   -20.0 0 7.52         $        "
11     c/z   -20.0 0 7.62         $        "
12     c/z   -20.0 0 8.414        $        "
13     c/z   -20.0 0 8.514        $        "
20     c/z   0  20.0  7.52        $        "
21     c/z   0  20.0  7.62        $        "
22     c/z   0  20.0  8.414       $        "
23     c/z   0  20.0  8.514       $        "
30     c/z   20.0  0  7.52        $        "
31     c/z   20.0  0  7.62        $        "
32     c/z   20.0  0  8.414       $        "
33     c/z   20.0  0  8.514       $        "
100    pz    0                    $bottom of mixer pump
200    pz    480.0                $top of the bottom section
101    cz    56.0                 $radius of the seal discs
109    pz    10.0                 $bottom of disc 1
110    pz    15.1                 $top of disc 1
111    pz    9.9                  $cont. on bottom of disc 1
112    pz    15.2                 $cont. on top of disc 1
120    pz    61.0                 $bottom of disc 2
121    pz    66.1                 $top of disc 2
122    pz    60.9                 $cont. on bottom of disc 2
123    pz    66.2                 $cont. on top of disc 2
130    pz    122.0                $bottom of disc 3
131    pz    127.1                $top of disc 3
132    pz    121.9                $cont. on bottom of disc 3
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133  pz    127.2                  $cont. on top of disc 3
140  pz    183.0                  $bottom of disc 4
141  pz    188.1                  $top of disc 4
142  pz    182.9                  $cont. on bottom of disc 4
143  pz    188.2                  $cont. on top of disc 4
150  pz    244.0                  $bottom of disc 5
151  pz    249.1                  $top of disc 5
152  pz    243.9                  $cont. on bottom of disc 5
153  pz    249.2                  $cont. on top of disc 5
160  pz    305.0                  $bottom of disc 6
161  pz    310.1                  $top of disc 6
162  pz    304.9                  $cont. on bottom of disc 6
163  pz    310.2                  $cont. on top of disc 6
170  pz    366.0                  $bottom of disc 7
171  pz    372.1                  $top of disc 7
172  pz    365.9                  $cont. on bottom of disc 7
173  pz    372.2                  $cont. on top of disc 7
180  pz    457.5                  $bottom of disc 8
181  pz    462.6                  $top of disc 8
182  pz    457.4                  $cont. on bottom of disc 8
183  pz    462.7                  $cont. on top of disc 8
209  pz    495.2                  $top of impeller/volute region
210  pz    570.1                  $bottom of disc 9
211  pz    575.2                  $top of disc 9
212  pz    570.0                  $cont. on bottom of disc 9
213  pz    575.3                  $cont. on top of disc 9
220  pz    670.1                  $bottom disc 10
221  pz    675.2                  $top of disc 10
222  pz    670.0                  $cont. on bottom of disc 10
223  pz    675.3                  $cont. on top of disc 10
230  pz    770.1                  $bottom of disc 11
231  pz    775.2                  $top of disc 11
232  pz    770.0                  $cont. on bottom of disc 11
233  pz    775.3                  $cont. on top of disc 11
240  pz    870.1                  $bottom of disc 12
241  pz    875.2                  $top of disc 12
242  pz    870.0                  $cont. on bottom of disc 12
243  pz    875.3                  $cont. on top of disc 12
400  pz   1016.0                  $top of cont. portion of mixer pump (400 in)
420  pz    652.0                  $top of pump/pipes end
440  pz   1555.0                  $ 51 ft above bottom of pump
451  pz    -53.975                $air gap betwn pump & inner end plate
452  pz    -57.150                $outer side of inner end plate
453  pz    -58.420                $half inch air gap btwn plates
454  pz    -63.500                $outer side of outer end plate
455  pz    -68.580                $ tally surface 2" past end plate
41   c/z   0 -43.0  7.52          $1mm thick cont. inside pipe
42   c/z   0 -43.0  7.62          $inside pipe dia.
43   c/z   0 -43.0  8.414         $outside pip dia.
44   c/z   0 -43.0  8.514         $1mm cont. outside pipe
51   c/z   -43.0 0  7.52          $1mm cont. inside pipe
52   c/z   -43.0 0  7.62          $inside pipe dia.
53   c/z   -43.0 0  8.414         $outside pipe dia.
54   c/z   -43.0 0  8.514         $1mm cont. outside pipe
61   c/z   0  43.0  7.52          $   "    "
62   c/z   0  43.0  7.62.         $   "    "
63   c/z   0  43.0  8.414         $   "    "
64   c/z   0  43.0  8.514         $   "    "
71   c/z   43.0  0  7.52          $   "    "
72   c/z   43.0  0  7.62          $   "    "
73   c/z   43.0  0  8.414         $    "   "
74   c/z   43.0  0  8.514         $   "  "
90   cz    20.0                   $ support column inner wall
91   cz    20.32                  $ support column outer wall
92   cz    20.42                  $ 1mm cont. on surface of column
93   cz    80.015                 $ inner radius shipping asby struct
94   cz    81.285                 $ outer radius   "      "    "
95   cz    85.095                 $ inner radius annulus cover
96   cz    85.730                 $ outer radius annulus cover
```

```
97   cz    90.810              $ tally surface--2" out from annulus cover
1000 so    4000                $atmosphere

mode     p
phys:p   10 1 0
idum     1 0 0  0 0
c        cell numbers
c        1   2   3   4   10   11   12   13   20   21   22   23
imp:p    1   2m  2m  2m  1    2m   2m   2m   1    2m   2m   2m
c        30  31  32  33  41   42   43   44   51   52
         1   2m  2m  2m  1    2m   2m   2m   1    2m
c        53  54  61  62  63   64   71   72   73   74
         2m  2m  1   2m  2m   2m   1    2m   2m   2m
c        90  91  92  93
         1   2m  2m  1m
c        110  111  112  120  121  122
         1m   2m   1m   .5m  2m   1m
c        130  131  132  140  141  142  150  151  152
         .5m  2m   1m   .5m  2m   1m   .5m  2m   1m
c        160  161  162  170  171  172  180  181  182
         .5m  2m   1m   .5m  2m   1m   .5m  2m   1m
c        210  211  212  220  221  222  230  231  232
         .5m  2m   1m   .5m  2m   1m   .5m  2m   1m
c        240  241  242
         .5m  2m   1m
c        300  301  302  304  306  308  310  312  314
         2m   1m   1m   1m   1m   1m   1m   1m   1m
c        320  322  324  326  328  330  601  602  603
         1m   1m   1m   1m   1m   1m   2m   1m   1m
c        604  605  651-667   1001
          1m   1m  11r          0
sdef     sur=0  erg=.662  wgt=5.897e+12  cel=d1  rad fcel=d2  pos fcel=d3
         ext fcel=d4 axs=0 0 1
c        wgt = (360 uCi/g)(1.74 g/cc)(3.7E+4 dps/uCi)(.946X.9)(4.80E+4 cc)
c            + (360      )(1.74     )(3.7e+4        )(.946x.9)(2.508e+4  )
sc1      source cells
#        si1      sp1
         l        d
         4        2.553e+3
         10       8.528e+4
         11       2.283e+3
         13       2.553e+3
         23       2.553e+3
         30       8.528e+4
         31       2.283e+3
         33       2.553e+3
         44       9.147e+2
         51       3.056e+4
         52       8.181e+2
         54       9.147e+2
         64       9.147e+2
         71       3.056e+4
         72       8.181e+2
         74       9.147e+2
         92       6.832e+3
         93       1.915e+4
         111      9.852e+2
         112      9.852e+2
         121      9.852e+2
         122      9.852e+2
         131      9.852e+2
         132      9.852e+2
         141      9.852e+2
         142      9.852e+2
         151      9.852e+2
         152      9.852e+2
         161      9.852e+2
         162      9.852e+2
         171      9.852e+2
```

```
        172     9.852e+2
        181     9.852e+2
        182     9.852e+2
        211     9.852e+2
        212     9.852e+2
        221     9.852e+2
        222     9.852e+2
        231     9.852e+2
        232     9.852e+2
        241     9.852e+2
        242     9.852e+2
c       sample radius
ds2     s 102 142 103 104 106 143 107 108 110 144 111 112 114 145
          115 116 117 146 118 119 120 121 122 123 124 125 126 127 128
          129 130 131 132 133 134 135 136 137 138 139 140 141
si102   8.414   8.514
si142   0       7.52
si103   7.52    7.62
si104   8.414   8.514
si106   8.414   8.514
si143   0.      7.52
si107   7.52    7.62
si108   8.414   8.514
si110   8.414   8.514
si144   0       7.52
si111   7.52    7.62
si112   8.414   8.514
si114   8.414   8.514
si145   0       7.52
si115   7.52    7.62
si116   8.414   8.514
si117   20.32   20.42
si146   0       20.0
si118   0       56.0
si119   0       56.0
si120   0       56.0
si121   0       56.0
si122   0       56.0
si123   0       56.0
si124   0       56.0
si125   0       56.0
si126   0       56.0
si127   0       56.0
si128   0       56.0
si129   0       56.0
si130   0       56.0
si131   0       56.0
si132   0       56.0
si133   0       56.0
si134   0       56.0
si135   0       56.0
si136   0       56.0
si137   0       56.0
si138   0       56.0
si139   0       56.0
si140   0       56.0
si141   0       56.0
sc3     sample position
ds3     l
        0   -20.0    0
        -20.0   0.   0.
        -20.0   0    0
        -20.0   0    0
        0    20.0    0
        20.0    0    0
        20.0    0    0
        20.0    0    0
        0   -43.0    0
        -43.0   0    0
```

```
        -43.0    0    0
        -43.0    0    0
        0    43.0    0
        43.0     0    0
        43.0     0    0
        43.0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
           0     0    0
c       sample extent
ds4     s  202 242 203 204 206 243 207 208 210 244 211 212 214 245
           215 216 217 246 218 219 220 221 222 223 224 225 226 227
           228 229 230 231 232 233 234 235 236 237 238 239 240 241
si202   0  480
si242   0  480
si203   0  480
si204   0  480
si206   0  480
si243   0  480
si207   0  480
si208   0  480
si210   480  652
si244   480  652
si211   480  652
si212   480  652
si214   480  652
si245   480  652
si215   480  652
si216   480  652
si217   480  1016
si246   480  495.2
si218   9.9    10.0
si219   15.1   15.2
si220   60.9   61.0
si221   66.1   66.2
si222   121.9  122.0
si223   127.1  127.2
si224   182.9  183.0
si225   188.1  188.2
si226   243.9  244.0
si227   249.1  249.2
si228   304.9  305.0
si229   310.1  310.2
si230   365.9  366.0
si231   372.1  372.2
si232   457.4  457.5
```

```
si233   462.6  462.7
si234   570.0  570.1
si235   575.2  575.3
si236   670.0  670.1
si237   675.2  675.3
si238   770.0  770.1
si239   775.2  775.3
si240   870.0  870.1
si241   875.2  875.3
m1        1001.50 .4372       $H 101 SY Slurry
          6000.50 .0170       $C
          7014.50 .0579      $N
          8016.50 .3725      $O
         11023.50 .0975      $Na
         13027.50 .0113      $Al
         15031.50 .0011      $P
         17000.50 .0029      $Cl
         19000.50 .0026      $K
m2        8016.50  .21       $O air number fraction
          7014.50  .79       $N
m3       26000.55 1.0        $Fe iron
m4        8016.50 -.4407     $O concrete weight fraction
         14000.50 -.2157     $Si
         20000.50 -.1306     $Ca
         26000.55 -.0788     $Fe
         13027.50 -.0607     $Al
         12000.50 -.0376     $Mg
         19000.50 -.0066     $K
         11023.50 -.0182     $Na
         22000.50 -.0049     $Ti
          1001.50 -.0031     $H
         25055.50 -.0013     $Mn
         15031.50 -.0009     $P
         16032.50 -.0009     $S
m5       82000.50  1.0       $Pb shielding
c
f5:p     0.0  62 550  +5
fc5      contact on pump
fm5      1.3                 $increase tally by 30% for unmodeled surfaces
c
f15:p    0.0  90.811  12.55  +5
fc15    cover contact y axis, z=12.55 cm
c
f25:p    90.811  0.0  12.55  +5
fc25    cover contact x axis, z=12.55 cm
c
f35:p    0.0  90.811  38.05  +5
fc35    cover contact y axis, z=38.05 cm
c
f45:p    90.811  0.0  38.05  +5
fc45    cover contact x axis, z=38.05 cm
c
f55:p    0.0  90.811  338.05  +5
fc55    cover contact y axis, z=338.05 cm
c
f65:p    90.811  0.0  338.05  +5
fc65    cover contact x axis, z=338.05 cm
c
f75:p    0.0  90.811  487.6  +5
fc75    cover contact y axis, z=487.6 cm
c
f85:p    90.811  0.0  487.6  +5
fc85    cover contact x axis, z=487.6 cm
c
f95:p    0.0  90.811  566.0  +5
fc95    cover contact y axis, z=566.0 cm
c
f105:p    90.811  0.0  566.0  +5
fc105    cover contact x axis, z=566.0 cm
```

```
c
f115:p    0.0   0.0  1555.0  +5
fc115   top of assembly, center
c
f125:p  45.   0.0   1555.0   +5
fc125   top of assembly, off-center x-axis
c
f135:p   0.0  0.0   -68.579  +5
fc135   center of bottom plates, 2 in out
c
f145:p   0.0  90.811  600.0  +5
fc145   cover contact y axis, z=12.55 cm
c
f155:p   90.811  0.0  600.0  +5
fc155   cover contact x axis, z=12.55 cm
c
f165:p   0.0  90.811  650.0  +5
fc165   cover contact y axis, z=38.05 cm
c
f175:p   90.811  0.0  650.0  +5
fc175   cover contact x axis, z=38.05 cm
c
f185:p   0.0  90.811  700.00  +5
fc185   cover contact y axis, z=338.05 cm
c
f195:p   90.811  0.0  700.00  +5
fc195   cover contact x axis, z=338.05 cm
c
f205:p   0.0  90.811  750.0  +5
fc205   cover contact y axis, z=487.6 cm
c
f215:p   90.811  0.0  750.0  +5
fc215   cover contact x axis, z=487.6 cm
c
f225:p   0.0  90.811  800.0  +5
fc225   cover contact y axis, z=566.0 cm
c
f235:p   90.811  0.0  800.0  +5
fc235   cover contact x axis, z=800.0 cm
c
f245:p   0.0  90.811  850.0  +5
fc245   cover contact y axis, z=850.0 cm
c
f255:p   90.811  0.0  850.0  +5
fc255   cover contact x axis, z=850.0 cm
c
f265:p   0.0  90.811  900.0  +5
fc265   cover contact y axis, z=900.0 cm
c
f275:p   90.811  0.0  900.0  +5
fc275   cover contact x axis, z=900.0 cm
c
f285:p   0.0  90.811  950.00  +5
fc285   cover contact y axis, z=950.00 cm
c
f295:p   90.811  0.0  950.00  +5
fc295   cover contact x axis, z=950.00 cm
c
f305:p   0.0  90.811  1000.  +5
fc305   cover contact y axis, z=1000. cm
c
f315:p   90.811  0.0  1000.  +5
fc315   cover contact x axis, z=1000. cm
c
f325:p   0.0  90.811  1050.  +5
fc325   cover contact y axis, z=1050. cm
c
f335:p   90.811  0.0  1050.  +5
fc335   cover contact x axis, z=1050. cm
```

```
c
f345:p   0.0  90.811  1100.  +5
fc345   cover contact y axis, z=1100. cm
c
f355:p   90.811  0.0  1100.  +5
fc355   cover contact x axis, z=1100. cm
c
f365:p   0.0  90.811  1350.  +5
fc365   cover contact y axis, z=1350. cm
c
f375:p   90.811  0.0  1350.  +5
fc375   cover contact x axis, z=1350. cm
c
f385:p   0.0  90.811  1400.  +5
fc385   cover contact y axis, z=1400. cm
c
f395:p   90.811  0.0  1400.  +5
fc395   cover contact x axis, z=1400. cm
c
f405:p   0.0  90.811  1450.  +5
fc405   cover contact y axis, z=1450. cm
c
f415:p   90.811  0.0  1450.  +5
fc415   cover contact x axis, z=1450. cm
c
f425:p   0.0  90.811  1500.  +5
fc425   cover contact y axis, z=1500. cm
c
f435:p   90.811  0.0  1500.  +5
fc435   cover contact x axis, z=1500. cm
c
f445:p   0.0  90.811  1550.  +5
fc445   cover contact y axis, z=1550. cm
c
f455:p   90.811  0.0  1550.  +5
fc455   cover contact x axis, z=1550. cm
c
c
ctme    360.                      $time limit
```

CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

DOCUMENT REVIEWED_ ESTIMATED DOSE RATES OF THE SURFACE OF THE 101-SY MIXER PUMP SHIPPING CONTAINER

AUTHOR(s)___S.R. Gedeon

I. Method(s) of Review

- (✓) Input data checked for accuracy
- (✓) Independent calculation performed
  - (✓) Hand calculation
  - ( ) Alternate computer code:
- ( ) Comparison to experiment or previous results
- ( ) Alternate method (define)

II. Checklist (either check or enter NA if not applied)

- (✓) Task completely defined
- (✓) Activity consistent with task specification
- (✓) Necessary assumptions explicitly stated and supported
- (✓) Resources properly identified and referenced
- (✓) Resource documentation appropriate for this application
- (✓) Input data explicitly stated
- (✓) Input data verified to be consistent with original source
- (✓) Geometric model adequate representation of actual geometry
- (✓) Material properties appropriate and reasonable
- (NA) Mathematical derivations checked including dimensional consistency
- (NA) Hand calculations checked for errors
- (✓) Assumptions explicitly stated and justified
- (✓) Computer software appropriate for task and used within range of validity
- (NA) Use of resource outside range of established validity is justified
- (✓) Software runstreams correct and consistent with results
- (✓) Software output consistent with input
- (✓) Results consistent with applicable previous experimental or analytical findings
- (✓) Results and conclusions address all points and are consistent with task requirements and/or established limits or criteria
- (✓) Conclusions consistent with analytical results and established limits
- (NA) Uncertainty assesment appropriate and reasonable
- ( ) Other (define)

III. Comments:

IV. REVIEWER: R J Morford DATE: 7-20-94

6.0 STRUCTURAL EVALUATION

6.1 INTRODUCTION

Evaluations in this section are provided to assure that the packaging structural system is adequate to withstand designated normal conditions of transfer and other specified structural requirements of the packaging. The structural evaluation is based on requirements provided in the following sections.

6.2 STRUCTURAL REQUIREMENTS

6.2.1 Packaging Materials

Packaging construction materials shall be based on the following requirements for the transfer and storage of the package:

1. Packaging construction materials shall be selected to assure that there will be no significant chemical, galvanic, or other reaction among the packaging components or between the package components and the package contents, including possible reaction resulting from inleakage of water to the maximum credible extent during the 20 year specified lifetime of the packaging.

2. Material structural properties shall conform to packaging structural design analysis provided in this SEP.

3. Packaging containment materials with thickness between 0.4 in. and 4.0 in. shall meet packaging category III fracture toughness requirements shown in Table 6 of NUREG/CR-1815. The Lowest Service Temperature (LST) for design purposes shall be 0 °F.

6.2.2 Packaging Dimensions

The waste shipping container shall be sized to transfer and contain for storage the "package contents" described in Part A, Section 2.0 of the SEP. Specifically, the designated hydrogen mitigation mixer pump placed in a flexible bag assembly. Clearance dimensions required for the packaging enclosure cavity shall consider adequate clearance for installing the flexible bag assembly.

6.2.3 Tiedown System

Tiedown devices that are attached to the shipping container shall be capable of holding the package on the transport trailer during sudden stops and cornering speeds of 15 mph without exceeding the yield strength of the tiedown device or its connection point to the package. In addition, tiedown devices that are a structural part of the package must be capable of withstanding, without generating stress in any material of the package in excess of its yield strength, a static force applied to the center of gravity of the package having a vertical component of two times the weight of the package with its contents, a horizontal component along the direction in which the vehicle travels of 10 times the weight of the package with its contents, and a horizontal component in the transverse direction of five times the weight of the package with its contents. Any other structural part of the package which could be used to tie down the package shall be rendered inoperable for tying down the package during transport, or shall be designed with strength equivalent to that required for tiedown devices. Each tiedown device which is a structural part of a package must be designed so that failure of the device under excessive load would not impair the ability of the package to meet other requirements of this section.

The tiedown system used to secure the package to the transport vehicle shall be designed and evaluated to assure that the tiedown assemblies used to secure the package against movement in any direction have the aggregate static breaking strength of at least 1½ times the weight of the package. Design and analysis of the tiedown system shall be provided as part of the packaging design project and will be included as part of the SEP documentation.

6.2.4 Lifting Devices

Attachments shall be provided on the shipping container as required to safely lift the waste package and secure the package during transfer. Any lifting attachment that is a structural part of the package shall be designed with one of the following:

- A minimum safety factor of three against yielding.

- A safety factor of five based on the ultimate strength of the material.

When the lifting attachment is used as intended, it must be designed so that a lifting device failure caused by an excessive load would not impair the package from meeting other criteria. Any structural part of the package not approved for lifting the package must be capable of being rendered inoperable for lifting the package during transfer or must be designed with strength equivalent to that required for the approved lifting attachments.

6.2.5 Closure Design

The package shall have positive closure devices that cannot be opened unintentionally and shall keep the closures on. The closure shall also meet the requirements for the primary containment barrier of the package for transfer and storage of the waste. The closure system, if required, shall provide for remote closure with guides allowing remote lid positioning. Any penetrations on the package that will not be used shall be provided with acceptable closure devices.

6.2.6 Normal Transfer Conditions

Specific requirements for normal conditions of transfer and testing of the packaging are shown in Part B, Section 4.2. The drop test for structural evaluations shall consist of a simulated 1 ft drop of a unshielded HMMP Package, a 1 ft drop with partial shielding to column line 14, and a 1 ft drop of a fully shielded HMMP Package from a horizontal position onto a 12 in. thick reinforced concrete slab with #9 rebar at 12 in. spacings for reinforcement. In addition, the penetration, vibration, and pressure testing described in Part B, Section 4.2 will also be evaluated in the structural section of this SEP.

6.3 STRUCTURAL EVALUATION AND CONCLUSIONS

6.3.1 Packaging Materials

The shipping container is designed for a 20 year lifetime in the environment of the CWC mixed waste storage facility. Significant galvanic reaction will not be present since all containment materials are similar. Internal corrosion due to possible leakage of the contents is not considered critical since the storage tank waste material is normally 10 pH or higher. The structural materials are carbon steel and all exposed surfaces are painted to prevent external corrosion during the specified package lifetime. The structural strength of the packaging materials required to safely contain and lift the package has been analyzed in the structural analysis shown in Part B, Section 6.4. Results of the analysis indicated that the packaging material is structurally safe for containing and lifting the maximum contents of 138,800 lb for the shipping container.

Evaluation of packaging containment materials to meet the required brittle fracture criteria was based on an analysis of 2 in. thick, normalized (fine grain practice) American Society for Testing and Materials (ASTM) A516 steel in accordance with specifications and criteria presented in NUREG 1815, *Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping containers Up to Four Inches Thick* (Holman and Langland 1981). An evaluation of the brittle fracture guidelines in NUREG 1815 (Holman and Langland 1981) for onsite transfers of radioactive materials under the conditions of this SEP was conducted. In Table 6 of NUREG 1815 (Holman and Langland 1981), there are no requirements for ferritic steels of yield strengths greater than 100 ksi when the material thickness is less than 0.4 in. When material thicknesses are greater than 0.4 in., steels that are made to normalized (fine grain practice) or better, no fracture toughness testing is required. The evaluation indicates that the specified ASTM A516 fine grain material for the shipping container is considered acceptable to meet designated brittle fracture criteria without requiring specific fracture toughness testing and Nil Ductility Testing (NDT) by the manufacturer of the material.

6.3.2 Packaging Dimensions

The packaging internal cavity dimensions are 63 in. in diameter and 52 ft in length. The internal cavity is considered sufficient to contain the HMMP.

6.3.3 Tiedown System

A tiedown analysis for devices attached to the package is shown in Part B, Section 6.5 and indicates that the strength of the attachments meet the identified tiedown requirements and are considered safe for the intended use.

A sketch of the proposed tiedown system that will be used to secure the package to the vehicle is shown in Part B, Section 6.5. The system is based on using the tilt/trailer assembly with the interfacing strongback to transport the package containing the pump. Analysis of the tiedown system indicates that the proposed system is considered safe to secure the shielded or unshielded HMMP Package on the transport vehicle during normal transfer operations. The tiedown system is based on 12 tiedown points on the HMMP Package with 16 cable legs. The breaking strength of tiedown cables will be equal to or exceed 15,430 lb.

6.3.4 Lifting Devices

Evaluation of the lifting attachment analysis provided in Part B, Section 6.5 indicates that the strength of the attachments meet the above design requirements and are considered safe for the intended usage. Other parts of the package not approved for lifting are not readily accessible and do not have any means to inadvertently connect hoisting equipment.

6.3.5 Closure Design

The closure devices (end plates) were analyzed in the drop tests shown in Part B, Section 6.4 for normal conditions of transfer and were shown to maintain the integrity of the seal after dropping the package onto a 12 in. thick reinforced concrete surface with #9 rebar for reinforcement. This test is considered sufficient to assure that the package closures will not leak for a rollover onto soft soil. Remote operation to install or remove closures is not required for a contact handled package shielded to 100 mrem/h. Closures are provided to seal the vent opening during transfer of the package. These closures provide positive sealing and are considered safe for containment of the package during transfer and will be removed during storage of the package for installation of an approved high-efficiency particulate air (HEPA) filter.

6.3.6 Normal Transfer Conditions

Results of analyses for simulated drop tests of the HMMP Package are shown in Part B, Section 6.4. The analysis was based on the determination if critical structural components of the package will exceed yield stresses during impact of the package from a horizontal drop. If yield stresses are not exceeded, the packaging containment body and end closures will be considered to have maintained their integrity following the drop test. Results of the test analysis indicated that the yield stresses were not exceeded and that the package successfully passed the drop tests.

Evaluation of assumed vibration movements of the package during transfer were analyzed and are shown in Part B, Section 6.4. Results of this study indicated that with the package properly secured to the transport vehicle, and with specified administration controls being applied per this SEP, vibration is not a consideration.

The packaging was evaluated to determine if unacceptable damage would result from dropping an object on the surface of the packaging per requirements described in Part B, Section 4.2. Results of a simulated penetration test are shown in Part B, Section 6.4 and indicated that the packaging containment barrier would not be damaged following the simulated test.

Criteria (Part B, Section 4.2) for normal transfer condition tests require that the package be evaluated to determine if it will safely withstand specific internal and external pressures during normal transport of the package. Results of the pressure tests are shown in Part B, Section 6.4 and indicate that the package will safely withstand the specified pressure tests without damage to the containment barrier.

6.4 STRUCTURAL ANALYSIS

6.4.1 Weight and Center of Gravity Determination

ENGINEERING ANALYSIS

Drawing H-2-83734 Doc. No. 101-SY-WTCG-01 Page 1 of 25
Building Tank 241-SY-101 Rev. 0 Job No.
Subject Weight and Center of Gravity Determination
Originator S. S. Shiraga Date 07/29/94
Checker S. R. Crow Date 08/25/94

I. Objectives:

The objective of this is to determine the weight and center of gravity of the Hydrogen Mitigation Mixer Pump Package.

II. References:

1. Industrial Press, Machinery's Handbook, 20th Edition.
2. AISC, American Institute Of Steel Construction, Manual Steel Construction, Ninth Edition.
3. WHC, Drawing, No. H-2-83734, "Hydrogen Mixer Pump Storage Container".
4. Ingersoll-Rand, Compressed Air and Gas Data, 2nd Edition.

III. Results and Conclusions:

The weight and center of gravity calculated herein, form the basis for other engineering evaluations applicable to this package. The calculated values a conservative estimates of the actual weight and are the primary input parame for the drop, lifting, and vibration evaluations. For reasons of conservatism all calculated weights have been rounded upwards. Center of gravity values are all relative to the center of the Bottom End Blind Flange, except for the Top Caps which are relative to the front face of the Top End Flange. The weight and center of gravity of the package for various loading combinations are as follows:

1. Weight of empty package no shielding: $W_{empty} = 57,000$ lbs

   CG of empty package no shielding: $cg_{epack} = 27.3$ ft

2. Weight of empty package with shielding to Column 14:

   $$W_{sh1pack} = 88,000 \text{ lbs}$$

   CG of empty package with shielding to Column 14:

   $$cg_{sh1pack} = 22.36 \text{ ft}$$

3. Weight of empty package with full shielding (Column 25):

   $$W_{sh2pack} = 130,000 \text{ lbs}$$

   CG of empty package with full shielding (Column 25):

   $$cg_{sh2pack} = 26.62 \text{ ft}$$

4. Weight of loaded package with no shielding:

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$$W_{pack} = 76{,}000 \text{ lbs}$$

CG of loaded package with no shielding:

$$cg_{pack} = 28.45 \text{ ft}$$

5. Weight of loaded package shielded to Column 14:

$$W_{packsh1} = 110{,}000 \text{ lbs}$$

CG of loaded package shielded to Column 14:

$$cg_{packsh1} = 29.59 \text{ ft}$$

6. Weight of loaded package fully shielded to Column 25:

$$W_{packsh2} = 145{,}000 \text{ lbs}$$

CG of loaded package fully shielded to Column 25:

$$cg_{packsh2} = 31.83 \text{ ft}$$

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IV. Engineering Evaluation:

Weight Determination of 101-SY Container:

Carbon steel material density (Reference 1, page 2269):

$$\rho_{cstl} = 0.284\ \frac{lbs}{in^3}$$

From Reference 3

1. Main containment pipe:

OD of pipe: $od_{pipe} = 64$ in Wall Thickness: $t_{pipe} = 0.5$ in

Length: $l_{pipe} = 52$ ft + 0.75 in

Cross section area:

$$A_{pipe} = \pi\ \frac{od_{pipe}^2 - (od_{pipe} - 2\ t_{pipe})^2}{4}$$

Weight of pipe: $W_{pipe} = \rho_{cstl} \cdot A_{pipe} \cdot l_{pipe}$

$W_{pipe} = 17{,}698$ lbs

Calculational Roundoff of Weight: $W_1 = 18{,}000$ lbs

2. Stiffening Rings Type 1 (with ears, 16 each):

Outer diameter (excluding ears): $od_{sr1} = 5$ ft + 11.625 in

Inside diameter: $id_{sr1} = 5$ ft + 4 in

Thickness of rings: $t_{sr1} = 1.5$ in

Area of ring:

$$A_{sr1} = \pi\ \frac{od_{sr1}^2 - id_{sr1}^2}{4}$$

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For Conservatism model ears as right triangles:

Height: $h_{ear} = 2\ \text{ft} + 2\ \text{in}$ Base: $b_{ear} = 6.5\ \text{in}$

Area of ear:

$$A_{ear} = \frac{1}{2}\, b_{ear}\, h_{ear}$$

Weight of ring: $W_{sr1} = \rho_{cstl} \cdot (A_{sr1} + 2 \cdot A_{ear}) \cdot t_{sr1}$

$W_{sr1} = 418\ \text{lbs}$

Calculational Roundoff of Weight: $W_2 = 450\ \text{lbs}$

3a. Stiffening Rings Type 2a (with flats, 3 each):

Area excluding flats same as above:

Width of flat: $wi_{sr2} = 3\ \text{in}$ Length of flat: $l_{sr2} = 2\ \text{ft} + 9\ \text{in}$

For conservatism assume rectangular shape.

Area of flats: $A_{flat} = wi_{sr2} \cdot l_{sr2}$

Attachment lug (assume half the weight carried by each ring)

Thickness of long plate with hole: $t_{alh} = 2\ \text{in}$

Height of plate: $h_{alh} = 11.625\ \text{in}$

Width of plate: $wi_{alh} = 8\ \text{in}$

Weight of long plate with hole:

$W_{lh} = \rho_{cstl} \cdot h_{alh} \cdot wi_{alh} \cdot t_{alh}$

Thickness of short plate: $t_{as} = 1.5\ \text{in}$

Height of plate: $h_{as} = 3\ \text{in}$

Width of plate: $w_{as} = 9\ \text{in}$

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Weight of bottom support plate:

$$w_{as} = \rho_{cstl}\cdot h_{as}\cdot w_{as}\cdot t_{as}$$

Total weight of one attachment lug:

$$w_{alug} = w_{lh} + w_{as}$$

Weight of ring: $W_{sr2a} = \rho_{cstl}\cdot(A_{sr1} + 2\cdot A_{flat})\cdot t_{sr1} + w_{alug}$

$w_{sr2a} = 495$ lbs

Calculational Roundoff of Weight: $w_{3a} = 525$ lbs

3b. Stiffening Rings Type 2b (with flats, 4 each):

Weight of ring only: $w_{sr2b} = \rho_{cstl}\cdot(A_{sr1} + 2\cdot A_{flat})\cdot t_{sr1}$

Lifting lug:

Thickness of lifting lug: $t_{ll} = 2$ in

Area of ring:

Radius: $r_{ll} = 4.75$ in

Height of straight section: $h_{ll} = 1$ ft + 2.625 in

Width of lug: $wi_{ll} = 9.5$ in

Total area: $A_{ll} = (\pi\cdot r_{ll}^2)/2 + h_{ll}\cdot wi_{ll}$

Weight of one lifting lug: $w_{ll} = \rho_{cstl}\cdot A_{ll}\cdot t_{ll}$

Weight of ring: $W_{sr2b} = w_{sr2b} + w_{ll}$ $W_{sr2b} = 550$ lbs

Calculational Roundoff of Weight: $W_{3b} = 600$ lbs

4. Bottom End Flange:

Outside diameter of flange: $od_{bef} = 5$ ft + 11.625 in

Thickness of flange: $t_{bef} = 2$ in

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Area of flange:

$$A_{bef} = \pi \frac{od_{bef}^2}{4}$$

Area of flats same as above.

Weight of Bottom End Flange: $W_{bef} = \rho_{cstl} \cdot (A_{bef} + 2 \cdot A_{flat}) \cdot t_{bef} + w_{alug}$

$W_{bef} = 2{,}465$ lbs

Calculational Roundoff of Weight: $W_4 = 2{,}600$ lbs.

5. Outside Top End Flange (Open):

Outside diameter of flange: $od_{tef} = 5$ ft + 11.625 in

Thickness of flange: $t_{tef} = 2$ in

ID of flange is od of the pipe.

Area of the flange:

$$A_{tef} = \pi \frac{od_{tef}^2 - od_{pipe}^2}{4}$$

Weight of Outside Top End Flange: $W_{tef} = \rho_{cstl} \cdot A_{tef} \cdot t_{tef}$

$W_{tef} = 461$ lbs

Calculational Roundoff of Weight: $W_5 = 500$ lbs

6. Inner bottom blind flange:

OD of flange: $od_{ibf} = od_{pipe} - 2 \cdot t_{pipe}$

Thickness of flange: $t_{ibf} = 2$ in

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Area of flange:

$$A_{ibf} = \pi \frac{od_{ibf}^2}{4}$$

Weight of inner bottom flange: $W_{ibf} = \rho_{cstl} \cdot A_{ibf} \cdot t_{ibf}$.

$W_{ibf} = 1{,}771$ lbs

Calculational Roundoff of Weight: $W_6 = 1{,}800$ lbs

7. Inner Top Flange (Open):

OD of flange is same as above.

ID of flange: $id_{itf} = 4\ \text{ft} + 10\ \text{in}$

Area of flange:

$$A_{itf} = \pi \frac{od_{ibf}^2 - id_{itf}^2}{4}$$

Thickness: $t_{itf} = 2$ in

Weight of flange: $W_{itf} = \rho_{cstl} \cdot A_{itf} \cdot t_{itf}$

$W_{itf} = 270$ lbs

Calculational Roundoff of Weight: $W_7 = 300$ lbs

8. Built-in Outer Funnel:

Gusset plate thickness: $t_{gus} = 0.375$ in

Gusset length: $l_{gus} = 10.75$ in Gusset height: $h_{gus} = 9.25$ in

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Area of gusset minus cut-out:

$$A_{gus} = l_{gus}\, h_{gus} - \frac{1}{2}\, l_{gus}\,(h_{gus} - 2.5\ in)$$

Weight of 12 gussets: $w_{gus} = 12 \cdot \rho_{cstl} \cdot A_{gus} \cdot t_{gus}$

Outer funnel plate, treated as a frustum of a right circular cone:

Plate thickness: $t_{frcc} = 0.250\ \text{in}$

Height of cone: $h_{frcc} = 10.750\ \text{in}$

Outer radius of cone:

$$R_{frcc} = \frac{id_{icf}}{2}$$

Inner radius of cone:

$$r_{frcc} = \frac{3\ ft + 8.5\ in}{2}$$

Surface area of section:

$$A_{frcc} = \pi\,(R_{frcc} + r_{frcc})\,\sqrt{(R_{frcc} - r_{frcc})^2 + h_{frcc}^2}$$

Weight of outer funnel plate:

$$w_{ofp} = \rho_{cstl} \cdot A_{frcc} \cdot t_{frcc}$$

Weight of outer funnel:

$w_{ifunnel} = w_{gus} + w_{ofp}$ $w_{ifunnel} = 226\ \text{lbs}$

Calculational Roundoff of Weight: $W_8 = 300\ \text{lbs}$

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9. Funnel Plate:

Plate thickness: $t_{fpl} = 0.5$ in

OD of plate: $od_{fpl} = 5$ ft + 3 in

ID of plate: $id_{fpl} = 3$ ft + 8.5 in

Weight of funnel plate:

$$w_{fpl} = \rho_{cstl}\,\pi\,\frac{od_{fpl}^2 - id_{fpl}^2}{4}\,t_{fpl}$$

$$w_{fpl} = 222 \text{ lbs}$$

Calculational Roundoff of Weight: $W_9 = 300$ lbs

10. Built-in Inner Funnel:

Thickness of inner funnel: $t_{ifp} = 0.250$ in

Top section, treat as a half of a cone:

Outside radius: $R_{ifcone} = 5$ ft + 3 in

Inside radius: $r_{ifcone} = 3$ ft + 8.5 in

Height of cone: $h_{ifcone} = 9.5$ in

Surface area of funnel:

$$A_{ifcone} = \frac{\pi\,(R_{ifcone} + r_{ifcone})\sqrt{(R_{ifcone} - r_{ifcone})^2 + h_{ifcone}^2}}{2}$$

Weight of half cone:

$w_{hcone} = \rho_{cstl} \cdot A_{ifcone} \cdot t_{ifp}$ $\quad w_{hcone} = 249$ lbs

Approximate remaining sections as two right circular triangles.

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Length of base:

Angle: $\alpha_{if} = 30 \text{ deg}$

Radius same as ID of pipe.

$$l_{ifb} = R_{ifcone} \cdot \alpha_{if}$$

Height of triangle is same as for cone.

Area of triangular sections:

$$A_{iftri} = 2\left(\frac{1}{2}\, l_{ifb}\, h_{ifcone}\right)$$

Weight of triangular section (two sections):

$w_{iftri} = 2 \cdot (\rho_{cstl} \cdot A_{iftri} \cdot t_{ifp})$ $w_{iftri} = 44 \text{ lbs}$

Weight of inner funnel:

$w_{if} = w_{hcone} + w_{iftri}$ $w_{if} = 294 \text{ lbs}$

Calculational Roundoff of Weight: $w_{10} = 350 \text{ lbs}$

11. 3/4 inch thick saddle:

Thickness of plate: $t_{34sad} = 0.750 \text{ in}$

Radius of midplane curvature:

$$r_{34sad} = 1\ ft + 10\ in + \frac{t_{34sad}}{2}$$

Total included angle of curvature: $\alpha_{34sad} = 22 \text{ deg}$

Width of saddle: $wi_{34sad} = r_{34sad} \cdot \alpha_{34sad}$

Length of saddle: $l_{sad} = 51 \text{ ft} + 2.75 \text{ in} - 1 \text{ in} - 2 \text{ in} - 3/4 \text{ in}$

Weight of 3/4 inch thick saddle plate:

$$w_{34sad} = \rho_{cstl} \cdot l_{sad} \cdot wi_{34sad} \cdot t_{34sad}$$

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$w_{34sad} = 1{,}118$ lbs

Calculational Roundoff of Weight: $W_{11} = 1{,}200$ lbs

12. 1/4 thick saddle plates (2 each):

Thickness of saddle: $t_{14sad} = 0.250$ in

Width of rolled section:

Angle of roll: $\alpha_{14sad} = 45\ \mathrm{deg} - \alpha_{34sad}$

Radius of roll is same as ID of pipe.

$wi_{rs14sad} = R_{ifcone} \cdot \alpha_{14sad}$

Width of straight section: $wi_{14sad} = 2\ \mathrm{ft} + 10.5\ \mathrm{in}$

Weight of both sections of 1/4 inch saddles:

$$w_{14sad} = 2 \cdot [\rho_{cstl} \cdot (wi_{rs14sad} + wi_{14sad}) \cdot l_{sad} \cdot t_{14sad}]$$

$$w_{14sad} = 5{,}187\ \mathrm{lbs}$$

Calculational Roundoff of Weight: $W_{12} = 5{,}500$ lbs

13. Saddle support plate, 1/2 inch thick (2 each):

Height: $h_{12ssp} = 8.75$ in

Thickness of plate: $t_{12ssp} = 0.5$ in

Weight of both plates: $w_{12ssp} = 2 \cdot (\rho_{cstl} \cdot l_{sad} \cdot h_{12ssp} \cdot t_{12ssp})$

$w_{12ssp} = 1{,}518$ lbs

Calculational Roundoff of Weight: $W_{13} = 1{,}600$ lbs

14. Saddle support plates, 1/8 inch thick (2 each):

Width: $wi_{18ssp} = 2\ \mathrm{ft} + 6.25\ \mathrm{in}$

Thickness of plate: $t_{18ssp} = 0.125$ in

Weight of both plates:

$$w_{18ssp} = 2 \cdot (\rho_{cstl} \cdot l_{sad} \cdot wi_{18ssp} \cdot t_{18ssp})$$

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W_{18ssp} = 1,312 lbs

Calculational Roundoff of Weight: W_{14} = 1,400 lbs

15. Vent (1 each):

Pipe parameters:

Length: l_{vent} = 4.5 in

(Reference 4, page 34-64).

Weight per foot:

$$w_{pv} = 5.79 \frac{lbs}{ft}$$

Weight of pipe section: $w_{pv} = w_{pv} \cdot l_{vent}$

Flange:

OD of flange: od_{vf} = 3.25 in

ID of flange: id_{vf} = 2 in

Thickness: t_{vf} = 0.5 in

Weight of flange:

$$w_{vf} = \rho_{cstl} \, \pi \left(\frac{od_{vf}^2 - id_{vf}^2}{4} \right) t_{vf}$$

Weight of vent:

$w_{vent} = w_{vp} + w_{vf}$ w_{vent} = 3 lbs

Calculational Roundoff of Weight: W_{15} = 10 lbs.

16. Outer shielding shell (thin section):

ID of shell: id_{shell} = 5 ft + 8 in

Thickness of shell: t_{516sh} = 0.3125 in

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Cross sectional area:

$$A_{516sh} = \pi \frac{(id_{shell} + t_{516sh})^2 - id_{shell}^2}{4}$$

Lengths of shells, columns 1 to 8 and 15 to 25:

$15_1 = 9.75\ \mathrm{in} - t_{bef}/2 - t_{sr1}/2$

$15_2 = (2\cdot \mathrm{ft} + 10\ \mathrm{in}) - 9.75\ \mathrm{in} - t_{sr1}$

$15_3 = (4\ \mathrm{ft} + 10.25\ \mathrm{in}) - (2\ \mathrm{ft} + 10\ \mathrm{in}) - t_{sr1}$

$15_4 = (5\ \mathrm{ft} + 7.750\ \mathrm{in}) - (4\ \mathrm{ft} + 10.25\ \mathrm{in}) - t_{sr1}$

$15_5 = (8\ \mathrm{ft} + 3.250\ \mathrm{in}) - (5\ \mathrm{ft} + 7.750\ \mathrm{in}) - t_{sr1}$

$15_6 = (10\ \mathrm{ft} + 10.750\ \mathrm{in}) - (8\ \mathrm{ft} + 3.250\ \mathrm{in}) - t_{sr1}$

$15_7 = (13\ \mathrm{ft} + 6.250\ \mathrm{in}) - (10\ \mathrm{ft} + 10.750\ \mathrm{in}) - t_{sr1}$

$15_8 = (32\ \mathrm{ft} + 8.250\ \mathrm{in}) - (30\ \mathrm{ft} + 0.750\ \mathrm{in}) - t_{sr1}$

$15_9 = (35\ \mathrm{ft} + 3.750\ \mathrm{in}) - (32\ \mathrm{ft} + 8.250\ \mathrm{in}) - t_{sr1}$

$15_{10} = (37\ \mathrm{ft} + 11.250\ \mathrm{in}) - (35\ \mathrm{ft} + 3.750\ \mathrm{in}) - t_{sr1}$

$15_{11} = (40\ \mathrm{ft} + 6.750\ \mathrm{in}) - (37\ \mathrm{ft} + 11.250\ \mathrm{in}) - t_{sr1}$

$15_{12} = (43\ \mathrm{ft} + 2.250\ \mathrm{in}) - (40\ \mathrm{ft} + 6.750\ \mathrm{in}) - t_{sr1}$

$15_{13} = (45\ \mathrm{ft} + 9.750\ \mathrm{in}) - (43\ \mathrm{ft} + 2.250\ \mathrm{in}) - t_{sr1}$

$15_{14} = (48\ \mathrm{ft} + 5.250\ \mathrm{in}) - (45\ \mathrm{ft} + 9.750\ \mathrm{in}) - t_{sr1}$

$15_{15} = (49\ \mathrm{ft} + 2.750\ \mathrm{in}) - (48\ \mathrm{ft} + 5.250\ \mathrm{in}) - t_{sr1}$

$15_{16} = (51\ \mathrm{ft} + 2.750\ \mathrm{in}) - (49\ \mathrm{ft} + 2.750\ \mathrm{in}) - t_{sr1}$

$15_{17} = (52\ \mathrm{ft} + 0.750\ \mathrm{in}) - (51\ \mathrm{ft} + 2.750\ \mathrm{in}) - t_{sr1}/2 - t_{tef}/2$

$$15_{tot} = 15_1 + 15_2 + 15_3 + 15_4 + 15_5 + 15_6 + 15_7 + 15_8 + 15_9 + 15_{10} + 15_{11} + 15_{12} + 15_{13} + 15_{14} + 15_{15} + 15_{16} + 15_{17}$$

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Weight of Thredolet and plug (Reference: H. E. Atkins, Jr, 7/18/94):

$w_{thred} = 20.1 \text{ lbs}$

Weight of thin outer shell:

$w_{516sh} = (\rho_{cstl} \cdot A_{516sh} \cdot 15_{tot}) + 17 \cdot w_{thred}$ $w_{516sh} = 3{,}823 \text{ lbs}$

Calculational Roundoff of Weight: $W_{16} = 4{,}000 \text{ lbs}$

17. Outer shielding shell (thick section):

Thickness of shell: $t_{12sh} = 0.5 \text{ in}$

Cross sectional area:

$$A_{12sh} = \pi \frac{(id_{shell} + t_{12sh})^2 - id_{shell}^2}{4}$$

Length of shells Columns 8 to 15:

$ll_1 = (16 \text{ ft} + 1.750 \text{ in}) - (13 \text{ ft} + 6.250 \text{ in}) - t_{sr1}$

$ll_2 = (18 \text{ ft} + 9.250 \text{ in}) - (16 \text{ ft} + 1.750 \text{ in}) - t_{sr1}$

$ll_3 = (21 \text{ ft} + 4.750 \text{ in}) - (18 \text{ ft} + 9.250 \text{ in}) - t_{sr1}$

$ll_4 = (24 \text{ ft} + 0.250 \text{ in}) - (21 \text{ ft} + 4.750 \text{ in}) - t_{sr1}$

$ll_5 = (24 \text{ ft} + 9.750 \text{ in}) - (24 \text{ ft} + 0.250 \text{ in}) - t_{sr1}$

$ll_6 = (27 \text{ ft} + 5.250 \text{ in}) - (24 \text{ ft} + 9.750 \text{ in}) - t_{sr1}$

$ll_7 = (30 \text{ ft} + 0.750 \text{ in}) - (27 \text{ ft} + 5.250 \text{ in}) - t_{sr1}$

$lltot = ll_1 + ll_2 + ll_3 + ll_4 + ll_5 + ll_6 + ll_7$

Weight of thick outer shell:

$w_{12sh} = (\rho_{cstl} \cdot A_{12sh} \cdot ll_{tot}) + 7 \cdot w_{thred}$ $w_{12sh} = 2{,}882 \text{ lbs}$

Calculational Roundoff of Weight: $W_{17} = 3{,}000 \text{ lbs}$

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18. Shielding:

Cross sectional area:

$$A_{shsp} = \pi\,\frac{id^2_{shell} - od^2_{pipe}}{4}$$

Density of lead (Reference 1, page 2269):

$$\rho_{pb} = 0.4096\cdot \mathrm{lbs/in}^3$$

Assume 65% density for shot (equivalent density):

$$\rho_{epb} = 0.65\cdot\rho_{pb}$$

Weight per unit length of lead shielding:

$$w_{pbsh} = \rho_{epb}\cdot A_{shsp}$$

$$w_{pbsh} = 110\cdot \mathrm{lbs/in}$$

Lead weight up to Column 14:

Lead Length:

$$len_{sh1} = 15_1 + 15_2 + 15_3 + 15_4 + 15_5 + 15_6 + 15_7 + 11_1 + 11_2 + 11_3 + 11_4 + 11_5 + 11_6$$

Weight of lead: $W_{pbshl} = w_{pbsh}\cdot len_{sh1}$ $W_{pbshl} = 30{,}859$ lbs

Calculational Roundoff of Weight: $W_{18a} = 32{,}000$ lbs

Lead full length to Column 25:

Lead length: $len_{sh2} = 15_{tot} + 11_{tot}$

Weight of lead: $W_{pbsh2} = w_{pbsh}\cdot len_{sh2}$ $W_{pbsh2} = 64{,}947$ lbs

Calculational Roundoff of Weight: $W_{18b} = 66{,}000$ lbs

19. Outer Top Cap:

Flange:

Thickness: $t_{otcf} = 2.250$ in

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OD: $od_{otcf} = 5\ ft + 11.625\ in$

ID: $id_{otcf} = 5\ ft + 5\ in$

Cross sectional area:

$$A_{otcf} = \pi \frac{od_{otcf}^2 - id_{otcf}^2}{4}$$

Weight of outer top cap flange: $w_{otcf} = \rho_{cstl} \cdot A_{otcf} \cdot t_{otcf}$

Housing:

Thickness: $t_{otch} = 0.375\ in$ Length: $l_{otch} = 2\ ft + 1.875\ in$

ID: $id_{otch} = 5\ ft + 5\ in$

OD: $od_{otch} = id_{otch} + 2 \cdot t_{otch}$

Cross sectional area:

$$A_{otch} = \pi \frac{od_{otch}^2 - id_{otch}^2}{4}$$

Weight of housing: $w_{otch} = \rho_{cstl} \cdot A_{otch} \cdot l_{otch}$

End plate:

Thickness: $t_{otcep} = 0.750\ in$

OD: $od_{otcep} = id_{otch}$

Cross sectional area:

$$A_{otcep} = \pi \frac{od_{otcep}^2}{4}$$

Weight of End plate: $w_{otcep} = \rho_{cstl} \cdot A_{otcep} \cdot t_{otcep}$

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Weight of bolts (1 inch, 4 inch long, weight per 100): $w_{otcb100} = 162\ \text{lbs}/100$

Reference 2, page 4-146.

Number of bolts: $n_{bolt} = 32$

Weight of bolts: $w_{otcb} = n_{bolt} \cdot w_{otcb100}$

Weight of outer top cap:

$W_{otc} = w_{otcf} + w_{otch} + w_{otcep} + w_{otcb}$ $W_{otc} = 1{,}779\ \text{lbs}$

Calculational Roundoff of Weight: $W_{19} = 1{,}900\ \text{lbs}$

20. Inner Top Cap:

Flange:

Thickness: $t_{itcf} = 2.250\ \text{in}$

OD: $od_{itcf} = 5\ \text{ft} + 3\ \text{in}$

ID: $id_{itcf} = 4\ \text{ft} + 10\ \text{in}$

Cross sectional area:

$$A_{itcf} = \pi \frac{od_{itcf}^2 - id_{itcf}^2}{4}$$

Weight of flange: $w_{itcf} = \rho_{cstl} \cdot A_{itcf} \cdot t_{itcf}$

Housing:

Thickness: $t_{itch} = 0.500\ \text{in}$ Length: $l_{itch} = 1\ \text{ft} + 11.875\ \text{in}$

OD: $od_{itch} = id_{itcf}$

ID: $id_{itch} = od_{itch} - 2 \cdot t_{itch}$

Cross sectional area:

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$$A_{itch} = \pi \frac{od_{itch}^2 - id_{itch}^2}{4}$$

Weight of flange: $w_{itch} = \rho_{cstl} \cdot A_{itch} \cdot l_{itch}$

Retaining Ring:

Thickness: $t_{itcrr} = 0.375\ \text{in}$ Length: $l_{itcrr} = 2.6875\ \text{in}$

ID: $id_{itcrr} = od_{itcf}$

OD: $od_{itcrr} = id_{itcrr} + 2 \cdot t_{itcrr}$

Cross sectional area:

$$A_{itcrr} = \pi \frac{od_{itcrr}^2 - id_{itcrr}^2}{4}$$

Weight of retaining ring: $w_{itcrr} = \rho_{cstl} \cdot A_{itcrr} \cdot l_{itcrr}$

Gussets (8 each):

Thickness: $t_{itcgus} = 0.500\ \text{in}$

Length: $l_{itcgus} = 7.1875\ \text{in}$

Height: $h_{itcgus} = 7.0\ \text{in}$

Weight of gussets: $w_{itcgus} = 8 \cdot \rho_{cstl} \cdot l_{itcgus} \cdot h_{itcgus} \cdot t_{itcgus}$

Retainer Plate:

Thickness: $t_{itcrp} = 0.500\ \text{in}$

OD: $od_{itcrp} = 3\ \text{ft} + 7\ \text{in}$

ID: $id_{itcrp} = 4\ \text{ft} + 9\ \text{in}$

Cross sectional area:

Weight of retainer plate: $w_{itcrp} = \rho_{cstl} \cdot A_{itcrp} \cdot t_{itcrp}$

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$$A_{itcrp} = \pi \frac{od_{itcrp}^2 - id_{itcrp}^2}{4}$$

End plate:

Thickness: $t_{itcep} = 0.750$ in

OD: $od_{itcep} = id_{itch}$

Cross sectional area:

$$A_{itcep} = \pi \frac{od_{itcep}^2}{4}$$

Weight of end plate: $w_{itcep} = \rho_{cstl} \cdot A_{itcep} \cdot t_{itcep}$

Weight of bolts (1 inch, 4 inch long, weight per 100): $w_{itcb100} = 162$ lbs/100

Reference 2, page 4-146.

Number of bolts: $n_{bolt} = 28$

Weight of bolts: $w_{itcb} = n_{bolt} \cdot w_{itcb100}$

Weight of inner top cap:

$$W_{itc} = w_{itcf} + w_{itch} + w_{itcrr} + w_{itcgus} + w_{itcrp} + w_{itcep} + w_{itcb}$$

$W_{itc} = 1{,}463$ lbs

Calculational Roundoff of Weight: $W_{20} = 1{,}500$ lbs

21. Payload weight and CG (Reference from H. E. Atkins, Jr, 7/18/94):

Weight: $W_{pay} = 19{,}427$ lbs

CG from bottom of outer top flange: $cg_{pay1} = 19.42$ ft

CG from bottom outer flange center is:

$cg_{pay2} = (52\ fy + 0.750\ in) - cg_{pay1} - t_{bef}/2$ $cg_{pay2} = 32.56$ ft

Calculational Roundoff of Weight: $W_{21} = 20{,}000$ lbs

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Total weight of package w/o shielding:

$$W_{epack} = W_1 + 16\cdot W_2 + 3\cdot W_{3a} + 4\cdot W_{3b} + W_4 + W_5 + W_6 + W_7 + W_8 + W_9 + W_{10} + W_{11} + W_{12} + W_{13} + W_{14} + W_{15} + W_{16} + W_{17} + W_{19} + W_{20}$$

$$W_{epack} = 55{,}435 \text{ lbs}$$

Calculational Roundoff of Weight: $W_{empty} = 57{,}000$ lbs

Total weight of package empty with shielding to Column 14:

$W_{sh1pack} = W_{epack} + W_{18a}$ $W_{sh1pack} = 87{,}435$ lbs

Calculational Roundoff of Weight: $W_{emptysh1} = 88{,}000$ lbs

Total weight of package empty with shielding to Column 25:

$W_{sh2pack} = W_{epack} + W_{18b}$ $W_{sh2pack} = 121{,}435$ lbs

Calculational Roundoff of Weight: $W_{emptysh2} = 130{,}000$ lbs

Total weight of loaded package no shielding:

$W_{pack} = W_{epack} + W_{21}$ $W_{pack} = 75{,}435$ lbs

Calculational Roundoff of Weight: $W_{fpack} = 76{,}000$ lbs

Total weight of loaded package shielded up to Column 14:

$W_{packsh1} = W_{pack} + W_{18a}$ $W_{packsh1} = 107{,}435$ lbs

Calculational Roundoff of Weight: $W_{fpacksh1} = 110{,}000$ lbs

Total weight of loaded package shielded up to Column 25:

$W_{packsh2} = W_{pack} + W_{18b}$ $W_{packsh2} = 141{,}435$ lbs

Calculational Roundoff of Weight: $W_{fpacksh2} = 145{,}000$ lbs

Approximate CG calculations of package:

From center of bottom outer flange.

Package weight without top caps, shielding or rings:

$$W_{base} = W_1 + W_6 + W_7 + W_9 + W_{10} + W_{11} + W_{12} + W_{13} + W_{14} + W_{15} + W_{16} + W_{17}$$

$$W_{base} = 37{,}760 \text{ lbs}$$

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Calculational Roundoff of Weight: $W_{base1} = 39{,}000\ \text{lbs}$

Assume CG of this portion at center of pipe from bottom:

$cg_{base1} = l_{pipe}/2 + t_{bef}/2$ $\qquad cg_{base1} = 26.11\ \text{ft}$

CG of stiffener rings:

Reference is from center of bottom end flange.

$l_{sr1} = 0\ \text{in}$

$l_{sr2} = 9.750\ \text{in}$

$l_{sr3} = 2\ \text{ft} + 10\ \text{in}$

$l_{sr4} = 4\ \text{ft} + 10.250\ \text{in}$

$l_{sr5} = 5\ \text{ft} + 7.750\ \text{in}$

$l_{sr6} = 8\ \text{ft} + 3.25\ \text{in}$

$l_{sr7} = 10\ \text{ft} + 10.750\ \text{in}$

$l_{sr8} = 13\ \text{ft} + 6.25\ \text{in}$

$l_{sr9} = 16\ \text{ft} + 1.750\ \text{in}$

$l_{sr10} = 18\ \text{ft} + 9.25\ \text{in}$

$l_{sr11} = 21\ \text{ft} + 4.750\ \text{in}$

$l_{sr12} = 24\ \text{ft} + 0.250\ \text{in}$

$l_{sr13} = 24\ \text{ft} + 9.750\ \text{in}$

$l_{sr14} = 27\ \text{ft} + 5.250\ \text{in}$

$l_{sr15} = 30\ \text{ft} + 0.750\ \text{in}$

$l_{sr16} = 32\ \text{ft} + 8.25\ \text{in}$

$l_{sr17} = 35\ \text{ft} + 3.750\ \text{in}$

$l_{sr18} = 37\ \text{ft} + 11.250\ \text{in}$

$l_{sr19} = 40\ \text{ft} + 6.750\ \text{in}$

$l_{sr20} = 43\ \text{ft} + 2.25\ \text{in}$

$l_{sr21} = 45\ \text{ft} + 9.750\ \text{in}$

$l_{sr22} = 48\ \text{ft} + 5.25\ \text{in}$

$l_{sr23} = 49\ \text{ft} + 2.750\ \text{in}$

$l_{sr24} = 51\ \text{ft} + 2.750\ \text{in}$

$l_{sr25} = 52\ \text{ft} + 0.750\ \text{in}$

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$$cg_{sr} = \frac{\begin{array}{l} W_4\, l_{sr1} + W_{3a}\, l_{sr2} + W_2\, l_{sr3} + W_{3b}\, l_{sr4} + W_{3b}\, l_{sr5} \\ + W_2\, l_{sr6} + W_2\, l_{sr7} + W_2\, l_{sr8} + W_2\, l_{sr9} + W_2\, l_{sr10} \\ + W_2\, l_{sr11} + W_{3a}\, l_{sr12} + W_{3a}\, l_{sr13} + W_2\, l_{sr14} + W_2\, l_{sr15} \\ + W_2\, l_{sr16} + W_2\, l_{sr17} + W_2\, l_{sr18} + W_2\, l_{sr19} + W_2\, l_{sr20} \\ + W_2\, l_{sr21} + W_{3b}\, l_{sr22} + W_{3b}\, l_{sr23} + W_2\, l_{sr24} + W_5\, l_{sr25} \end{array}}{W_4 + W_5 + 16\, W_2 + 3\, W_{3a} + 4\, W_{3b}}$$

$$cg_{sr} = 21.94 \text{ ft}$$

CG of shielding materials for shielding up to Column 14:

Assume concentrated in the center of each shell.

$d_1 = l_{sr2} - 15_1/2 - t_{sr1}/2$

$d_2 = l_{sr3} - 15_2/2 - t_{sr1}/2$

$d_3 = l_{sr4} - 15_3/2 - t_{sr1}/2$

$d_4 = l_{sr5} - 15_4/2 - t_{sr1}/2$

$d_5 = l_{sr6} - 15_5/2 - t_{sr1}/2$

$d_6 = l_{sr7} - 15_6/2 - t_{sr1}/2$

$d_7 = l_{sr8} - 15_7/2 - t_{sr1}/2$

$d_8 = l_{sr9} - 11_1/2 - t_{sr1}/2$

$d_9 = l_{sr10} - 11_2/2 - t_{sr1}/2$

$d_{10} = l_{sr11} - 11_3/2 - t_{sr1}/2$

$d_{11} = l_{sr12} - 11_4/2 - t_{sr1}/2$

$d_{12} = l_{sr13} - 11_5/2 - t_{sr1}/2$

$d_{13} = l_{sr14} - 11_6/2 - t_{sr1}/2$

$$cg_{sh14} = \frac{\begin{array}{l} (d_1\, 15_1 + d_2\, 15_2 + d_3\, 15_3 + d_4\, 15_4 + d_5\, 15_5 + d_6\, 15_6 + d_7\, 15_7 \\ + d_8\, 11_1 + d_9\, 11_2 + d_{10}\, 11_3 + d_{11}\, 11_4 + d_{12}\, 11_5 + d_{13}\, 11_6) \end{array}}{\begin{array}{l} (15_1 + 15_2 + 15_3 + 15_4 + 15_5 + 15_6 + 15_7 + 11_1 \\ + 11_2 + 11_3 + 11_4 + 11_5 + 11_6) \end{array}}$$

$$cg_{sh14} = 13.79 \text{ ft}$$

CG of shielding materials for shielding up to Column 25:

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Assume concentrated in the center of each shell.

$d_{14} = l_{sr15} - 11_7/2 - t_{sr1}/2$

$d_{15} = l_{sr16} - 15_8/2 - t_{sr1}/2$

$d_{16} = l_{sr17} - 15_9/2 - t_{sr1}/2$

$d_{17} = l_{sr18} - 15_{10}/2 - t_{sr1}/2$

$d_{18} = l_{sr19} - 15_{11}/2 - t_{sr1}/2$

$d_{19} = l_{sr20} - 15_{12}/2 - t_{sr1}/2$

$d_{20} = l_{sr21} - 15_{13}/2 - t_{sr1}/2$

$d_{21} = l_{sr22} - 15_{14}/2 - t_{sr1}/2$

$d_{22} = l_{sr23} - 15_{15}/2 - t_{sr1}/2$

$d_{23} = l_{sr24} - 15_{16}/2 - t_{sr1}/2$

$d_{24} = l_{sr25} - 15_{17}/2 - t_{tef}/2$

$$cg_{sh25} = \frac{\begin{array}{c} d_1\,15_1 + d_2\,15_2 + d_3\,15_3 + d_4\,15_4 + d_5\,15_5 + d_6\,15_6 + d_7\,15_7 \\ + d_8\,11_1 + d_9\,11_2 + d_{10}\,11_3 + d_{11}\,11_4 + d_{12}\,11_5 + d_{13}\,11_6 \\ + d_{14}\,11_7 + d_{15}\,15_8 + d_{16}\,15_9 + d_{17}\,15_{10} + d_{18}\,15_{11} + d_{19}\,15_{12} \\ + d_{20}\,15_{13} + d_{21}\,15_{14} + d_{22}\,15_{15} + d_{23}\,15_{16} + d_{24}\,15_{17} \end{array}}{15_{tot} + 11_{tot}}$$

$$cg_{sh25} = 26.04 \text{ ft}$$

CG of top caps relative to bottom of outer top flange:

Outer top cap:

$$cg_{otc} = \frac{w_{otcf}\,\frac{t_{otcf}}{2} + w_{otch}\left(t_{otcf} + \frac{l_{otch}}{2}\right) + w_{otcep}\,(t_{otcf} + l_{otch})}{W_{otc}}$$

$$cg_{otc} = 1.36 \text{ ft}$$

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Inner top cap:

$$cg_{itc} = \frac{\begin{aligned} & w_{itcf}\left(t_{itf} + \frac{t_{itcf}}{2}\right) + w_{itch}\left(t_{itf} + t_{itcf} + \frac{l_{itch}}{2}\right) + w_{itcrr}\left(t_{itf} + \frac{l_{itcrr}}{2}\right) \\ & + w_{itcgus}\left(t_{itf} + t_{itcf} + l_{itch} - \frac{l_{itcgus}}{2} - \frac{t_{itcep}}{2}\right) \\ & + w_{itcrp}\left[(t_{itf} + t_{itcf} + l_{itch}) - l_{itcgus} - \frac{t_{itcrp}}{2} - \frac{t_{itcep}}{2}\right] \\ & + w_{itcep}\left(t_{itf} + t_{itcf} + l_{itch} - \frac{t_{itcep}}{2}\right) \end{aligned}}{W_{itc}}$$

$$cg_{itc} = 1.39 \text{ ft}$$

CG of package empty with no shielding:

$$CG_{epack} = \frac{\begin{aligned} & W_{basel}\, cg_{basel} + (W_4 + W_5 + 16\ W_2 + 3\ W_{3a} + 4\ W_{3b})\, cg_{sr} \\ & + W_{19}\left(cg_{otc} + l_{sr25} + \frac{t_{tef}}{2}\right) + W_{20}\left(cg_{itc} + l_{sr25} + \frac{t_{tef}}{e}\right) \end{aligned}}{W_{epack}}$$

$$CG_{epack} = 27.3 \text{ ft}$$

CG of loaded package with no shielding:

$$CG_{pack} = (W_{epack}\ CG_{epack} + W_{pay}\ cg_{pay2})/W_{pack}$$

$$CG_{pack} = 28.45 \text{ ft}$$

CG of loaded package with shielding to Column 14:

$$CG_{packsh1} = (W_{pack}\ CG_{pack} + W_{18a}\ cg_{sh14})/W_{sh1pack}$$

$$CG_{packsh1} = 29.59 \text{ ft}$$

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CG of loaded package with shielding to Column 25:

$$CG_{packsh1} = (W_{pack}\ CG_{pack} + W_{18a}\ cg_{sh25})/W_{sh2pack}$$

$$CG_{packsh2} = 31.83 \text{ ft}$$

CG of empty package with shielding to Column 14:

$$CG_{sh1pack} = (W_{epack}\ CG_{epack} + W_{18a}\ cg_{sh14})/W_{sh1pack}$$

$$CG_{sh1pack} = 22.36 \text{ ft}$$

CG of empty package with shielding to Column 25:

$$CG_{sh2pack} = (W_{epack}\ CG_{epack} + W_{18b}\ cg_{sh25})/W_{sh2pack}$$

$$CG_{sh2pack} = 26.62 \text{ ft}$$

Total impact length of package: $L_{tot} = 52 \text{ ft} + 2.750 \text{ in}$

$$L_{tot} = 626.75 \text{ in}$$

6.4.2 Determination of G Loading on 12 in. Thick Reinforced Concrete

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Subject Determination of G Loading on 12 in Thick Reinforced Concrete
Originator S. S. Shiraga Date 07/31/94
Checker P. M. Nguyen PMNguyen Date 08/09/94

I. Objectives:

The objective of this analysis is to determine the deceleration loads for various load configurations of the Hydrogen Mixer Mitigation Pump (HMMP) Package when subjected to a simulated 12 inch drop onto a flat horizontal 12 inch thick reinforced concrete slab per Reference 1.

II. References:

1. WHC-SD-TP-PDC-019, "Packaging Design Criteria Transfer and Disposal of Hydrogen Mixer Pump".
2. WHC, Engineering Change Notice 606676, dated June 27, 1994.
3. US-NRC, 10 CFR Part 71, "Packaging and Transportation of Radioactive Materials".
4. EPRI, Electric Power Research Institute, EPRI NP-4830, "The Effect of Target Hardness on the Structural Design of Concrete Storage Pads for Spent Fuel Casks", October 1986.
5. ACI, American Concrete Institute, Manual of Concrete Practice 1989, Part III.
6. WHC, Drawing No. H-2-83734, "Hydrogen Mixer Pump Storage Container".

III. Results and Conclusions:

As stated in Reference 1, to show structural integrity of the package, an simulated analytical drop of the package onto a 12 inch thick reinforced concrete pad is to be performed. Although not consistent with Reference 2, this criterion simulates the condition which exist on the site boundary for on-site transfers. The deceleration load parameters for simulating the drop were determined by using the methodology established in Reference 4. The use of this methodology is justified on the basis that the container is similar in construction to a spent fuel container. The package similar to a spent fuel container is constructed of steel with a relative overall hardness greater than concrete.

Based upon the methodology outlined in Reference 4, the results show the deceleration loading factors for various load conditions as:

1. Package loaded without shielding: $g_{dec} = 33.4$
2. Package loaded and partially shielded: $g_{dec} = 32.3$
3. Package loaded and fully shielded: $g_{dec} = 25.3$

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The results are used in subsequent drop evaluations. The three configurations were chosen to parametrically determined the largest loads on the package and various critical components. This required since the deceleration loads are inversely dependent on the weight. In part, this is due to the methodology which accounts for the impact energy absorbed by the concrete as it fails under impact. The heavier and stiffer the package the more the concrete fails which absorbs more energy of impact, thereby decreasing the deceleration loading on the package.

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Subject Determination of G Loading on 12 in Thick Reinforced Concrete
Originator S. S. Shiraga Date 07/31/94
Checker P. M. Nguyen Date 08/09/94

IV. Engineering Evaluation:

Calculational assumptions based on EPRI Document (Reference 4):

Assumptions:

Concrete thickness: $h = 12$ in

Cover rebar: $c = 2$

Concrete strength: $f_c = 4,000$ psi

Soil Modulus of Elasticity: $E_s = 25 \times 10^3$ psi

$S_y = 60 \times 10^3$ psi

For normal weight concrete (Reference 5, page 318/318R-83), concrete modulus of elasticity:

$$E_c = (57,000\ f_c^{0.5})\ \text{psi}^{0.5}$$

This forced to have psi units, since the constant 57,000 has built in $\text{psi}^{0.5}$ units.

$$E_c = 3.6 \times 10^6\ \text{psi}$$

#9 rebar (Reference 5, Table B.1, Part III)

$$A_9 = [\pi\ (1.13\ \text{in})^2]/4$$

Package length (Reference 6): $L = 52$ ft + 2.750 in

Weight of packages:

W_{pack}
76,000 lbs
110,000 lbs
145,000 lbs

Width of footprint: $d = 10$ in

For a side drop:

$$a = (A_9\ S_y)/(0.85\ F_c\ h) \qquad I_c = (L\ h^3)/12$$

Ultimate moment capacity of the concrete slab:

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$$M_u = A_s S_y (d - a/2)$$

$$M_u = 557{,}353 \text{ lbs in}$$

$$\beta = \left(\frac{E_s}{4\ E_c\ I_c}\right)^{\frac{1}{4}} \qquad \beta = 0.012\ in^{-1}$$

Foot print area: $A = L\ d$

Target hardness number:

$$S_n = \frac{2\ A\ E_s\ M_u\ f_c}{(W_{pack_n})^3\ \beta}$$

S_n
135,187
44,586
19,466

Curve Fit of Data for Interpolation (Reference 4):

Cask G loading from EPRI data at 12 inches:

x_i	y_i
200	5
12,900	21
25,800	28
86,000	32.5
218,000	42
400,000	50

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Originator S. S. Shiraga Date 07/31/94
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G loadings from curve interpolation at 12 inches:

gl_n
33.41
32.34
25.3

6.4.3 Pressure Increase and Decrease Evaluation

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Building Tank 241-SY-101 Rev. 0 Job No.
Subject Pressure Increase and Decrease Evaluation
Originator S. S. Shiraga Date 08/01/94
Checker S. R. Crow Date 08/15/94

I. Objectives:

The objective of this evaluation is to evaluate the pressurization of the package as required in Reference 1.

II. References:

1. WHC-SD-TP-PDC-019, Rev. 0, "Packaging Design Criteria Transfer and Disposal of Hydrogen Mitigation Mixer Pump".
2. ASME, American Society of Mechanical Engineers, Boiler and Pressure Vessels. Section VIII, Division 2, 1989.
3. WHC, Drawing No. H-2-83734, "Hydrogen Mixer Pump Storage Container".
4. Roark, <u>Formulas for Stress and Strain</u>, 4th Edition.

III. Results and Conclusions:

Per Reference 1, this evaluation is to consider increased external pressure o the package of 20 psi and decreased external pressure of 3.5 psi. The larges pressure differential results from decreased external pressure. Only the largest pressure differential of 11.2 psi which is the decrease in external pressure is evaluated herein, since it is the worst case loading. The inner top cap and the 2 inch thick inner blind flange at the bottom end are considered as the primary containment boundaries.

The results show that the package design is adequate to withstand the pressure differentials specified in Reference 1. Also the results are used in conjunction with drop evaluation to determine performance under combined loading.

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IV. Engineering Evaluation:

Pressure Change Evaluation Inner Blind Flange:

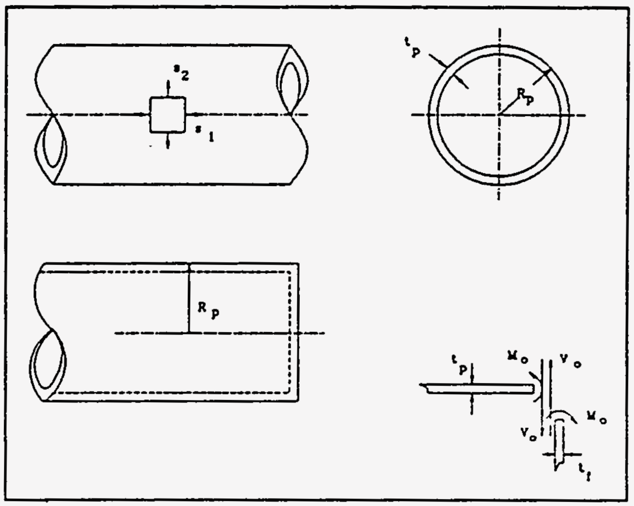

Figure 1

Modulus of Elasticity (Reference 2): $E_{cstl} = 29.26 \times 10^6$

Poisson's ratio (Reference 2): $v_{cstl} = 0.3$

Containment boundary pipe ID: $id_p = 5\ ft + 3\ in$

Pipe outside radius: $R_p = id_p/2$

Wall thickness: $t_p = 0.500\ in$

ASME allowable at temperature: $s_a = 23{,}270\ psi$

Per Reference 2, page 513, for allowable bending and discontinuity stresses:

$$1.5\ s_a = 34{,}905\ psi$$

Flange thickness: $t_f = 2.00\ in$

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Rigidity Factors (Reference 4, page 298):

Flange:

$$D_f = \frac{E_{cstl}\ t_f^3}{12\left(1 - \nu_{cstl}^2\right)}$$

Pipe:

$$D_p = \frac{E_{cstl}\ t_p^3}{12\left(1 - \nu_{cstl}^2\right)}$$

$$\lambda_p = \left(3\ \frac{1 - \nu_{cstl}^2}{R_p^2\ t_p^2}\right)^{\frac{1}{4}}$$

Container mid section stress (Reference 4, page 298, Case 1):

Evaluate for worst case: reduction in external pressure (Reference 1):

$$P_{red} = 11.2 \text{ psi}$$

Meridional stress:

$s_1 = (P_{red}\ R_p)/2(t_p)$ $s_1 = 353$ psi

Hoop stress:

$s_2 = (P_{red}\ R_p)/t_p$ $s_2 = 706$ psi

Total stress:

$s_{tot} = s_1 + s_2$ $s_{tot} = 1{,}058$ psi

Margin of Safety:

$$MS_{mid} = \frac{s_a}{s_{tot}} - 1$$

$$MS_{mid} = 21$$

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Package end discontinuity stress (Reference 4, page 307, Case 30):

Discontinuity moment at joint:

$$M_o = \frac{\dfrac{P_{red}\,R_p^3\,\lambda_p^2\,D_p}{4\,D_f\,(1+\nu_{cstl})} + \dfrac{2\,P_{red}\,R_p^2\,\lambda_p^3\,E_{cstl}\,t_f\,D_p}{E_{cstl}\,t_p\left(1-\frac{1}{2}\nu_{cstl}\right)\left[E_{cstl}\,t_f + 2\,R_p\,D_p\,\lambda_p^3\,(1-\nu_{cstl})\right]}}{2\,\lambda_p + \dfrac{2\,R_p\,\lambda_p^2\,D_p}{D_f\,(1+\nu_{cstl})} - \dfrac{\lambda_p\,E_{cstl}\,t_f}{E_{cstl}\,t_f + 2\,D_p\,\lambda_p^3\,R_p\,(1-\nu_{cstl})}}$$

$$M_o = 321.4 \text{ lbs}$$

Discontinuity radial shear at joint:

$$V_o = M_o\left[2\,\lambda_p + \frac{2\,R_p\,\lambda_p^2\,D_p}{D_f\,(1+\nu_{cstl})}\right] - \frac{P_{red}\,R_p^3\,\lambda_p^2\,D_p}{4\,D_f\,(1+\nu_{cstl})}$$

$$V_o = 123 \text{ lbs/in}$$

Stress in pipe at joint:

Hoop stresses:

$$s_{hbmax} = \frac{2\,M_o}{t_p}\,\lambda_p^2\,R_p$$

$$s_{hbmax} = 4{,}248 \text{ psi}$$

$$s_{hsmax} = \frac{-2\,V_o}{t_p}\,\lambda_p\,R_p$$

$$s_{hsmax} = -5{,}035 \text{ psi}$$

Total hoop stress:

$s_{thmax} = s_{hbmax} + s_{hsmax} + s_2$ $s_{thmax} = -81$ psi

Meridional stress: $s_{mbmax} = (6\,M_o)/t_p^2$ $s_{mbmax} = 7{,}714$ psi

$s_{msmax} = (1.932\,V_o)/(\lambda_p\,t_p^2)$ $s_{msmax} = 2{,}944$ psi

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Total Meridional stress:

$s_{tmmax} = s_{mbmax} + s_{msmax} + s_1$ $s_{tmmax} = 11{,}010$ psi

Total stress on pipe at discontinuity:

$s_{btot} = s_{tmmax} + s_{thmax}$ $s_{btot} = 10{,}929$ psi

Margin of Safety:

$MS_1 = (1.5\ s_a / s_{btot}) - 1$ $MS_1 = 2.19$ OK

Package inner blind flange stress (Reference 4, page 307, Case 30):

Flange Pressure Loading: $W_o = P_{red}\ \pi\ R_p^2$ $W_o = 34{,}913$ lbs

Model flange as flat plate with diameter of pipe, which is simply supported using small deflection theory.

Inverse of Poisson's Ratio: $m = 1/v_{cstl}$

Maximum radial stress from pressure at center of flange:

$$s_{fr} = \frac{3\ W_o}{8\ \pi\ m\ t_f^2}(3\ m + 1)$$

$$s_{fr} = 3{,}438 \text{ psi}$$

Maximum radial stress from moment at center of flange:

$$s_{fmr} = \frac{6\ M_o}{t_f^2}$$

$$s_{fmr} = 482 \text{ psi}$$

Shear stress:

$s_s = V_o/t_f$ $s_s = 62$ psi

Total flange stress:

$s_{ftot} = s_{fr} + s_{fmr} + s_s$ $s_{ftot} = 3{,}982$ psi

Margin of Safety:

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$MS_2 = (1.5\ s_a/s_{ftot}) - 1$ $MS_2 = 7.77$ OK

Pressure Change Evaluation Inner Top Cap:

Since this unit is equipped with an inner top cap, evaluate inner top cap stresses.

Top cap pipe thickness: $t_{tcp} = 0.500$ in

Outside diameter of top cap pipe: od_{tcp}: 4 ft + 10 in

Outside pipe radius: $R_{tcp} = od_{tcp}/2$

Flange thickness: $t_{tcf} = 0.750$ in

Flange radius: $R_{tcf} = (od_{tcp} - 2\ t_{tcp})/2$

Rigidity Factors (Reference 4, page 298):

Flange:

$$D_1 = \frac{E_{cstl}\ t_{tcf}^3}{12\left(1 - \nu_{cstl}^2\right)}$$

Pipe:

$$D_2 = \frac{E_{cstl}\ t_{tcp}^3}{12\left(1 - \nu_{cstl}^2\right)}$$

$$\lambda_2 = \left(3\ \frac{1 - \nu_{cstl}^2}{R_{tcp}^2\ t_{tcp}^2}\right)^{\frac{1}{4}}$$

Container mid section stress (Reference 4, page 298, Case 1):

Evaluate for worst case: reduction in external pressure (Reference 1):

$P_{red} = 11.2$ psi

Meridional stress:

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$s_{1tcp} = (P_{red}\ R_{tcp})/(2\ t_{tcp})$ $s_{1tcp} = 325$ psi

Hoop stress:

$s_{2tcp} = (P_{red}\ R_{tcp})/t_{tcp}$ $s_{2tcp} = 650$ psi

Top cap end discontinuity stress (Reference 4, page 307, Case 30):

Discontinuity moment at joint:

$$M_{tco} = \frac{\dfrac{P_{red}\ R_{tcp}^3\ \lambda_2^2\ D_2}{4\ D_1\ (1 + \nu_{cstl})} + \dfrac{2\ P_{red}\ R_{tcp}^2\ \lambda_2^3\ E_{cstl}\ t_{tcf}\ D_2}{E_{cstl}\ t_{tcp}\left(1 - \dfrac{1}{2}\ \nu_{cstl}\right)\left[E_{cstl}\ t_{tcf} + 2\ R_{tcp}\ D_2\ \lambda_2^3\ (1 - \nu_{cstl})\right]}}{2\ \lambda_2 + \dfrac{2\ R_{tcp}\ \lambda_2^2\ D_2}{D_1\ (1 + \nu_{cstl})} - \dfrac{\lambda_2\ E_{cstl}\ t_{tcf}}{E_{cstl}\ t_{tcf} + 2\ D_2\ \lambda_2^3\ R_{tcp}\ (1 - \nu_{cstl})}}$$

$M_{tco} = 968$ lbs

Discontinuity radial shear at joint:

$$V_{tco} = M_{tco}\left[2\ \lambda_2 + \frac{2\ R_{tcp}\ \lambda_2^2\ D_2}{D_1\ (1 + \nu_{cstl})}\right] - \frac{P_{red}\ R_{tcp}^3\ \lambda_2^2\ D_2}{4\ D_1\ (1 + \nu_{cstl})}$$

$V_{tco} = 338$ lbs/in

Stress in pipe at joint:

Hoop stresses:

$$s_{htbmax} = \frac{2\ M_{tco}}{t_{tcp}}\ \lambda_2^2\ R_{tcp}$$

$s_{htbmax} = 12{,}796$ psi

$$s_{htsmax} = \frac{-2\ V_{tco}}{t_{tcp}}\ \lambda_2\ R_{tcp}$$

$s_{htsmax} = -13{,}245$ psi

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Total hoop stress:

$s_{tthmax} = s_{htbmax} + s_{htsmax} + s_{2tcp}$ $s_{tthmax} = 201$ psi

Meridional stress:

$s_{mtbmax} = (6\ M_{tco})/t^2_{tcp}$ $s_{mtbmax} = 23{,}234$ psi

$s_{mtsmax} = (1.932\ V_o)/\lambda_p\ t^2_p$ $s_{mtsmax} = 2{,}944$ psi

Total meridional stress:

$s_{ttmmax} = s_{mtbmax} + s_{mtsmax} + s_{1tcp} + s_{ttmmax} = 26{,}502$ psi

Total stress on pipe at discontinuity:

$s_{bttot} = s_{ttmmax} + s_{tthmax}$ $s_{bttot} = 26{,}703$ psi

Margin of Safety:

$MS_1 = (1.5\ s_a/s_{bttot}) - 1$ $MS_1 = 0.31$ OK

Package bottom flange stress (Reference 4, page 307, Case 30):

Flange Pressure Loading: $W_{tco} = P_{red}\ \pi\ R^2_{tcp}$ $W_{tco} = 29{,}591$ lbs

Model flange as flat plate with diameter of pipe, which is simply supported using small deflection theory.

Inverse of Poisson's Ratio: $m = 1/\nu_{cstl}$

Maximum radial stress from pressure at center of flange:

$$s_{ftcr} = \frac{3\ W_{tco}}{8\ \pi\ m\ t^2_{tcf}}(3\ m + 1)$$

$s_{ftcr} = 20{,}722$ psi

Maximum radial stress from moment at center of flange:

$$s_{ftcmr} = \frac{6\ M_{tco}}{t^2_{tcf}}$$

$s_{ftcmr} = 10{,}326$ psi

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Shear stress:

$s_{tcs} = V_{tco}/t_{tcf}$ $s_{tcs} = 451$ psi

Total flange stress:

$s_{fttot} = s_{ftcr} + s_{ftcmr} + s_{tcs}$ $s_{fttot} = 31{,}499$ psi

Margin of Safety:

$MS_2 = (1.5\ s_a/s_{fttot}) - 1$ $MS_2 = 0.11$ OK

Inner top cap flange/pipe junction stress calculations:

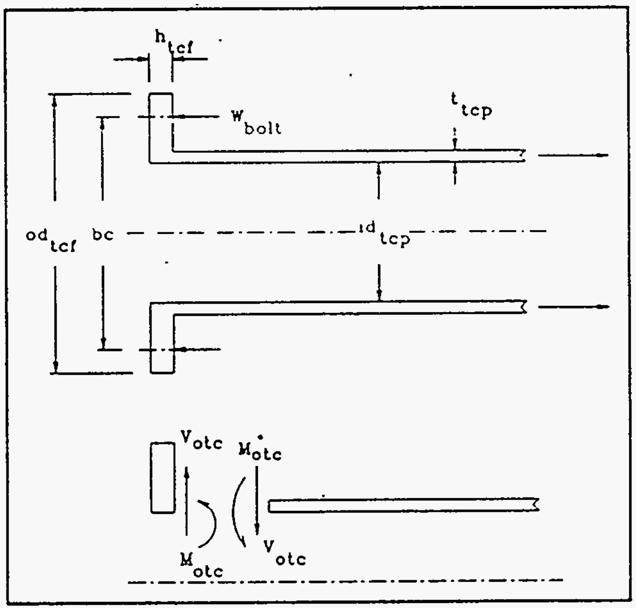

Figure 2

Model as Roark Case 32, flanged and bolted pipe.

Resultant bolt tension from preload (ASME Evaluation):

W_{bolt} 19,969 lbs

OD of pipe: $od_{tcp} = 4$ ft + 10 in

ID of pipe: $id_{tcp} = od_{tcp} - 2(t_{tcp})$

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OD of Flange: od_{tcf} = 5 ft + 3 in

Flange thickness: h_{tcf} = 2.25 in

Bolt circle diameter: bc = 5 ft + 1 in

Dimensional factors:

$$f = \sqrt{id_{tcp}\ t_{tcp}} \qquad T_1 = \frac{t_{tcp}^3 \left(3\ id_{tcp}^2 + 5\ od_{tcf}^2\right)}{h_{tcf}^3 \left(od_{tcf}^2 - id_{tcp}^2\right)}$$

$$T_2 = \frac{3.58\ t_{tcp}^3}{h_{tcf}^3 \left(od_{tcf}^2 - id_{tcp}^2\right)} \left[\frac{od_{tcf}^2}{3} \ln\left(\frac{bc}{id_{tcp}}\right) + 0.1 \left(bc^2 - id_{tcp}^2\right)\right]$$

Radial Shear:

$$V_{otc} = \frac{\left(f^2 - \frac{h_{tcf}^3}{t_{tcp}} T_1\right) \left(t_{tcp} + 0.2325\ f\ T_1\right) P_{red} - 2\ T_2 \left(h_{tcf} + 0.5377\ f\right) W_{bolt}}{1.860\ f\ t_{tcp} + T_1 \left[h_{tcf}^2 \left(2 + 0.1160\ \frac{f}{t_{tcp}}\ T_1\right) + 1.6103\ f\ h_{tcf} + 0.866\ f^2\right]}$$

$$V_{otc} = -43 \text{ lbs/in}$$

Moment:

$$M_{otc} = \frac{\left(h_{tcf}^2\ T_1 + 1.86\ f\ t_{tcp}\right) V_{otc} + h_{tcf}\ T_2\ W_{bolt} - 0.5\ t_{tcp}\ P_{red} \left(f^2 - \frac{h_{tcf}^3}{2\ t_{tcp}}\ T_1\right)}{1.5\ T_1\ h_{tcf} - 3.464\ t_{tcp}}$$

$$M_{otc} = 190 \text{ lbs}$$

Longitudinal bending stress in pipe:

$$s'_{tcp1} = \frac{6\ M_{otc}}{t_{tcp}^2}$$

$$s'_{tcp1} = 4{,}549 \text{ psi}$$

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Longitudinal direct stress in pipe:

$$s_{tcp1} = \frac{W_{bolt} + P_{red}\,\pi\left(\frac{1}{2}\,id_{tcp} - \frac{1}{2}\,t_{tcp}\right)^2}{\pi\,id_{tcp}\,t_{tcp}}$$

$$s_{tcp1} = 537 \text{ psi}$$

Radial bending stress in flange:

$$s'_{tcf1} = \frac{6}{h_{tcf}^2}\left(M_{otc} - \frac{1}{2}\,V_{otc}\,h_{tcf}\right)$$

$$s'_{tcf1} = 282 \text{ psi}$$

Radial direct stress in flange:

$s_{tcf1} = (V_o/h_{tcf}) + P_{red}$ $s_{tcf1} = 66$ psi

$$s'_{tcf2} = s'_{tcf1} + \frac{0.80}{h_{tcf}^2\left(od_{tcf}^2 - id_{tcp}^2\right)}\left[od_{tcf}^2\left(-15\,M_{otc} + 7.5\,h_{tcf}\,V_{otc} + 1.492\,W_{bolt}\ln\left(\frac{bc}{id_{tcp}}\right)\right) + 0.4475\,W_{bolt}\left(bc^2 - id_{tcp}^2\right)\right]$$

$$s'_{tcf2} = -138 \text{ psi}$$

Tangential hoop stress in flange:

$s_{tcf2} = [h^2_{tcf}/(4\,t^3_{tcp})]\,T_1\,(V_o + h_{tcf}\,P_{red})$ $s_{tcf2} = 679$ psi

Total stress in pipe:

$s_{pipe} = s_{tcp1} + s'_{tcp1}$ $s_{pipe} = 5{,}086$ psi

Total stress in flange:

$s_{flange} = s_{tcf1} + s'_{tcf1} + s_{tcf2} + s'_{tcf2}$ $s_{flange} = 888$ psi

Pipe Margin of Safety:

$MS_{pipe} = (1.5\,s_a/s_{pipe}) - 1$ $MS_{pipe} = 6$ OK

Flange Margin of Safety:

$MS_{flange} = (1.5\,s_a/s_{flange}) - 1$ $MS_{flange} = 38$ OK

6.4.4 ASME Design and Bolt Engagement Verification

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Checker P. M. Nguyen Date 08/08/94

I. Objectives:

The objective of this evaluation is to verify the package bolts and flange design loads are in accordance with Reference 2. Also the thread engagement of the inner top cap closure flange is evaluated to insure proper strength of flange material with respect to bolting material. The outer top cap loading is not evaluated since it is not considered a containment boundary for transportation.

II. References:

1. WHC-SD-TP-019, Rev. 0, "Packaging Design Criteria Transfer and Disposal of Hydrogen Mixer Pump".
2. ASME, American Society of Mechanical Engineers, Boiler and Pressure Vessels, Section VIII, Division 2, 1989.
3. Industrial Press, Machinery's Handbook, 20rd Edition.
4. WHC, Drawing No. H-2-83734, "Hydrogen Mixer Pump Storage Container".
5. Flexicarb Product Specification.
6. ASTM, American Society for Testing and Materials, ASTM A307, 1989.

III. Results and Conclusions:

The results of this engineering evaluation, independently verifies that the design is adequate to withstand the pressure loads specified in Reference 1 by meeting the requirements of Reference 2. Also, the specified thread engagement is sufficient to provide a flange strength equivalent to the bolt strength, which insures the bolts will not pull away from the material. Bolt stress values are also used in conjunction with drop evaluations.

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IV. Engineering Evaluation:

ASME Section VIII, Division 2, Verification and Data:

Determination of pipe material allowables and parameters at temperature, Reference 2, Tbl. ACS-1, page 77.

$$s_a = \left[23300 + \frac{(23.1 - 23.3)\cdot 10^3}{(200 - 100)}(115 - 100)\right] psi$$

$$s_a = 23{,}270 \text{ psi}$$

Allowable for bending and discontinuity stresses (Reference 2, page 513):

$s_{a1} = 1.5\ s_a$ $\quad$ $s_{a1} = 34{,}905$ psi

Modulus of Elasticity at temperature, Reference 3, page 70.

$$E_{cstl} = \left[28.8\cdot 10^6 + \left[\left(\frac{28.8 - 29.5}{200 - 70}\right)(115 - 200)\cdot 10^6\right]\right] psi$$

$$E_{cstl} = 2.93 \times 10^7 \text{ psi}$$

Poisson's ratio with no cyclic loading based on yield, (Reference 2, page 516):

$s_{yb} = 38{,}000$ psi $\quad$ $s_{ab} = 38{,}000$ psi

$\nu_{cstl} = 0.5 - 0.2(s_{yb}/s_{ab})$ $\quad$ $\nu_{cstl} = 0.3$

Design pressure: $p_{des} = 11.2$ psi

Allowable tensile on bolting material: $s_{ab} = 55{,}000$ psi

Bolt Loading (Reference 2, Section 3-320, page 488):

Gasket factor from Reference 5:

$m = 2$ $\quad$ $y = 1{,}000$ psi

Inner flange gasket outer diameter: $od_{gas} = 4$ ft + 11.750 in

Inner flange gasket inner diameter: $id_{gas} = 4$ ft + 7.750 in

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Inner flange gasket seat diameter: $id_{itf} = 4$ ft + 10 in

$N = (od_{gas} - id_{itf})/2$ in

Basic gasket seating width: $b_o = N/2$

Since gasket seating width > 1/4, effective gasket seating is:

$$b = \frac{\sqrt{b_o}}{2}\ in$$

With $b_o > 1/4$, diameter at location of gasket reaction is:

$G = od_{gas} - 2(b)$ $G = 59.09$ in

Total hydrostatic end force:

$H = 0.785\ G^2\ p_{des}$ $H = 30{,}697$ lbs

Total joint surface compression load:

$H_p = 2\ b\ (3.14)\ G\ m\ p_{des}$ $H_p = 2{,}749$ lbs

Required bolt load (internal pressure):

$W_{m1} = H + H_p$ $W_{m1} = 33{,}446$ lbs

Total bolt load required for gasket sealing:

$W_{m2} = (3.14)\ b\ G\ y$ $W_{m2} = 61{,}361$ lbs

Since $W_{m1} < W_{m2}$ Gasket seating governs for determining bolt torque.

Bolt diameter: $d_{bolt} = 1$ in Number of bolts: $n_{bolt} = 28$

Threads per inch: $n_{th} = 8/in$

Load per bolt for gasket seating:

$W_{bolt} = W_{m2}/n_{bolt}$ $W_{bolt} = 2{,}191$ lbs

Assume a torquing coefficient of: $K_{coef} = 0.2$

Required tightening torque to seat gasket:

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$T_{req} = K_{coef}\ W_{bolt}\ d_{bolt}$ $T_{req} = 37$ ft-lbs

Specified bolt torque, Reference 4: $T_{prel} = 310$ ft-lbs

Therefore gasket adequately seated and sealed.

Bolt loading:

Preload on bolts: $w_{act} = T_{prel}/(K_{coef}\ d_{bolt})$ $w_{act} = 18{,}600$ lbs

Hydrostatic load per bolt: $h_{hyro} = H/28$ $h_{hyro} = 1{,}096$ lbs

Total load per bolt: $w_{btot} \approx w_{act} + h_{hyro}$ $w_{btot} = 19{,}696$ lbs

Tensile stress in area of bolts, Reference 6:

$$A_b = 0.7845\left(d_{bolt} - \frac{0.9473}{n_{th}}\right)^2$$

Total stress per bolt: $s_{bolt} = w_{btot}/A_b$ $s_{bolt} = 32{,}304$ psi

Margin of Safety based on tensile:

$MS_{bolt} = (s_{ab}/s_{bolt}) - 1$ $MS_{bolt} = 0.7$

Flange bolt design loads:

Internal pressure load:

$$W_{op} = W_{m1}$$

Required total bolt area:

$$A_{m2} = W_{m2}/s_{ab}$$

Gasket load:

$$W_{gsk} = \frac{(A_{m2} + A_b)s_{ab}}{2}$$

$$W_{gsk} = 47{,}448 \text{ lbs}$$

Flange moments from internal pressure:

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ID of flange: $B = id_{itf}$

Thickness of hub back of flange assumed as: $g_1 = 0.5$ in

Bolt circle diameter: $C = 5$ ft + 1 in

Radial distance from bc to intersection of hub and back of flange:

$$R_1 = [(C - B)/2] - g_1$$

Hydrostatic end force on area inside of flange:

$H_D = 0.785\ B^2\ p_{des}$ $H_D = 29{,}576$ lbs

Gasket load: $H_G = W_{op} - H$ $H_G = 2{,}749$ lbs

Difference between total hydrostatic end force and the end force on area inside of the flange.

$H_T = H - H_D$ $H_T = 1{,}121$ lbs

Radial distance from the bolt circle to the circle on which H_D acts:

$$h_D = R_1 + 0.5\ g_1$$

Radial distance from gasket load reaction to the bolt circle:

$$h_G = (C - G)/2$$

Radial distance from the bolt circle to the circle on which H_T acts:

$$h_T = (R_1 + g_1 + h_G)/2$$

Component of moment due to H_D:

$M_D = H_D\ h_D$ $M_D = 36{,}970$ lbs-in

Component of moment due to H_G:

$M_G = H_G\ h_G$ $M_G = 2{,}627$ lbs-in

Component of moment due to H_T:

$M_T = H_T\ h_T$ $M_T = 1{,}376$ lbs-in

Total moments from internal pressure:

$M_{opress} = M_D + M_G + M_T$ $M_{opress} = 40{,}974$ lbs-in

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Moment from gasket seating:

$M_{ogas} = [W_{gas} (C - G)]/2$ $M_{ogas} = 45{,}346$ lbs-in

Hub Flange Stresses (for integral type flange):

Flange thickness: $t_{fb} = 2$ in

Hub length: $h = 0.5$ in

Thickness of hub at small end: $g_o = 0.5$ in

Hub factor:

$$h_o = \sqrt{B\, g_o}$$

Ratio of thicknesses: $(g_1/g_o) = 1$

Ratio of hub lengths: $(h/h_o) = 0.09$

From Reference 2, page 497:

Factors for integral type flanges: $F = 0.908920$ $V = 0.550103$

From Reference 2, page 499:

Hub correction factor for integral type flanges: $f = 1$

Flange OD: $A = 5$ ft + 3 in

Ratio of OD to ID of flange:

$K_1 = A/B$ $K_1 = 1.09$

From Reference 2, page 496, K Factors:

$$U = \frac{K_1^2 \left(1 + 8.55246 \log(K_1)\right) - 1}{1.36136 \left(K_1^2 - 1\right) \left(K_1 - 1\right)}$$

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$$T_1 = \frac{K_1^2\,(1 + 8.55246\,\log(K_1)) - 1}{\left[1.04720 + 1.9448\,(K_1)^2\right](K_1 - 1)}$$

$d = (U/V)\ h_o\ g^2_o$ $\qquad ec = F/h_o$ $\qquad z = (K^2_1 + 1)/(K^2_1 - 1)$

$$L = \frac{t_{fb}\ ec + 1}{T_1} + \frac{t_{fb}^3}{d}$$

$$Y = \frac{1}{K_1 - 1}\left(0.66845 + 5.71690\,\frac{K_1^2\,\log(K_1)}{K_1^2 - 1}\right)$$

Longitudinal hub stress:

$S_H = (f\ M_{ogas})/(L\ g_1^2\ B)$ $\qquad S_H = 3{,}732$ psi

Operation:

$s_h = (f\ M_{opress})/(L\ g_1^2\ B)$ $\qquad s_h = 3{,}372$ psi

Total combined stress: $H_t = S_H + s_h$ $\qquad H_t = 7{,}105$ psi

Radial flange stress:

Gasket seating:

$$S_R = \frac{(1.33\ t_{fb}\ ec + 1)\ M_{ogas}}{L\ t_{fb}^2\ B}$$

$S_R = 338$ psi

Operation:

$$s_r = \frac{(1.33\ t_{fb}\ ec + 1)\ M_{opress}}{L\ t_{fb}^2\ B}$$

$s_r = 305$ psi

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Total combined stress: $R_t = S_R + s_r$ $R_t = 643$ psi

Tangential flange stresses:

Gasket seating:

$$S_T = \frac{Y\, M_{ogas}}{t_{fb}^2\, B} - z\, S_R$$

$S_T = 473$ psi

Operation:

$$s_t = \frac{Y\, M_{opress}}{t_{fb}^2\, B} - z\, s_r$$

$s_t = 427$ psi

Total combined stress: $T_t = S_T + s_t$ $T_t = 900$ psi

Allowable Design Stresses for ASTM A-516 Gr. 70, Normalized:

$s_a = 23{,}270$ psi

$1.5\ s_a = 34{,}905$ psi

For conservatism base on combined stresses:

Paragraph (a)(1): $H_t < 1.5\ s_a$ OK

Paragraph (b): $R_t < s^a$ OK

Paragraph (c): $T_t < s_a$ OK

Paragraph (d): $(H_t + R_t)/2 < s_a$ OK

Paragraph (e): Check weld size

Weld size, assume only one leg: $w_w = 0.500$ in

Weld area: $A_w = 0.707\ w_w\, \pi\, B$

Shear stress on weld: $\tau_w = W_{m2}/A_w$ $\tau_w = 953$ psi

ASME allowable on weld: $s_{wa} = 0.8\ s_a$ $s_{wa} = 18{,}616$ psi

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Checker P. M. Nguyen PMN Date 08/08/94

Margin of Safety:

$MS_w = (s_{wa}/\tau_w) - 1$ $MS_w = 18.54$ OK

Thread Length Engagement Check:

Reference 3, page 1278, for 1-8UN x 4 Bolt:

$K_{nmax} = 0.86$ in $E_{smin} = 0.92$ in $n_{th} = 8/\text{in}$

Bolt effective tensile area:

$$A_t = 0.7845\,[1\text{ in} - (0.9743/n_{th})]^2$$

Required effective engagement length, since tensile strengths are approximately equal:

$$L_e = \frac{2\,A_t}{(\pi\ K_{nmax})\left[\frac{1}{2} + 0.57735\ n_{th}\,(E_{smin} - K_{nmax})\right]}$$

$$L_e = 0.58\text{ in}$$

Actual thread engagement:

Bolt length: $l_{bolt} = 4$ in

Gasket thickness: $t_{gask} = 1/8$ in

Flange thickness: $t_{itcf} = 2.25$ in

$L_{act} = l_{bolt} - t_{gask} - t_{itcf}$ $L_{act} = 1.62$ in

Margin of Safety:

$MS_{te} = (L_{act}/L_e) - 1$ $MS_{te} = 1.82$ OK

6.4.5 Package Lifting Evaluation

ENGINEERING ANALYSIS

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Building Tank 241-SY-101	Rev. 0	Job No.	
Subject Package Lifting Evaluation			
Originator S. S. Shiraga		Date 07/30/94	
Checker P. M. Nguyen		Date 08/03/94	

I. Objectives:

The objective of this evaluation is to determine if the structural integrity of the package remains intact during lifting.

II. References:

1. American Society of Mechanical Engineers,"Boiler and Pressure Vessels", Section VIII, Division 2, 1989.
2. American Institute of Steel Construction, Manual of Steel Construction, Ninth Edition.
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", 1993.
4. WHC, Drawing No. H-2-83734, "Hydrogen Mixer Pump Storage Container".
5. AWS, American Welding Society, AWS/ANSI D1.1, "Structural Welding Code"

III. Results and Conclusions:

The packaging cognizant engineer (S. R. Crow) has stated that the package will be horizontally lifted with a straight vertical lift using two cranes. Subsequently only a straight horizontal lifting situation is evaluated. Since perfectly straight vertical lifts are not always possible, for conservatism, the lifting of the package is modeled as a simply supported beam with concentrated load at the center of gravity. To further add conservatism, the lifting is modeled as if the package were to be lifted by the end stiffening rings. To account for acceleration loading by the lift, the g loading factor for lifting is incorporated from Reference 3.

Due to the long length of the package, the allowable material strengths for this evaluation, are derived from Reference 2 to insure buckling of the inner containment boundary or tear out of the lifting lugs do not occur. The weld allowable strength on the lifting lugs were established from Reference 5, bridge building standards to added conservatism.

Results of the analysis show that there are sufficient margins of safety to for safe lifting of the container. This is demonstrated in the evaluation by showing:

1. Localized buckling of the inner containment boundary will not occur.
2. Tear out of the lifting lugs will not occur.
3. Lifting lug welds will not fail.

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IV. Engineering Evaluation:

Yield Strength of material from Reference 1:

$$s_y = 38,000 \text{ psi}$$

Assume crane components are rigid and straight vertical lift.

Package parameters (Reference 4):

OD of pipe: $od_{pipe} = 64$ in Wall thickness: $t_{pipe} = 0.500$ in

ID of pipe: $id_{pipe} = od_{pipe} - 2\,(t_{pipe})$

Area: $A_{pipe} = \pi\,(od_{pipe}^2 - id_{pipe}^2)/4$

Moment of inertia: $I_{pipe} = \pi\,(od_{pipe}^4 - id_{pipe}^4)/64$

Outer shell cross section (thin portion):

ID of shell: $id_{sh1} = 5 \text{ ft} + 8 \text{ in}$ Wall thickness: $t_{sh1} = 0.3125$ in

OD of shell: $od_{sh1} = id_{sh1} + 2\,(t_{sh1})$

Cross sectional area: $A_{sh1} = \pi\,(od_{sh1}^2 - id_{sh1}^2)/4$

Moment of inertia: $I_{sh1} = \pi\,(od_{sh1}^4 - id_{sh1}^4)/64$

Total moment of section: $I_{p1} = I_{pipe} + I_{sh1}$

Outer shell cross section (thick portion):

ID of shell: $id_{sh2} = 5 \text{ ft} + 8 \text{ in}$ Wall thickness: $t_{sh2} = 0.500$ in

OD of shell: $od_{sh2} = id_{sh1} + 2\,(t_{sh2})$

Cross sectional area: $A_{sh2} = \pi\,(od_{sh2}^2 - id_{sh2}^2)/4$

Moment of inertia: $I_{sh2} = \pi\,(od_{sh2}^4 - id_{sh2}^4)/64$

Total moment of section: $I_{p2} = I_{pipe} + I_{sh2}$

Total Length of package excluding top caps: $l_{pack} = 626.75$ in

Weight of loaded package with full shielding: $W_{pack} = 145,000$ lbs

CG of container from bottom end flange: $cg_{pack} = 31.83 \text{ ft} + 1 \text{ in}$

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G loading factor for lift from (Reference 3): $g_{lift} = 1.5$

AISC allowable determination for unsupported lateral length, Reference 2:

Limiting Width to Thickness Ratio:

$$330{,}000 \text{ psi}/s_y = 86.84$$

Width to thickness ratio of pipe: $od_{pipe}/t_{pipe} = 128$

Since width to thickness ratio exceeds specified AISC allowables (Reference 2) not a compact section.

Therefore AISC allowable bending stress:

$$F_b = 0.60\ s_y \qquad F_b = 22{,}800 \text{ psi}$$

Conservatively model as a simply supported beam with a concentrated load at the cg.

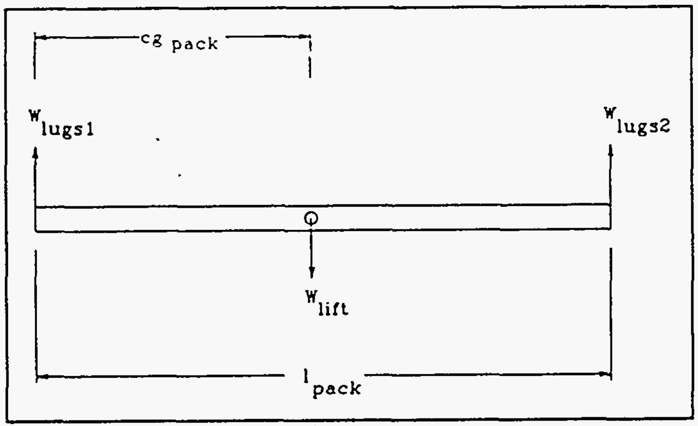

Figure 1

Load due to lifting: $W_{lift} = g_{lift}\ W_{pack}$

Length between supports is assumed as the length of the package without top caps:

$$M_{max} = [W_{lift}\ cg_{pack}\ (l_{pack} - cg_{pack})]/l_{pack}$$

$$M_{max} = 2.7 \times 10^6 \text{ ft lbs}$$

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Bending at cg of package:

$$\sigma_{b1} = \frac{M_{max}\,\frac{od_{sh1}}{2}}{I_{p1}}$$

$$\sigma_{b1} = 12{,}435 \text{ psi}$$

Maximum shear loading at cg:

$$P_1 = [W_{lift}\,(l_{pack} - cg_{pack})]/l_{pack}$$

$$P_1 = 84{,}602 \text{ lbs}$$

$$\tau_{max1} = (2\,P_1)/A_{sh1}$$

$$\tau_{max1} = 2{,}523 \text{ psi}$$

Maximum total stress:

$\sigma_{totl} = \sigma_{b1} + \tau_{max1}$ $\sigma_{totl} = 14{,}958$ psi

Margin of Safety:

$MS_{lift} = (F_b/\sigma_{totl}) - 1$ $MS_{lift} = 0.52$ OK

Evaluate Lifting Lug:

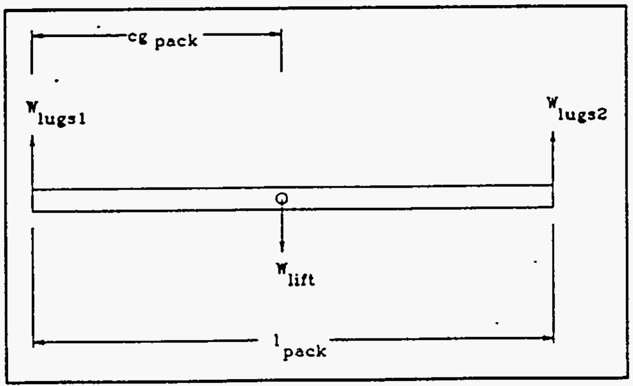

Figure 2

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Checker P. M. Nguyen PMN Date 08/03/94

Material yield strength, (Reference 1): $s_{yl} = 36{,}000$ psi

AISC shear allowable (Reference 2):

$F_v = 0.33\ s_{yl}$ $F_v = 11{,}880$ psi

Load per lifting lug with entire load at cg:

$W_{lugs1} = (W_{lift}\ cg_{pack})/l_{pack}$ $W_{lugs1} = 132{,}898$ lbs

$W_{lugs2} = [W_{lift}\ (l_{pack} - cg_{pack})]/l_{pack}$ $W_{lugs2} = 84{,}602$ lbs

Largest lifting load on lug: $W_{lug} = W_{lugs1}/2$ $W_{lug} = 66{,}449$ lbs

Shear tearout of material:

Hole material: $d_{hole} = 2.5625$ in

Lug thickness: $t_{lug} = 2.0$ in

Distance from edge: $a_{hole} = 4.75\text{ in} - d_{hole}/2$

$\tau_{tearout} = W_{lug}/(2\ a_{hole}\ t_{lug})$

$\tau_{tearout} = 4{,}789$ psi

Margin of Safety:

$MS_{lug} = F_v/\tau_{tearout} - 1$ $MS_{lug} = 1.48$ OK

Weld evaluation:

Weld size: $w_w = 0.75$ in

For conservatism assume welds on front side only and loaded in shear.

Length of welds per side: $l_w = 1\text{ ft} + 2.625\text{ in}$

AWS allowable for welds in shear (Reference 5): $F_w = 0.4\ s_{yl}$ $F_w = 14{,}400$ psi

Assuming fillet weld throat are of 1 inch of weld at 45°:

$A_t = 0.707\ w_w$

Allowable load per inch of weld:

$f_w = F_w\ A_t$ $f_w = 7{,}636$ lbs/in

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Checker P. M. Nguyen PMN Date 08/03/94

Load on welds:

$f_l = W_{lug}/(2\ l_w)$ $f_l = 2{,}272$ lbs/in

Margin of Safety:

$MS_w = (f_w/f_l) - 1$ $MS_w = 2.36$ OK

6.4.6 Penetration Evaluation

ENGINEERING ANALYSIS

Drawing H-2-83734 Doc. No. 101-SY-PEN-01 Page 1 of 3
Building Tank 241-SY-101 Rev. 0 Job No.
Subject Penetration Evaluation
Originator S. S. Shiraga Date 07/26/94
Checker M. D. Clements M.D. Clements Date 07/30/94

I. Objectives:

The objective of this evaluation is to determine the ability of the HMMP package to withstand the stress induced by the dropping of a 13 lbs steel bar onto the packaging as required by Reference 1 and 2.

II. References:

1. US-NRC, 10 CFR Part 71, "Packaging and Transportation of Radioactive Materials".
2. WHC-SD-TP-PDC-019, Rev. 0, "Packaging Design Criteria Transfer and Disposal of Hydrogen Mitigation Mixer Pump".
3. WHC Drawing No. H-2-83734.
4. "Structures to Resist the Effects of Accidental Explosion-Department of the Army, Navy, and Air Force", PM 5-1300 June 1969.
5. "Fundamentals of Protective Design", US Army Corp of Engineers (1943).

III. Results and Conclusions:

The penetration evaluation is performed for the thinnest outer shield retaining shell of the package. As required by Reference 1 and 2, this has been determined as the weakest exposed part of the package.

The evaluation is based on empirical projectile penetration data provided in References 4 and 5. The analysis shows the thinnest section of the package resists penetration by 13 lbs projectile falling onto it from a height of 40 inches. The calculated margin of safey is 0.92 or 92%. It is concluded that the package design is adequate in meeting the requirements of Reference 1 and 2.

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Originator S. S. Shiraga Date 07/26/94
Checker M. D. Clements MDC Date 07/30/94

IV. Engineering Evaluation:

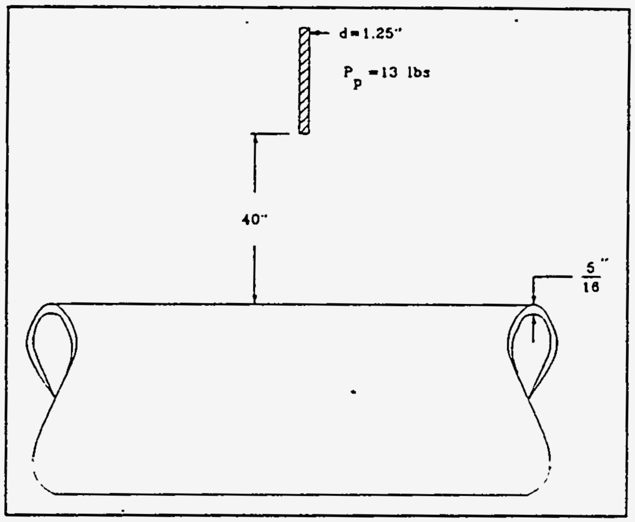

Figure 1

Diameter of projectile (Reference 1): d = 1.25 inches

Height of projectile fall (Reference 1): h = 40 inches

Mass of projectile (Reference 1): w_p = 13 lbs

Outer shell thickness (thinnest section): t_{sh} = 0.3125 inch

Velocity of free fall:

$$v_p = \sqrt{2\ g\ h}$$

$$v_p = 14.65 \text{ ft/sec}$$

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Penetration distance into reinforced concrete (Reference 4):

$$s_{con} = \frac{5.423\ w_p \left[\frac{v_p}{(ft/sec)}\right]^{1.33}}{10^4\ lbs/inch \left(\frac{d}{inch}\right)^{1.8}}$$

$$s_{con} = 0.168 \text{ inch}$$

The penetration distance calculated above is the penetration into reinforced concrete, this can be translated into the perforation limit for steel according to Reference 5, by the following equation:

$$t_{pen} = \frac{1.216\ s_{con} + 1.4\ d}{12}$$

$$t_{pen} = 0.163 \text{ inch}$$

Margin of Safety:

$$MS_{pen} = \frac{t_{sh}}{t_{pen}} - 1$$

$$MS_{pen} = 0.92 \quad \textit{Therefore OK}$$

6.4.7 Low Temperature Brittle Fracture Evaluation

ENGINEERING ANALYSIS

Drawing H-2-83734 Doc. No. 101-SY-BRF-01 Page 1 of 3
Building Tank 241-SY-101 Rev. 0 Job No.
Subject Low Temperature Brittle Fracture Evaluation
Originator S. S. Shiraga Date 07/27/94
Checker M. D. Clements M.D. Clements Date 07/31/94

I. Objectives:

The objective of this evaluation is to verify that the containment materials used in the fabrication of the disposal packaging meets the brittle fracture requirements of Reference 2 at the design temperature range of -10°F to 115°F in order to satisfy the requirements of Reference 1.

II. References:

1. WHC-SD-TP-PDC-019, Rev. 0, "Packaging Design Criteria Transfer and Disposal of Hydrogen Mitigation Mixer Pump".
2. ASME, American Society of Mechanical Engineers, Boiler and Pressure Vessels, Section VIII, Division 1, 1989.
3. WHC Drawing No. H-2-83734, "Hydrogen Mixer Pump Storage Container".

III. Results and Conclusions:

The results of this evaluation shows that major portions of the packaging containment boundary materials used in the the design do not meet all the requirements for extreme low temperature service identified in Reference 2. Specifically the primary containment flanges have nominal thickness in excess of 1.75 inch, which is the limiting exemption thickness at the operating temperature of -10°F. By Reference 2, this would require impact testing of the material to insure safe operation. However, an essential component of low temperature brittle fracture is stress. When not in use and with no internal pressure only the primary containment piping and Inner Top Cap Flange bolts are under load. These component are well within the requirements for exemption from impact testing. And since the containment flanges would not be under any significant loads, this would allow the flanges to exceed the thickness limits specified in Reference 2, without impact testing of the material. However, it is imperative that the Safety Evalution for Packaging (SEP) states that no movement or handling of the container or application of any external load is allowed for temperatures below 0°F, as a safety precaution. Also, since the contents of the packaging may generate hydrogen gas, the package must be vented to prevent pressurization at extreme low temperatures, to prevent significant loading of the flanges.

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Building Tank 241-SY-101 Rev. 0 Job No.
Subject Low Temperature Brittle Fracture Evaluation
Originator S. S. Shiraga Date 07/27/94
Checker M. D. Clements Date 07/31/94

IV. Engineering Evaluation:

Containment component materials of construction (Reference 3):

1) Inner Top Cap 1 inch bolts: ASTM-A 307, Grade B
2) Containment and shielding piping 0.500 and 0.3125 inch thick: ASTM-A 516, Grade 70 (Normalized)
3) Inner Top Cap Material, (thickest) 2.25 inch: ASTM-A 516, Grade 70 (Normalized)
4) Inner Hub Flange, 2.25 inch thick: ASTM-A 516, Grade 70 (Normalized)
5) Bottom Outer End Flange, 2 inch thick: ASTM-A 516, Grade 70 (Normalized)

Section UG-20 Design Temperatures (Reference 2, page 20), states that the requirements for exemption from Impact Testing are:

Paragraph (1)(b):	Nominal thickness for noted materials in Curve D of Figure UCS-66.
Paragraph (2):	Hydrostatic testing, since package primary containment is not under pressure, none required. Outer shell is decay pressure tested.
Paragraph (3):	Design temperatures no warmer than 650°F nor colder than -20°F. Design temperatures as specified in Reference 1 are -10°F and 115°F.
Paragraph (4):	No shock or mechanical loading at low temperatures extreme.
Paragraph (5):	Since one way transport and no movement at extreme low temperatures, no cyclic loads.

Based on containment boundary material thicknesses and data from Curve D of Figure UCS-66, operation or use of the packaging under temperatures less than 0°F requires that the material be impact tested per the requirements of Reference 2. The flange thickness specified would require impact testing of the material at the low temperature specified in Reference 1.

Components which are normally under constant load, whether in use or not, are; the bolts, containment piping and shielding shells. From the data on Figure UCS-66, the containment piping and shielding shells are capable for use to temperatures of -40°F without the requirement for impact testing. The Inner Top Cap containment bolts, from the notes on page 172 of Reference 2, are exempt from

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Drawing H-2-83734 Doc. No. 101-SY-BRF-01 Page 3 of 3
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Checker M. D. Clements MDC Date 07/31/94

impact testing to -20°F. Both these temperatures are below the low temperature requirement stated in Reference 1. *Therefore OK.*

Curve From UCS-66:

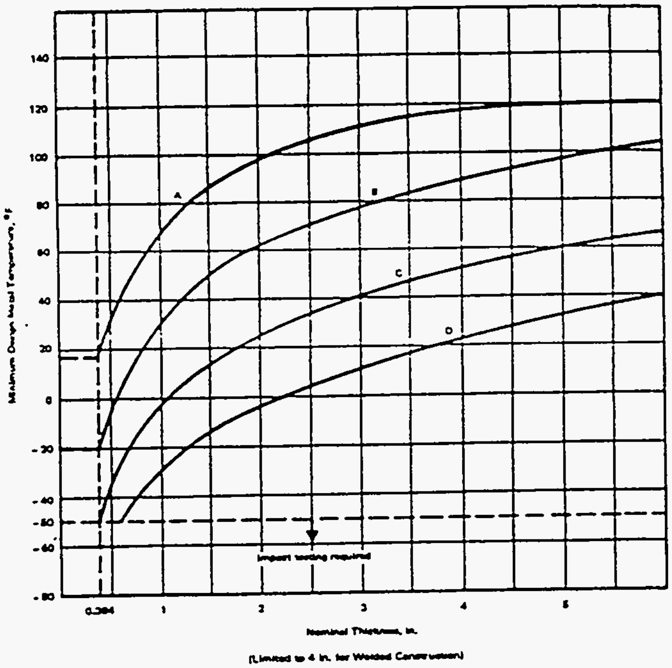

FIG. UCS-66 IMPACT TEST EXEMPTION CURVES [SEE UCS-66(a)]

Figure 1

6.4.8 Vibration Evaluation (Induced by Peak Shock Loading)

ENGINEERING ANALYSIS

Drawing H-2-83734 Doc. No. 101-SY-VIB-01 Page 1 of 24
Building Tank 241-SY-101 Rev. 0 Job No.
Subject Vibration Evaluation (Induced by Peak Shock Loading)
Originator S. S. Shiraga Date 07/31/94
Checker H. E. Adkins Jr. Harold E. Adkins Jr. Date 09/14/94

I. Objectives:

The objective of this vibration evaluation is to determine the stresses induced by peak shock loading during peak shock loading during transportation of the 101-SY package.

II. References:

1. ANSI 14.23, "Draft American National Standard Design Basis for Resistance to Shock and Vibration of Radioactive Material Packages Greater than One Ton in Truck Transport", 1987.
2. ASME, American Society of Mechanical Engineers, Boiler and Pressure Vessels, Section VIII, Division 2, 1989.
3. Industrial Press, Machinery's Handbook, 20th Edition.
4. WHC, Drawing No. H-2-83734, "Hydrogen Mixer Pump Storage Container".
5. Church, A. H., Mechanical Vibrations, 2nd Edition.

III. Results and Conclusions:

Both the vertical and longitudinal peak shock loads are taken from data developed in Reference 1. (Since this is a one-time transfer cyclic fatigue stresses are not evaluated.) The vertical and longitudinal shock loadings are modeled in three sections based on the method of tie-down. The package restraints are modeled in two cases with clamped and fixed boundary conditions at each end and one as a cantilevered section. The maximum total stress in all cases occurred at the tied-down stiffener rings. For this evaluation only the vertical and longitudinal directions are evaluated, since the package is radially symmetrical and in the lateral direction, loading is less than for vertical loading. For conservatism the peak shock load stresses were combined with external pressure reduction stresses.

The results show that all stresses are well under the material strength allowables established in Reference 2. Consequently, the package design is adequate to withstand the combined effects of peak shock loads induced during transport as characterized in Reference 1 and external pressure reduction.

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IV. Engineering Evaluation:

Transportation Peak Vertical Shock Loading on 101 SY:

Since the package is restrained by the strongback and tie-downs at the supports, the system can be modeled as a series of clamped and fixed beams between the supports and as cantilevered sections on the outside. With the sections clamped and fixed, each unit is assumed to be independent of the other. Assume that each section is loaded with a pulsing sinusoidal force, acting at the center of the clamped and fixed sections and at the ends on the cantilevered section. Assume the package sections are of uniform sections, by assuming the weight is uniformly smeared over the length of the section. Assume that all materials are homogeneous, isotropic and obey Hooke's law.

The peak shock load is taken from data developed in Reference 1. The peak vertical shock load was loaded as:

$g_{ps} = 3.5$ at $\omega = 4\pi/\text{sec}$ for a duration of $T_p = 2\pi/\omega$

Container Parameters:

Material Modulus at 115°F $E_{cstl} = 29.1 \times 10^6$ psi

Pipe OD: $dp_{od} = 64$ in Pipe thickness: $t_{pw} = 0.500$ in

Pipe ID: $dp_{id} = dp_{od} - 2t_{pw}$

Assume all outer skin dimensions are the same:

Skin ID: $id_{sk} = 5$ ft + 8 in Skin thickness: $t_{s1} = 0.3125$ in

Skin OD: $od_{sk} = id_{sk} + 2t_{s1}$

Total Area:

$$A_p = \pi \frac{dp_{od}^2 - dp_{id}^2}{4} + \pi \frac{dp_{sk}^2 - id_{sk}^2}{4}$$

Total moment of inertia:

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$$I_p = \pi \frac{dp_{od}^4 - dp_{id}^4}{64} + \pi \frac{od_{sk}^4 - id_{sk}^4}{64}$$

Package Empty full shielded weight: $W_{pac} = 130{,}000$ lbs

Weight of top caps: $W_{tc} = 2{,}400$ lbs

Weight of package without top caps: $W_{con} = W_{pac} - W_{tc}$

Package payload: $W_{pc} = 20{,}000$ lbs

Length of container without top cap: $L_{con} = 626.75$ in

Total weight of package: $W_{pack} = W_{con} + W_{pc}$ $W_{pack} = 147{,}600$ lbs

Load per unit length: $w_{con} = W_{pack}/L_{con}$

Pulsating sinusoidal force: $F_v = g_{ps} w_{con} l \sin(\omega t)$

Where l is defined as the length of the section.

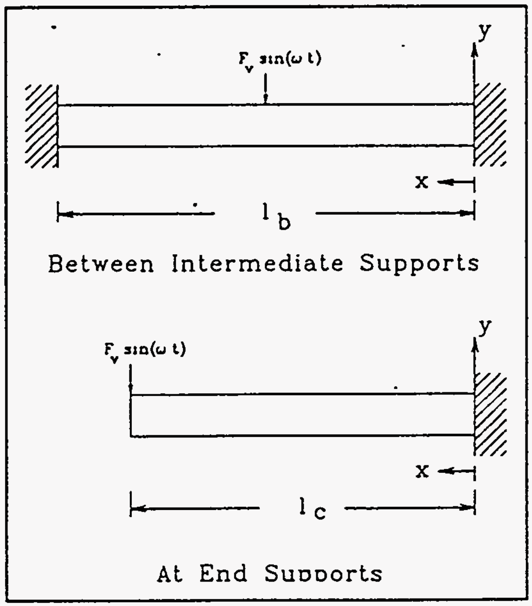

Figure 1

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Response equations for the clamped and fixed sections on strongback:

Length of section between supports:

Location of first support:

$$l_{s1} = \frac{9.75}{2}\ inches$$

Location of second support:

$$l_{s2} = (24\ ft + 0.25\ in) + \frac{(24\ ft + 9.750\ in) - (24\ ft + 0.25\ in)}{2}$$

$l_b = l_{s2} - l_{s1}$ $l_b = 24.01$ ft

Location where beam to be evaluated: $x = l_b$

Assume when the beam vibrates vertically in one of its natural modes, the deflection at any location varies harmonically with time as:

$$y = X(A\cos(\Omega t) + B\sin(\Omega t))$$

The general partial differential equation for free vibration then becomes:

$$d^4X/dx^4 - (k)^4X = 0$$

The general solution for the normal function of deflection then becomes:

$$X = C_1(\cos(kx) + \cosh(kx) + C_2(\cos(kx) - \cosh(kx)) + C_3(\sin(kx) + \sinh(kx) + C_4(\sin(kx) - \sinh(kx))$$

The boundary conditions for a clamped and fixed beam are:

At $x = 0$: $X = 0$ and $dX/dx = 0$

At $x = l_b$; $X = 0$ and $dX/dx = 0$

$$dX/d_x = C_1(-\sin(kx)k + \sinh(kx)k) + C_2(-\sin(kx)k - \sinh(kx)k) + C_3(\cos(kx)k + \cosh(kx)k) + C_4(\cos(kx)k - \cosh(kx)k)$$

$$X = C_2(\cos(kx) - \cosh(kx)) + C_4(\sin(kx) - \sinh(kx))$$

$$dX/d_x = C_2(-\sin(kx)k - \sinh(kx)k) + C_4(\cos(kx)k - \cosh(kx)k)$$

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From $x = 0$: $C_1 = C_3 = 0$

So that:

From $x = l_b$:

$$C_2(\cos(kl_b) - \cosh(kl_b)) + C_4(\sin(kl_b) - \sinh(kl_b)) = 0$$

$$C_2(\sin(kl_b) + \sinh(kl_b)) + C_4(-\cos(kl_b) + \cosh(kl_b)) = 0$$

A solution for the constants C_2 and C_4 are only obtained in the case where the determinant of the above equations equal zero. From the determinant:

$$\cos(kl_b)(\cosh(kl_b)) = 1$$

The non-zero roots of the above equation is approximated by:

$$k_i = \frac{\left(i + \frac{1}{2}\right)\pi}{l_b}$$

The normal function becomes:

$$X_i = \cosh(k_i x) - \cos(k_i x) - \alpha_i(\sinh(k_i x) - \sin(k_i x))$$

Where α_i is defined as:

$$\alpha_i = \frac{\cos(k_i\, l_b) - \cosh(k_i\, l_b)}{\sinh(k_i\, l_b) - \sin(k_i\, l_b)}$$

The response for a steady state forced vibration of a clamped and fixed beam is:

$$y = \frac{2F_v\, l_b^3}{E_{cstl}\, I_p} \sum_i^{\infty} \frac{X_i\, X_{load_i}}{(k_i\, l_b)^4}\, \beta_i \left(\sin(\omega\, t) - \frac{\omega}{\Omega_i}\sin(\Omega_i\, t)\right)$$

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Where X_{load} is defined as the normal function at the load.

$$X_{load_i} = \cosh\left(k_i \frac{l_b}{2}\right) - \cos\left(k_i \frac{l_b}{2}\right) - \alpha_i \left(\sinh\left(k_i \frac{l_b}{2}\right) - \sin\left(k_i \frac{l_b}{2}\right)\right)$$

Since: $M = E_{cstl} I_p d^2y/dx^2$

$$X_i = \cosh(k_i x) - \cos(k_i x) - \alpha_i(\sinh(k_i x) - \sin(k_i x))$$

$$d^2X_i/dx^2 = X''_i = (k_i)^2[\cosh(k_i x) + \cos(k_i x) - \alpha_i(\sinh(k_i x) + \sin(k_i x))]$$

$$d^3X_i/dx^3 = X'''_i = -(k_i)^3(-\sinh(k_i x) + \sin(k_i x) + \alpha_i \cosh(k_i x) + \alpha_i \cos(k_i x))$$

$$\sigma_b = \frac{2\, F_v\, l_b^3\, \frac{dp_{od}}{2}}{I_p} \sum_1^{\infty} \frac{X_{load_i}\, X''_i}{(k_i\, l_b)^4}\, \beta_i \left(\sin(\omega\, t) - \frac{\omega}{\Omega_i} \sin(\Omega_i\, t)\right)$$

$$V_b = 2\, F_v\, l_b^3 \sum_1^{\infty} \frac{X_{load_i}\, X'''_i}{(k_i\, l_b)^4}\, \beta_i \left(\sin(\omega\, t) - \frac{\omega}{\Omega_i} \sin(\Omega_i\, t)\right)$$

Determine stress, deflection and shear load for the first 5 modes at $x = l_b$ for one full period.

$$i = 1 \,..\, 5$$

Natural Frequency:

$$\Omega_i = \left[\left(i + \frac{1}{2}\right)\pi\right]^2 \sqrt{\frac{g\, E_{cstl}\, I_p}{w_{con}\, l_b^4}} \qquad k_i = \frac{\left(i + \frac{1}{2}\right)\pi}{l_b}$$

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Frequency ratio:

$$\beta_i = \frac{1}{\left[1 - \left(\frac{\omega}{\Omega_i}\right)^2\right]}$$

Normal function coefficient:

$$\alpha_i = \frac{\cosh(k_i\, l_b) - \cos(k_i\, l_b)}{\sinh(k_i\, l_b) - \sin(k_i\, l_b)}$$

Normal function at load:

$$X_{load_i} = \left(\cosh\left(k_i\,\frac{l_b}{2}\right) - \cos\left(k_i\,\frac{l_b}{2}\right)\right) - \alpha_i\left(\sinh\left(k_i\,\frac{l_b}{2}\right) - \sin\left(k_i\,\frac{l_b}{2}\right)\right)$$

Normal function of the section:

$$X_i = (\cosh(k_i x) - \cos(k_i x)) - \alpha_i(\sinh(k_i x) - \sin(k_i x))$$

Evaluation time intervals: $n = 0\,..\,8$ $t_n = n/8\ T_p$

Pulsating function magnitude: $F_v = g_{ps}\, w_{con}\, l_b$

Deflection:

$$y_n = \frac{2\,F_v\,l_{b3}^3}{E_{cstl}\,I_p}\sum_i^{\infty}\frac{X_i\,X_{load_i}}{(k_i\,l_b)^4}\,\beta_i\left(\sin(\omega\,t_n) - \frac{\omega}{\Omega_i}\sin(\Omega_i\,t_n)\right)$$

Moment normal function:

$$X''_i = (k_i)^2[\cosh(k_i x) + \cos\,(k_i x) - \alpha_i(\sinh(k_i x) + \sin(k_i x))]$$

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Bending stress:

$$\sigma_{b_n} = \frac{2\ F_v\ l_b^3\ \dfrac{dp_{od}}{2}}{I_p} \sum_i^{\infty} \frac{X_{load_i}\ X''_i}{(k_i\ l_b)^4}\ \beta_i \left(\sin(\omega\ t_n) - \frac{\omega}{\Omega_i}\sin(\Omega_i\ t_n)\right)$$

Shear normal function:

$$X'''_i = -(k_i)^3(-\sinh(k_i x) + \sin(k_i x) + \alpha_i(\cosh(k_i x) + \cos(k_i x))$$

Shear load:

$$V_{b_n} = 2\ F_v\ l_b^3 \sum_i \frac{X_{load_i}\ X'''_i}{(k_i\ l_b)^4}\ \beta_i \left(\sin(\omega\ t_n) - \frac{\omega}{\Omega_i}\sin(\Omega_i\ t_n)\right)$$

Maximum shear stress:

$$\tau_{shmax} = 2\ V_b/A_p$$

Total stress:

$$\sigma_{btot} = \sigma_b + \tau_{shmax}$$

t_n/sec	y_n/in	σ_b/psi	τ_{shmax}	σ_{btot}/psi
0	0	0	0	0
0,063	0	4,387	2,293	6,680
0.125	0	6,219	3,251	9,470
0.188	0	4,375	2,285	6,660
0.25	0	15	5	20
0.313	0	-4,420	-2,315	-6,735
0.375	0	-6,186	-3,236	-9,422
0.438	0	-4,425	-2,314	-6,739
0.5	0	41	25	66

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Maximum stress: $\sigma_{maxbt} = 9{,}470$ psi

ASME Maximum allowable from ASME data of ASTM A-516: $s_a = 23{,}270$ psi

Pressure reduction stress in pipe: $s_{tot} = 1{,}058$ psi

Total stress on pipe: $\sigma_{max1} = \sigma_{maxbt} + s_{tot}$ $\sigma_{max1} = 10{,}528$ psi

Margin of Safety:

$MS_{b1} = (s_a/\sigma_{max1}) - 1$ $MS_{b1} = 1.21$ OK

Response equations for the clamped and fixed sections from strongback:

Length of section between supports:

Length to trailer support: $l_{s3} = 51$ ft + 2.750 in

$l_{1b} = l_{s3} - l_{s2}$ $l_{1b} = 26.81$ ft

Location where beam to be evaluated: $x1 = l_{1b}$

Determine loading using same methodology as above.

Determine stress, deflection and shear load for the first 5 modes at $x1 = l_{1b}$ for one full period.

Natural frequency:

$$\Omega 1_i = \left[\left(i + \frac{1}{2}\right)\pi\right]^2 \sqrt{\frac{g\, E_{cstl}\, I_p}{w_{con}\, l_{1b^4}}} \qquad k1_i = \frac{\left(i + \frac{1}{2}\right)\pi}{l_{1b}}$$

Frequency ratio:

$$\beta 1_i = \frac{1}{\left[1 - \left(\frac{\omega}{\Omega} 1_i\right)^2\right]}$$

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Normal function coefficient:

$$\alpha1_i = \frac{\cosh(k1_i\ l_{1b}) - \cos(k1_i\ l_{1b})}{\sinh(k1_i\ l_1 b) - \sin(k1_i\ l_{1b})}$$

Normal function at load:

$$X1_{load_i} = \left(\cosh\left(k1_i\ \frac{l_{1b}}{2}\right) - \cos\left(k1_i \frac{l_{1b}}{2}\right)\right) - \alpha1_i \left(\sinh\left(k1_i\ \frac{l_{1b}}{2}\right) - \sin\left(k1_i\ \frac{l_{1b}}{2}\right)\right)$$

Normal function of the section:

$$X1_i = (\cosh(kl_i xl) - \cos(kl_i xl)) - \alpha l_i(\sinh(kl_i xl) - \sin(kl_i xl))$$

Pulsating function magnitude: $Fl_v = g_{ps}\ w_{con}\ l_{1b}$

Deflection:

$$y1_n = \frac{2\ F1_v\ l_{1b}^3}{E_{cstl}\ I_p} \sum_i^{\infty} \frac{X1_i\ X1_{load_i}}{(k1_i\ l_{1b})^4}\ \beta1_i \left(\sin(\omega\ t_n) - \frac{\omega}{\Omega1_i} - \sin(\Omega1_i\ t_n)\right)$$

Moment normal function:

$$Xl''_i = (kl_i)^2[\cosh(kl_i xl) + \cos(kl_i xl) - \alpha l_i(\sinh(kl_i xl) + \sin(kl_i xl))]$$

Bending stress:

$$\sigma1_{b_n} = \frac{2\ F1_v\ l_{1b}^3\ \frac{dp_{od}}{2}}{I_p} \sum_i^{\infty} \frac{X1_{load_i}\ X1''_i}{(k1_i\ l_{1b})^4}\ \beta1_i \left(\sin(\omega\ t_n) - \frac{\omega}{\Omega1_i}\ \sin(\Omega1_i\ t_n)\right)$$

Shear normal function:

$$Xl'''_i = -(kl_i)^3(\sinh(kl_i xl) + \sin(kl_i xl) + \alpha l_i \cosh(kl_i xl) + \alpha l_i \cos(kl_i xl))$$

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Shear load:

$$V1_{b_n} = 2\,F1_v\,l_{1b}^3 \sum_i^{\infty} \frac{X1_{load_i}\,X1'''_i}{(k1_i\,l_{1b})^4}\,\beta 1_i \left(\sin(\omega\,t_n) - \frac{\omega}{\Omega 1_i}\sin(\Omega 1_i\,t_n)\right)$$

Maximum shear stress:

$$\tau 1_{shmax} = 2\,V1_b/A_p$$

Total stress:

$$\sigma 1_{btot} = \sigma 1_b + \tau 1_{shmax}$$

t_n/sec	$y1_n$/in	$\sigma 1_b$/psi	$\tau 1_{shmax}$/psi	$\sigma 1_{btot}$/psi
0	0	0	0	0
0.063	0	5,344	2,498	7,842
0.125	0	7,974	3,739	11,713
0.188	0	5,241	2,450	7,691
0.25	0	173	84	256
0.313	0	-5,534	-2,596	-8,130
0.375	0	-7,843	-3,677	-11,520
0.438	0	-5,281	-2,469	-7,751
0.5	0	-246	-122	-369

Maximum stress: $\sigma_{maxblt} = 11{,}713$ psi

Total Pressure on pipe: $\sigma_{max2} = \sigma_{maxblt} + s_{tot}$ $\sigma_{max2} = 12{,}771$ psi

Margin of Safety:

$MS_{b2} = (s_a/\sigma_{max2}) - 1$ $MS_{b2} = 0.82$ OK

Response equations for the cantilevered sections:

Using the same method as above determine the response of the long cantilevered section.

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Length of top cap: $l_{tcap} = (2\text{ ft} + 1.875\text{ in}) + 0.375\text{ in} + 2.25\text{ in}$

Length of section between supports:

Length from support to top end flange:

$$l_{s4} = (52\text{ ft} + 0.750\text{ in}) - (51\text{ ft} + 2.750\text{ in})$$

$$l_c = l_{s4} + 1\text{ in} + l_{tcap}$$

Location where beam to be evaluated: $x_c = 0\text{ in}$

Additional weight due to top cap: $W_{tcap} = W_{tc}$

$$w_{con1} = W_{con}/L_{con} + W_{tcap}/l_{tcap}$$

Determine stress and deflection for the first 5 modes at $x = 0$ for one full period.

Natural Frequency:

$$\Omega_{c_i} = \left[\left(i - \frac{1}{2}\right)\pi\right]^2 \sqrt{\frac{g\, E_{cstl}\, I_p}{w_{con1}\, l_c^4}} \qquad k_{c_i} = \frac{\left(i - \frac{1}{2}\right)\pi}{l_c}$$

Frequency ratio:

$$\beta_{c_i} = \frac{1}{\left[1 - \left(\frac{\omega}{\Omega_{c_i}}\right)^2\right]}$$

Normal function coefficient:

$$\alpha_{c_i} = \frac{\cosh(k_{c_i}\, l_c) + \cos(k_{c_i}\, l_c)}{\sinh(k_{c_i}\, l_c) + \sin(k_{c_i}\, l_c)}$$

Normal function at load:

$$X_{cload} = (\cosh(k_c l_c) - \cos(k_c l_c)) - \alpha_c(\sinh(k_c l_c) - \sin(k_c l_c))$$

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Normal function of the section:

$$X_c = (\cosh(k_c x_c) - \cos(k_c x_c)) - \alpha_c(\sinh(k_c x_c) - \sin(k_c x_c))$$

Pulsating function magnitude: $F_{vc} = g_{ps}\, w_{con1}\, l_c$

Deflection:

$$y_{c_n} = \frac{2\, F_{vc}\, l_c^3}{E_{cstl}\, I_p} \sum_i^{\infty} \frac{X_{c_i}\, X_{cload_i}}{(k_{c_i}\, l_c)^4}\, \beta_{c_i} \left(\sin(\omega\, t_n) - \frac{\omega}{\Omega_{c_i}} \sin(\Omega_{c_i}\, t_n)\right)$$

Normal function of bending stress:

$$X''_c = (k_c)^2[\cosh(k_c x_c) + \cos(k_c x_c) - \alpha_c(\sinh(k_c x_c) + \sin(k_c x_c))]$$

Bending stress:

$$\sigma_{cb_n} = \frac{2\, F_{vc}\, l_c^3\, \frac{dp_{od}}{2}}{I_p} \sum_i \frac{X_{cload_i}\, X''_{c_i}}{(k_{c_i}\, l_c)^4}\, \beta_{c_i} \left(\sin(\omega\, t_n) - \frac{\omega}{\Omega_{c_i}} \sin(\Omega_{c_i}\, t_n)\right)$$

Normal function of shear load:

$$X'''_c = (k_c)^3[\sinh(k_c x_c) - \sin(k_c x_c) - \alpha_c(\cosh(k_c x_c) + \cos(k_c x_c))]$$

Shear load:

$$V_{cb_n} = 2\, F_{vc}\, l_c^3 \sum_i^{\infty} \frac{X_{cload_i}\, X'''_{c_i}}{(k_{c_i}\, l_c)^4}\, \beta_{c_i} \left(\sin(\omega\, t_n) - \frac{\omega}{\Omega_{c_i}} \sin(\Omega_{c_i}\, t_n)\right)$$

Maximum shear stress: $\tau_{cshmax} = 2\, V_{cb}/A_p$

Total stress: $\sigma_{ctot} = \sigma_b - \sigma_{cshmax}$

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t_p/sec	$\dot{y}_c$/in	σ_{cb}/psi	τ_{cshmax}/psi	σ_{ctot}/psi
0	0	0	0	0
0.063	0	872	-683	1,555
0.125	0	1,244	-977	2,221
0.188	0	871	-682	1,552
0.25	0	2	-2	4
0.313	0	-873	685	-1,558
0.375	0	-1,243	977	-2,221
0.438	0	-870	681	-1,551
0.5	0	-3	4	7

Maximum stress: $\sigma_{maxct} \doteq 2{,}221$ psi

Total stress on pipe: $\sigma_{max3} = \sigma_{maxct} + s_{tot}$ $\sigma_{max3} = 3{,}279$ psi

Margin of Safety:

$MS_{c1} = (s_a/\sigma_{max3}) - 1$ $MS_{c1} = 6.1$ OK

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Transportation longitudinal peak shock loading on 101SY:

Model as individual clamped and fixed beams between the supports and as a cantilever at the ends. Assume that load is pulsating sinusoidal force at mid span on the clamped and fixed beams and on the ends for the cantilever.

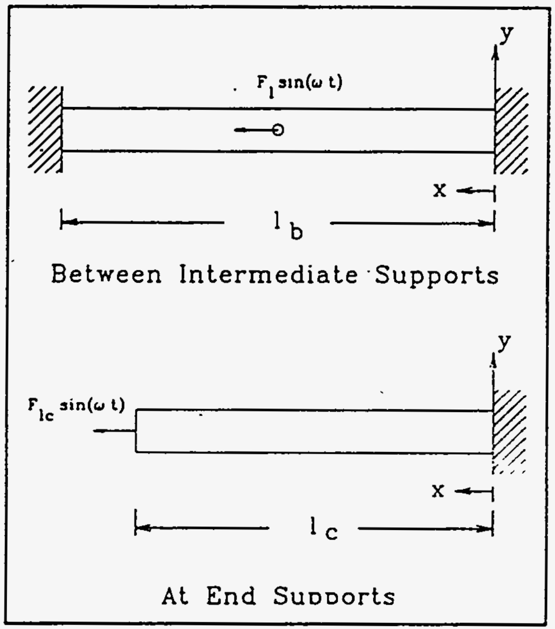

Figure 2

The peak shock load is taken from data developed in the ANSI 14.23 draft. The peak vertical shock load was defined as:

$g_{ps1} = 2.3$ at $\omega = (4\pi)/\text{sec}$ for a duration of $T_p = (2\pi)/\omega$

Container Parameters, Reference 4:

Material Modulus of 115°F: E_{cstl}: 29.1×10^6 psi

Density of carbon steel (Reference 3, pg. 2269): ρ_{cstl}: 0.2835 lbs/in^3

Acoustic velocity in carbon steel:

$$a_{cstl} = \sqrt{\frac{g\, E_{cstl}}{\rho_{cstl}}} \qquad a_{cstl} = 16{,}589\ ft\ \mathrm{sec}^{-1}$$

Pipe OD: $dp_{od} = 64$ in Pipe thickness: $t_{pw} = 0.500$ in

Pipe ID: $dp_{id} = dp_{od} - 2\, t_{pw}$

Cross sectional area of pipe: $A_p = \pi(dp_{od}^2 - dp_{id})/4$

Pipe cross sectional moment of inertia: $I_p = \pi(dp_{od}^4 - dp_{id}^4)/64$

Weight of top caps: $W_{tc} = 2{,}400$ lbs

Package empty fully shielded weight: $W_{pac} = 130{,}000$ lbs

Weight of package without top caps: $W_{con} = W_{pac} - W_{tc}$

Container payload: $W_{pc} = 20{,}000$ lbs

Length of container without top caps: $L_{con} = 626.75$ in

Total weight of container: $W_{pack} = W_{con} + W_{pc}$ $W_{pack} = 147{,}600$ lbs

Load per unit length: $w_{con} = W_{pack}/L_{con}$

Pulsating sinusoidal force: $F_1 = g_{psl}\, w_{con}\, l\, \sin(\omega\, t)$

Where l is defined as the length of the section.

Differential Equation of motion for longitudinal vibration:

$$\frac{d^2 u}{d t^2} = a_{cstl}^2 \frac{d^2 u}{d x^2}$$

Where u is defined as the displacement of the cross section.

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General solution is given as:

$$u(x,t) = \sum_{n} (A\cos(\Omega\ t) + B\sin(\Omega\ t))\left(C\cos\left(\frac{\Omega\ x}{a_{cstl}}\right) + D\sin\left(\frac{\Omega\ x}{a_{cstl}}\right)\right)$$

Where A, B, C, and D are constants to be determined by the boundary and initial conditions. Ω is defined as the natural frequency. It is assumed that all materials are homogenous, isotropic, and obey Hooke's law.

Derivation of normal function for clamped and fixed section:

Since the beam is assumed to be clamped and fixed, the displacement is equal to zero at the ends. The boundary conditions are $u_{x=0}=u_{x=1}=0$. Substituting these into the above equation:

$$u_{x=0} = \sum_{n} f(t)\left(C\cos\left(\frac{\Omega\ x}{a_{cstl}}\right) + D\sin\left(\frac{\Omega\ x}{a_{cstl}}\right)\right) = 0$$

Where f(t) is defined as time dependent function.

Then C=0 and:

$$u_{x=1} = \sum_{n} f(t)\ D\sin\left(\frac{\Omega\ x}{a_{cstl}}\right) = 0$$

Then: $\sin[(\Omega l)/a] = 0$ and $\Omega = (n\pi\Omega a_{cstl})/l$

Therefore the normal function then becomes:

$X(x) = D\sin[(n\ \pi\ x)/l]$

Clamped and fixed supported section between strongback:

Length of section between supports:

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Location of first support:

$$l_{s1} = \frac{9.75}{2}\ inches$$

Location of second support:

$$l_{s2} = (24\ ft + 0.25\ in) + \frac{(24\ ft + 9.750\ in) - (24\ ft + 0.25\ in)}{2}$$

$l_b = l_{s2} - l_{s1}$ $l_b = 24.01$ ft

Evaluation time intervals: $j = 0..8$ $t_j = j/8(T_p)$

Location of evaluation: $x_b = l_b$

Odd number node locations: $n = 1..5$ $i_n = 2n - 1$

Magnitude of pulsating force: $F_l = g_{psl}\ w_{con}\ l_b$ $F_l = 124{,}580$ lbs

Solve for time dependent function for forced vibration:

Since any displacement can be obtained by superposition of corresponding displacements to the normal modes of vibration, vibration by a disturbing force can be represented by a series:

$$u = \sum_n \psi\ X(x)$$

Where ψ is an unknown function of time.

By virtual work: $\delta u = X(x) = D \sin(n\pi x/l)$

Since the mass of an element between adjacent cross sections of the bar is $\rho A_p\ dx$, the virtual work done by the inertial force on the virtual displacement is:

$$\delta W_I = \int_0^l (-\rho\ A_p\ dx)\ \frac{d^2\ u}{d\ x^2}\ \delta u = -\ \rho\ A_p \int_0^l \left(\frac{d^2\ u}{d\ x^2}\right) D \sin\left(\frac{n\ \pi\ x}{l}\right) dx$$

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Substituting for u with the series:

$$\delta W_I = \frac{-\rho\ A_p\ l}{2}\ D\ \frac{d^2\ \psi}{d\ t^2}$$

Virtual work produced by the elastic force is:

$$\delta W_E = \int_0^l \left(E_{cstl}\ A_p\ \frac{d^2\ u}{d\ x^2} \right) dx\ \delta u$$

By substituting in for the above series:

$$\delta W_E = \frac{-n^2\ \pi^2\ E_{cstl}\ A_p}{8\ l}\ D\ \psi$$

Virtual work of the disturbing force where: $x = l/2$

$$\delta W_F = F(t)\ D \sin\left(\frac{n\ \pi}{2}\right) = F(t)\ D\ (-1)^{\frac{i-1}{2}}$$

Second term is a Fourier Series form.

Summing the above expressions gives the total virtual work:

$$\frac{\rho\ A_p\ l}{2}\ \frac{d^2}{d\ t^2}\ \psi + \frac{n^2\ \pi^2\ E_{cstl}\ A_p}{8\ l}\ \psi = F(t)\ \ (-1)^{\frac{i-1}{2}}$$

$$\frac{d^2}{d\ t^2}\ \psi + \left[\Omega_{(i_n)}\right]^2 \psi = \frac{2}{\rho_{cstl}\ A_p\ l_b}\ (-1)^{\frac{i_n-1}{2}}\ F_1 \sin(\omega\ t)$$

The natural frequency is defined as: $\Omega_i = (i_n \pi a_{cstl})/l_b$

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Using Duhamel integral (Reference 5, page 43):

$$\psi = \frac{2\ F_1\ (-1)^{\frac{i_n - 1}{2}}}{A_p\ \rho_{cstl}\ l_b\ \Omega_i} \int_0^t \sin(\omega\ (t - z))\ \sin[\Omega_i\ (t - z)]\ dz$$

$$\psi_{(i_n,j)} = \frac{2\ F_1\ (-1)^{\frac{i_n - 1}{2}}}{A_p\ \dfrac{\rho_{cstl}}{g}\ l_b\ \Omega_{(i_n)}} \cdot \frac{-\left[\begin{array}{l} -\omega\ \cos(\omega\ t_j)\ \sin[\Omega_{i_n}\ t_j] \\ +\ \Omega_{i_n}\ \sin(\omega\ t_j)\ \cos[\Omega_{i_n}\ t_j] \end{array}\right]}{\left[-\omega^2 + [\Omega_{(i_n)}]^2\right]}$$

Deflection:

$$u_j = \sum_n \psi\ (i_n, j)\ \sin\left(\frac{i_n\ \pi\ x_b}{l_b}\right)$$

If du/dx is defined as the strain, then by Hooke's Law, axial stress = E du/dx.

Axial stress:

$$s_{b_j} = E_{cstl}\left[\sum_n \psi_{(i_n,j)}\left(\cos\left(\frac{i_n\ \pi\ x_b}{l_b}\right)\ \frac{i_n\ \pi}{l_b}\right)\right]$$

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t_i/sec	u_i/in	s_b/psi
0	0	0
0.063	0	588
0.125	0	855
0.188	0	470
0.25	0	4
0.313	0	-521
0.375	0	731
0.438	0	-509
0.5	0	7

Maximum axial stress at stiffener ring interface:

$\sigma l_{bmax} = 855$ psi

Pressure reduction stress in pipe: $s_{tot} = 1{,}085$ psi

Total stress on pipe: $\sigma l_{bmax1} = \sigma l_{bmax} + s_{tot}$ $\sigma l_{bmax1} = 1{,}913$ psi

ASME allowable from previous date: $s_a = 23{,}270$ psi

Margin of Safety:

$MS_{bmax} = (s_a / \sigma l_{bmax1}) - 1$ $MS_{bmax} = 11.16$ OK

Clamped and fixed supported section outside of strongback:

Length of section between supports:

Length to trailer support: $l_{s3} = 51$ ft + 2.750 in

$ll_b = l_{s3} - l_{s2}$ $ll_b = 26.81$ ft

Location of evaluation: $xl_b = ll_b$

Magnitude of pulsating force: $Fl_l = g_{psl}\, w_{con}\, ll_b$ $Fl_l = 174{,}276$ lbs

The natural frequency is defined as: $\Omega l_i = (i_n\, \pi\, a_{cstl}) / ll_b$

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Using the same logic as above:

$$\psi 1_{(i_n,j)} = \frac{2\ F1_1\ (-1)^{\frac{i_n - 1}{2}}}{A_p\ \frac{\rho_{cstl}}{g} \cdot l1_b\ \Omega 1_{(i_n)}} \cdot \frac{-\left[\begin{array}{l} -\omega \cos(\omega\ t_j) \sin\left[\Omega 1_{(i_n)}\ t_j\right] \\ +\ \Omega 1_{(i_n)} \sin(\omega\ t_j) \cos\left[\Omega 1_{(i_n)}\ t_j\right] \end{array}\right]}{\left[-\omega^2 + \left[\Omega 1_{(i_n)}\right]^2\right]}$$

Deflection:

$$u1_j = \sum_n \psi 1_{(i_n,j)} \sin\left(\frac{i_n\ \pi\ x1_b}{l1_b}\right)$$

Axial stress:

$$s1_{b_j} = E_{cstl}\left[\sum_n \psi 1_{(i_n,j)} \left(\cos\left(\frac{i_n\ \pi\ x1_b}{l1_b}\right) \frac{i_n\ \pi}{l1_b}\right)\right]$$

t_j/sec	ul_j/in	sl_b/psi
0	0	0
0.063	0	-588
0.125	0	-857
0.188	0	655
0.25	0	6
0.313	0	628
0.375	0	-918
0.438	0	553
0.5	0	6

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Maximum axial stress at stiffener rings:

$\sigma l_{bmax} = 918$ psi

Total stress on pipe: $\sigma l_{maxt} = \sigma l_{bmax} + s_{tot}$ $\sigma l_{maxt} = 1{,}976$ psi

Margin of Safety:

$MS_{b1max} = (s_a/\sigma l_{maxt}) - 1$ $MS_{b1max} = 10.78$ OK

Cantilevered section:

Length of top cap: $l_{tc} = (2\text{ ft} + 1.875\text{ in}) + 0.375\text{ in} + 2.25\text{ in}$

Length from support to top end flange:

$l_{s4} = (52\text{ ft} + 0.750\text{ in}) - (51\text{ ft} + 2.750\text{ in})$

Length of cantilevered section: $l_c = l_{s4} + l_{tc} + 1$ in

Location of evaluation: $x_c = 0$ in

Add in additional length and weight of top hat: $W_{hat} = W_{tc}$

Assume additional weight distributed along axis: $w_{con1} = w_{con} + (W_{hat}/l_{tc})$

Magnitude of pulsating force: $F_{lc} = g_{psl}\, w_{con1}\, l_c$ $F_{lc} = 29{,}046$ lbs

The natural frequency is defined as: $\Omega_{c(i)} = (i_n\,\pi\, a_{cstl})/(2 l_c)$

From the same logic as above, the response equation becomes:

$$\phi_{(i_n,j)} = \frac{2\cdot F_{1c}}{\dfrac{\rho_{cst1}}{g} A_p\, l_c}\left[\frac{(-1)^{\left(\frac{i_n-1}{2}\right)}}{\left[\left[\Omega_{c(i_n)}\right]^2-\omega^2\right]}\sin(\omega\, t_j)\right]$$

Deflection:

$$u_{c_j} = \sum_n \phi_{(i_n,j)} \sin\left(\frac{i_n\,\pi\, x_c}{2\, l_c}\right)$$

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Axial stress:

$$s_{c_j} = E_{cstl}\left[\sum_{n}\Phi_{(i_n,j)}\cdot\left(\frac{1}{2}\cos\left(\frac{1}{2}\,\frac{i_n\,\pi\,x_c}{l_c}\right)\frac{i_n\,\pi}{l_c}\right)\right]$$

t_j/sec	u_c/in	s_c/psi
0	0	0
0.06	0	55
0.13	0	77
0.19	0	55
0.25	0	0
0.31	0	-55
0.38	0	-77
0.44	0	-55
0.5	0	-0

Maximum axial stress at stiffener ring:

σ_{cmax} = 77 psi

Total stress on pipe: $\sigma_{cmaxt} = \sigma_{cmax} + s_{tot}$ σ_{cmaxt} = 1,135 psi

Margin of Safety:

$MS_{cmax} = (s_a/\sigma_{cmaxt}) - 1$ MS_{cmax} = 19.5 OK

6.4.9 Drop Evaluation Loaded with No Shielding (101-SY Package)

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Originator S. S. Shiraga Date 07/30/94
Checker S. R. Crow Date 08/31/94

I. Objectives:

The objective of this evaluation is to assess the ability of the 101SY packaging without shielding to maintain leak tightness and structural integrity after a 1 foot flat drop onto a horizontal 12 thick concrete surface (References 1 and 2). Maintenance of leak tightness and structural integrity after a 1 foot drop is demonstrated by confirming the stresses in critical components and at critical locations of the package are adequately below the values established in Reference 8.

II. References:

1. WHC-SD-TP-019, Rev 0, "Packaging Design Criteria Transfer and Disposal of Hydrogen Mixer Pump".
2. WHC, Engineering Change Notice 606676, dated June 27, 1994.
3. American Institute of Steel Construction, Steel Construction Manual, 9th Edition.
4. US-NRC, 10 CFR Part 71, "Packaging and Transportation of Radioactive Materials".
5. WHC Drawing, No. H-2-83734, "Hydrogen Mixer Pump Storage Container".
6. EPRI NP-4830, "The Effect of Target Hardness on the Structural Design of Concrete Storage Pads for Spent Fuel Casks".
7. Roark, Formulas for Stress and Strain, 4th Edition.
8. American Society of Mechanical Engineers, Boiler and Pressure Vessels, Section VIII, Division 2, 1989.
9. American Society of Mechanical Engineers, Boiler and Pressure Vessels, Section VIII, Division 1, 1989.
10. American Welding Society, AWS/ANSI D 1.1, "Structural Welding Code".
11. Blodgett, O. W., Design of Welded Structures, 1976.
12. ASTM, American Society of Testing and Materials, Annual Book of ASTM Standards, Volume 15.08.
13. Industrial Press, Machinery's Handbook, 19th Edition.

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III. Results and Conclusions:

This engineering evaluation is based upon classical methods, which models the dynamic loads of impact as static equivalents. The calculations are based on the assumption that the time of loading is long as compared to the natural period of the package. The calculations are also based on elastic behavior of the material.

As stated in the G loading determination calculations, alternate criteria were developed to evaluate package integrity in Reference 1. Under these new criteria based upon Reference 6, the drop G loading is developed to determine the equivalent static loadings to be applied to the package. To insure adequate conservatism, all containment boundary allowables are based on the allowable strength criteria established in Reference 8. Allowables for other critical non-containment boundary components are base on either References 3 or 10 allowables.

The results show that with the new G loadings, for an unshielded package, all the components, materials and welds have adequate margins of safety to insure that the package will not loss containment in the event of a 1 foot drop. Flange and bolt margins are adequate based on Reference 2 allowables, to state with confidence that after a 1 foot drop the package will not leak or expose any portion of the payload to the environs. The structural evaluation also show that shield integrity will be maintained after a drop. This is indicated by the analysis which shows the thinnest section of the Outer Shell has sufficient strength to maintain structural integrity after a drop.

An analysis on the structural capability of the Outer Top Cap was not performed, since this not considered a transportation containment boundary. However, from the configuration as depicted in Reference 5, it is assumed that after a drop the Outer Top Cap will not maintain structural integrity or confinement and will require repair prior to use.

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Checker S. R. Crow Date 08/31/94

IV. Engineering Evaluation:

As per the PDC (References 1 and 2), assume a perfectly flat horizontal drop onto a concrete as specified in the References 1 and 2. Assume the package impacts on all stiffener rings and exterior flanges simultaneously. This analysis models a non-shielded loaded container.

Model drop loading as a beam with multiple supports using the three moment theorem in AISC, Reference 3. Assume package is uniformly loaded, except for payload and rings, as shown in Figure 1. The payload is modeled as a concentrated load with loading at the center of gravity and the rings are modeled as concentrated loads at the supports.

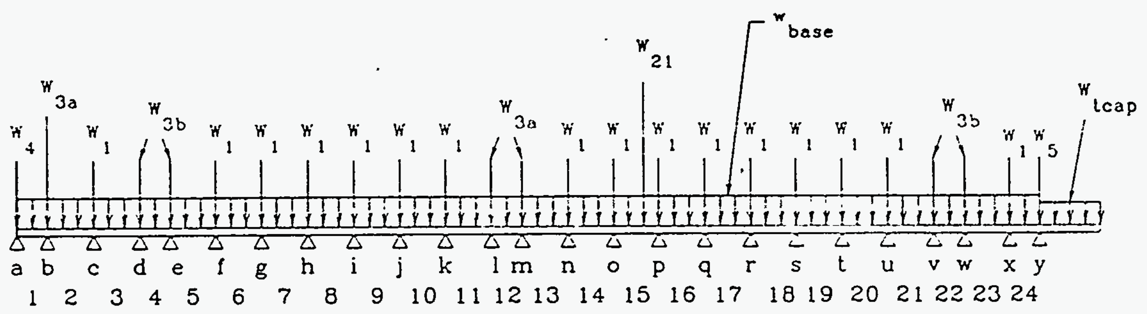

Figure 1

Dimensional parameters Reference 5:

Inner containment pipe:

OD: $od_{pipe} = 64$ in Wall thickness: $t_{pipe} = 0.500$ in

ID: $id_{pipe} = od_{pipe} - 2\ t_{pipe}$

Length of pipe: $l_{pipe} = 52$ ft + 0.75 in

Outer shell thin section:

ID: $id_{shell} = 5$ ft + 8 in Wall thickness: $t_{shell1} = 0.3125$ in

OD: $od_{shell1} = id_{shell} + 2\ t_{shell1}$

Outer shell thick section:

Wall thickness: $t_{shell2} = 0.5$ in

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OD: $od_{shell2} = id_{shell} + 2\ t_{shell2}$

G loading from EPRI drop data (Reference 6): $g_{dec} = 33.4$

Data from weight and center of gravity calculations:

Weight of package (except stiffeners and payload) uniformly distributed:

$W_{base} = 39{,}000$ lbs

Uniform distributed weight of package: $w_{base} = (g_{dec}\ W_{base})/l_{pipe}$

$w_{base} = 2{,}085$ lbs

Weight of stiffener and outer flanges rings:

Bottom end flange: $W_4 = 2{,}600$ lbs

Type 1 stiffener rings: $W_2 = 450$ lbs

Type 2a stiffener rings: $W_{3a} = 525$ lbs

Type 2b stiffener rings: $W_{3b} = 600$ lbs

Weight of payload: $W_{21} = 20{,}000$ lbs

CG of payload from center of bottom flange: $cg_{pay} = 32.56$ ft

This puts it between Columns 15 and 16.

Moment of inertia and cross sectional area of pipe:

Moment of inertia: $I_{pipe} = \pi(od_{pipe}^4 - id_{pipe}^4)/64$

Cross sectional area: $A_{pipe} = \pi(od_{pipe}^2 - id_{pipe}^2)/4$

Moment of inertia and cross sectional area of thin outer shell:

Moment of inertia: $I_{os1} = \pi(od_{shell1}^4 - id_{shell}^4)/64$

Cross sectional area: $A_{os1} = \pi(od_{shell1}^2 - id_{shell}^2)/4$

Moment of inertia and cross sectional area of thick outer shell:

Moment of inertia: $I_{os2} = \pi(od_{shell2}^4 - id_{shell}^4)/64$

Cross sectional area: $A_{os2} = \pi(od_{shell2}^2 - id_{shell}^2)/4$

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Moment of inertia and cross sectional area of composites:

Pipe with thin outer shell:

Moment of inertia: $I_1 = I_{pipe} + I_{os1}$

Cross sectional area: $A_1 = A_{pipe} + A_{os1}$

Pipe with thick outer shell:

Moment of inertia: $I_2 = I_{pipe} + I_{os2}$

Cross sectional area: $A_2 = A_{pipe} + A_{os2}$

Length between centerline of supports:

$l_1 = 9.750 \text{ in}$

$l_2 = (2 \text{ ft} + 10 \text{ in}) - l_1$

$l_3 = (4 \text{ ft} + 10.250 \text{ in}) - (2 \text{ ft} + 10 \text{ in})$

$l_4 = (5 \text{ ft} + 7.750 \text{ in}) - (4 \text{ ft} + 10.250 \text{ in})$

$l_5 = (8 \text{ ft} + 3.250 \text{ in}) - (5 \text{ ft} + 7.750 \text{ in})$

$l_6 = (10 \text{ ft} + 10.750 \text{ in}) - (8 \text{ ft} + 3.250 \text{ in})$

$l_7 = (13 \text{ ft} + 6.25 \text{ in}) - (10 \text{ ft} + 10.750 \text{ in})$

$l_8 = (16 \text{ ft} + 1.750 \text{ in}) - (13 \text{ ft} + 6.25 \text{ in})$

$l_9 = (18 \text{ ft} + 9.250 \text{ in}) - (16 \text{ ft} + 1.750 \text{ in})$

$l_{10} = (21 \text{ ft} + 4.750 \text{ in}) - (18 \text{ ft} + 9.250 \text{ in})$

$l_{11} = (24 \text{ ft} + 0.250 \text{ in}) - (21 \text{ ft} + 4.750 \text{ in})$

$l_{12} = (24 \text{ ft} + 9.750 \text{ in}) - (24 \text{ ft} + 0.250 \text{ in})$

$l_{13} = (27 \text{ ft} + 5.25 \text{ in}) - (24 \text{ ft} + 9.750 \text{ in})$

$l_{14} = (30 \text{ ft} + 0.750 \text{ in}) - (27 \text{ ft} + 5.25 \text{ in})$

$l_{15} = (32 \text{ ft} + 8.250 \text{ in}) - (30 \text{ ft} + 0.750 \text{ in})$

$l_{16} = (35 \text{ ft} + 3.750 \text{ in}) - (32 \text{ ft} + 8.250 \text{ in})$

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l_{17} = (37 ft + 11.750 in) - (35 ft + 3.750 in)

l_{18} = (40 ft + 6.750 in) - (37 ft + 11.750 in)

l_{19} = (43 ft + 2.250 in) - (40 ft + 6.750 in)

l_{20} = (45 ft + 9.750 in) - (43 ft + 2.250 in)

l_{21} = (48 ft + 5.25 in) - (45 ft + 9.750 in)

l_{22} = (49 ft + 2.750 in) - (48 ft + 5.25 in)

l_{23} = (51 ft + 2.750 in) - (49 ft +2.750 in)

l_{24} = (52 ft + 0.750 in) - (51 ft + 2.750 in)

CG of pump locations relative to Column 15 and 16:

Distance from Column 15: $d_a = cg_{pay}$ - (30 ft + 0.750 in)

Distance from Column 16: d_b = (32 ft + 8.25 in) - cg_{pay}

Using the Three Moment Theorem, determine moments at the supports:

End Conditions assuming simply supported:

At bottom end flange end: M_a = 0.0 lbs-in

At top end moments due to top caps exists, model as uniform cantilevered load of combined weight of both inner and outer top caps.

Weight of outer top cap: W_{19} = 1,900 lbs

Weight of inner top cap: W_{20} = 1,500 lbs

Total weight: $W_{tcap} = W_{19} + W_{20}$

Length of outer top cap: l_{tcap} = (2 ft + 1.875 in) + 2.25 in

Assume load is distributed in a triangular shape along the length:

$$M_y = -\left(\tfrac{1}{3}\, g_{dec}\, W_{tcap}\, l_{tcap}\right)$$

End Constraints: M_a = 0.0 lbs-in $M_y = -\left(\tfrac{1}{3}\, g_{dec}\, W_{tcap}\, l_{tcap}\right)$

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Span 1 and 2

$$M_a \frac{l_1}{I_1} + 2\,M_b\left(\frac{l_1}{I_1} + \frac{l_2}{I_1}\right) + M_c \frac{l_2}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_1^3}{I_1} + \frac{l_2^3}{I_1}\right)$$

Span 2 and 3

$$M_b \frac{l_2}{I_1} + 2\,M_c\left(\frac{l_2}{I_1} + \frac{l_3}{I_1}\right) + M_d \frac{l_3}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_2^3}{I_1} + \frac{l_3^3}{I_1}\right)$$

Span 3 and 4

$$M_c \frac{l_3}{I_1} + 2\,M_d\left(\frac{l_3}{I_1} + \frac{l_4}{I_1}\right) + M_e \frac{l_4}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_3^3}{I_1} + \frac{l_4^3}{I_1}\right)$$

Span 4 and 5

$$M_d \frac{l_4}{I_1} + 2\,M_e\left(\frac{l_4}{I_1} + \frac{l_5}{I_1}\right) + M_f \frac{l_5}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_4^3}{I_1} + \frac{l_5^3}{I_1}\right)$$

Span 5 and 6

$$M_e \frac{l_5}{I_1} + 2\,M_f\left(\frac{l_5}{I_1} + \frac{l_6}{I_1}\right) + M_g \frac{l_6}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_5^3}{I_1} + \frac{l_6^3}{I_1}\right)$$

Span 6 and 7

$$M_f \frac{l_6}{I_1} + 2\,M_g\left(\frac{l_6}{I_1} + \frac{l_7}{I_1}\right) + M_h \frac{l_7}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_6^3}{I_1} + \frac{l_7^3}{I_1}\right)$$

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Span 7 and 8, Transition from thin to thick outer shell:

$$M_g \frac{l_7}{I_1} + 2\, M_h \left(\frac{l_7}{I_1} + \frac{l_8}{I_2} \right) + M_i \frac{l_8}{I_2} = -\frac{w_{base}}{4} \left(\frac{l_7^3}{I_1} + \frac{l_8^3}{I_2} \right)$$

Span 8 and 9

$$M_h \frac{l_8}{I_2} + 2\, M_i \left(\frac{l_8}{I_2} + \frac{l_9}{I_2} \right) + M_j \frac{l_9}{I_2} = -\frac{w_{base}}{4} \left(\frac{l_8^3}{I_2} + \frac{l_9^3}{I_2} \right)$$

Span 9 and 10

$$M_i \frac{l_9}{I_2} + 2\, M_j \left(\frac{l_9}{I_2} + \frac{l_{10}}{I_2} \right) + M_k \frac{l_{10}}{I_2} = -\frac{w_{base}}{4} \left(\frac{l_9^3}{I_2} + \frac{l_{10}^3}{I_2} \right)$$

Span 10 and 11

$$M_j \frac{l_{10}}{I_2} + 2\, M_k \left(\frac{l_{10}}{I_2} + \frac{l_{11}}{I_2} \right) + M_l \frac{l_{11}}{I_2} = -\frac{w_{base}}{4} \left(\frac{l_{10}^3}{I_2} + \frac{l_{11}^3}{I_2} \right)$$

Span 11 and 12

$$M_k \frac{l_{11}}{I_2} + 2\, M_l \left(\frac{l_{11}}{I_2} + \frac{l_{12}}{I_2} \right) + M_m \frac{l_{12}}{I_2} = -\frac{w_{base}}{4} \left(\frac{l_{11}^3}{I_2} + \frac{l_{12}^3}{I_2} \right)$$

Span 12 and 13

$$M_l \frac{l_{12}}{I_2} + 2\, M_m \left(\frac{l_{12}}{I_2} + \frac{l_{13}}{I_2} \right) + M_n \frac{l_{13}}{I_2} = -\frac{w_{base}}{4} \left(\frac{l_{12}^3}{I_2} + \frac{l_{13}^3}{I_2} \right)$$

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Span 13 and 14

$$M_m \frac{l_{13}}{I_2} + 2\ M_n \left(\frac{l_{13}}{I_2} + \frac{l_{14}}{I_2} \right) + M_o \frac{l_{14}}{I_2} = -\frac{w_{base}}{4} \left(\frac{l_{13}^3}{I_2} + \frac{l_{14}^3}{I_2} \right)$$

Span 14 and 15, Transition from thick to thin outer shell and pump cg location:

$$M_n \frac{l_{14}}{I_2} + 2\ M_o \left(\frac{l_{14}}{I_2} + \frac{l_{15}}{I_1} \right) + M_p \frac{l_{15}}{I_1} = -\frac{w_{base}}{4} \left(\frac{l_{14}^3}{I_2} + \frac{l_{15}^3}{I_1} \right) + - \frac{g_{dec}\ W_{21}\ d_a \left(l_{15}^2 - d_a^2 \right)}{l_{15}\ I_1}$$

Span 15 and 16, pump cg location:

$$M_o \frac{l_{15}}{I_1} + 2\ M_p \left(\frac{l_{15}}{I_1} + \frac{l_{16}}{I_1} \right) + M_q \frac{l_{16}}{I_1} = -\frac{w_{base}}{4} \left(\frac{l_{15}^3}{I_1} + \frac{l_{16}^3}{I_1} \right) + - \frac{g_{dec}\ W_{21}\ d_b \left(l_{15}^2 - \right.}{l_{15}\ I_1}$$

Span 16 and 17

$$M_p \frac{l_{16}}{I_1} + 2\ M_q \left(\frac{l_{16}}{I_1} + \frac{l_{17}}{I_1} \right) + M_r \frac{l_{17}}{I_1} = -\frac{w_{base}}{4} \left(\frac{l_{16}^3}{I_1} + \frac{l_{17}^3}{I_1} \right)$$

Span 17 and 18

$$M_q \frac{l_{17}}{I_1} + 2\ M_r \left(\frac{l_{17}}{I_1} + \frac{l_{18}}{I_1} \right) + M_s \frac{l_{18}}{I_1} = -\frac{w_{base}}{4} \left(\frac{l_{17}^3}{I_1} + \frac{l_{18}^3}{I_1} \right)$$

Span 18 and 19

$$M_r \frac{l_{18}}{I_1} + 2\ M_s \left(\frac{l_{18}}{I_1} + \frac{l_{19}}{I_1} \right) + M_t \frac{l_{19}}{I_1} = -\frac{w_{base}}{4} \left(\frac{l_{18}^3}{I_1} + \frac{l_{19}^3}{I_1} \right)$$

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Span 19 and 20

$$M_s \frac{l_{19}}{I_1} + 2\,M_t\left(\frac{l_{19}}{I_1} + \frac{l_{20}}{I_1}\right) + M_u \frac{l_{20}}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_{19}^3}{I_1} + \frac{l_{20}^3}{I_1}\right)$$

Span 20 and 21

$$M_t \frac{l_{20}}{I_1} + 2\,M_u\left(\frac{l_{20}}{I_1} + \frac{l_{21}}{I_1}\right) + M_v \frac{l_{21}}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_{20}^3}{I_1} + \frac{l_{21}^3}{I_1}\right)$$

Span 21 and 22

$$M_u \frac{l_{21}}{I_1} + 2\,M_v\left(\frac{l_{21}}{I_1} + \frac{l_{22}}{I_1}\right) + M_w \frac{l_{22}}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_{21}^3}{I_1} + \frac{l_{22}^3}{I_1}\right)$$

Span 22 and 23

$$M_v \frac{l_{22}}{I_1} + 2\,M_w\left(\frac{l_{22}}{I_1} + \frac{l_{23}}{I_1}\right) + M_x \frac{l_{23}}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_{22}^3}{I_1} + \frac{l_{23}^3}{I_1}\right)$$

Span 23 and 24

$$M_w \frac{l_{23}}{I_1} + 2\,M_x\left(\frac{l_{23}}{I_1} + \frac{l_{24}}{I_1}\right) + M_y \frac{l_{24}}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_{23}^3}{I_1} + \frac{l_{24}^3}{I_1}\right)$$

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Table I

Moments	lbs·in
M_a	0
M_b	-73,228
M_c	-121,109
M_d	-55,388
M_e	-126,800
M_f	-184,611
M_g	-169,175
M_h	-173,106
M_i	-173,306
M_j	-168,088
M_k	-188,760
M_l	-111,291
M_m	-175,496
M_n	-40,985
M_o	-694,981
M_p	-304,407
M_q	-141,437
M_r	-181,906
M_s	-166,535
M_t	-170,304
M_u	-186,666
M_v	-117,448
M_w	-129,289
M_x	88,562
M_y	-1×10^6

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Maximum moments between supports and reactions at supports:

Span 1, $M_a<M_b$:

$$M_1 = \frac{w_{base}\, l_1^2}{8} - \frac{M_a + M_b}{2} + \frac{(M_a - M_b)^2}{2\, w_{base}\, l_1^2}$$

$$M_1 = 74{,}917 \text{ lbs-in}$$

$$R_a = \frac{w_{base}\, l_1}{2} - \frac{M_a - M_b}{l_1} + g_{dec}\, W_4$$

$$R_a = 89{,}494 \text{ lbs}$$

Span 2, $M_b<M_c$:

$$M_2 = \frac{w_{base}\, l_2^2}{8} - \frac{M_b + M_c}{2} + \frac{(M_b - M_c)^2}{2\, w_{base}\, l_2^2}$$

$$M_2 = 251{,}367 \text{ lbs-in}$$

$$R_b = \left(\frac{w_{base}\, l_1}{8} + \frac{M_a - M_b}{l_1}\right) + \left(\frac{w_{base}\, l_2}{8} - \frac{M_b - M_c}{l_2}\right) + g_{dec} W_{3a}$$

$$R_b = 31{,}932 \text{ lbs}$$

Span 3, $M_c>M_d$:

$$M_3 = \frac{w_{base}\, l_3^2}{8} - \frac{M_c + M_d}{2} + \frac{(M_c - M_d)^2}{2\, w_{base}\, l_3^2}$$

$$M_3 = 243{,}273 \text{ lbs-in}$$

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$$R_c = \left(\frac{w_{base}\ l_2}{8} + \frac{M_b - M_c}{l_2}\right) + \left(\frac{w_{base}\ l_3}{8} + \frac{M_c - M_d}{l_3}\right) + g_{dec}\ W_2$$

R_c = 26,935 lbs

Span 4, $M_d<M_e$:

$$M_4 = \frac{w_{base}\ l_4^2}{8} - \frac{M_d + M_e}{2} + \frac{(M_d - M_e)^2}{2\ w_{base}\ l_4^2}$$

M_4 = 128,166 lbs-in

$$R_d = \left(\frac{w_{base}\ l_3}{8} - \frac{M_c - M_d}{l_3}\right) + \left(\frac{w_{base}\ l_4}{8} - \frac{M_d - M_e}{l_4}\right) + g_{dec}\ W_{3b}$$

R_d = 24,029 lbs

Span 5, $M_e<M_f$:

$$M_5 = \frac{w_{base}\ l_5^2}{8} - \frac{M_e + M_f}{2} + \frac{(M_e - M_f)^2}{2\ w_{base}\ l_5^2}$$

M_5= 415,117 lbs-in

$$R_e = \left(\frac{w_{base}\ l_4}{8} + \frac{M_d - M_e}{l_4}\right) + \left(\frac{w_{base}\ l_5}{8} - \frac{M_e - M_f}{l_5}\right) + g_{dec}\ W_{3b}$$

R_e = 36,407 lbs

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Span 6, $M_f > M_g$:

$$M_6 = \frac{w_{base}\, l_6^2}{8} - \frac{M_f + M_g}{2} + \frac{(M_f - M_g)^2}{2\, w_{base}\, l_6^2}$$

$$M_6 = 435{,}555 \text{ lbs-in}$$

$$R_f = \left(\frac{w_{base}\, l_5}{8} + \frac{M_e - M_f}{l_5}\right) + \left(\frac{w_{base}\, l_6}{8} - \frac{M_f - M_g}{l_6}\right) + g_{dec}\, W_2$$

$$R_f = 33{,}775 \text{ lbs}$$

Span 7, $M_g < M_h$:

$$M_7 = \frac{w_{base}\, l_7^2}{8} - \frac{M_g + M_h}{2} + \frac{(M_g - M_h)^2}{2\, w_{base}\, l_7^2}$$

$$M_7 = 429{,}749 \text{ lbs-in}$$

$$R_g = \left(\frac{w_{base}\, l_6}{8} - \frac{M_f - M_g}{l_6}\right) + \left(\frac{w_{base}\, l_7}{8} - \frac{M_g - M_h}{l_7}\right) + g_{dec}\, W_2$$

$$R_g = 31{,}815 \text{ lbs}$$

Span 8, $M_h < M_i$:

$$M_8 = \frac{w_{base}\, l_8^2}{8} - \frac{M_h + M_i}{2} + \frac{(M_h - M_i)^2}{2\, w_{base}\, l_8^2}$$

$$M_8 = 431{,}811 \text{ lbs-in}$$

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$$R_h = \left(\frac{w_{base}\ l_7}{8} + \frac{M_g - M_h}{l_7}\right) + \left(\frac{w_{base}\ l_8}{8} - \frac{M_g - M_h}{l_8}\right) + g_{dec}\ W_2$$

$$R_h = 31{,}449 \text{ lbs}$$

Span 9, $M_i > M_j$:

$$M_9 = \frac{w_{base}\ l_9^2}{8} - \frac{M_i + M_j}{2} + \frac{(M_i - M_j)^2}{2\ w_{base}\ l_9^2}$$

$$M_9 = 429{,}308 \text{ lbs-in}$$

$$R_i = \left(\frac{w_{base}\ l_8}{8} + \frac{M_h - M_i}{l_8}\right) + \left(\frac{w_{base}\ l_9}{8} + \frac{M_i - M_j}{l_9}\right) + g_{dec}\ W_2$$

$$R_i = 31{,}290 \text{ lbs}$$

Span 10, $M_j < M_k$:

$$M_{10} = \frac{w_{base}\ l_{10}^2}{8} - \frac{M_j + M_k}{2} + \frac{(M_j - M_k)^2}{2\ w_{base}\ l_{10}^2}$$

$$M_{10} = 437{,}132 \text{ lbs-in}$$

$$R_j = \left(\frac{w_{base}\ l_9}{8} - \frac{M_i - M_j}{l_9}\right) + \left(\frac{w_{base}\ l_{10}}{8} - \frac{M_j - M_k}{l_{10}}\right) + g_{dec}\ W_2$$

$$R_j = 30{,}959 \text{ lbs}$$

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Span 11, $M_k > M_l$:

$$M_{11} = \frac{w_{base}\, l_{11}^2}{8} - \frac{M_k + M_l}{2} + \frac{(M_k - M_l)^2}{2\, w_{base}\, l_{11}^2}$$

M_{11} = 410,080 lbs-in

$$R_k = \left(\frac{w_{base}\, l_{10}}{8} + \frac{M_j - M_k}{l_{10}}\right) + \left(\frac{w_{base}\, l_{11}}{8} + \frac{M_k - M_l}{l_{11}}\right) + g_{dec}\, W_2$$

R_k = 29,646 lbs

Span 12, $M_l < M_m$:

$$M_{12} = \frac{w_{base}\, l_{12}^2}{8} - \frac{M_l + M_m}{2} + \frac{(M_l - M_m)^2}{2\, w_{base}\, l_{12}^2}$$

M_{12} = 177,869 lbs-in

$$R_l = \left(\frac{w_{base}\, l_{11}}{8} - \frac{M_k - M_l}{l_{11}}\right) + \left(\frac{w_{base}\, l_{12}}{8} - \frac{M_l - M_m}{l_{12}}\right) + g_{dec}\, W_{3a}$$

R_l = 23,921 lbs

Span 13, $M_m > M_n$:

$$M_{13} = \frac{w_{base}\, l_{13}^2}{8} - \frac{M_m + M_n}{2} + \frac{(M_m - M_n)^2}{2\, w_{base}\, l_{13}^2}$$

M_{13} = 371,218 lbs-in

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$$R_m = \left(\frac{w_{base}\, l_{12}}{8} + \frac{M_l - M_m}{l_{12}}\right) + \left(\frac{w_{base}\, l_{13}}{8} + \frac{M_m - M_n}{l_{13}}\right) + g_{dec}\, W_{3a}$$

R_m = 30,709 lbs

Span 14, $M_n<M_o$:

$$M_{14} = \frac{w_{base}\, l_{14}^2}{8} - \frac{M_n + M_o}{2} + \frac{(M_n - M_o)^2}{2\, w_{base}\, l_{14}^2}$$

M_{14} = 729,957 lbs-in

$$R_n = \left(\frac{w_{base}\, l_{13}}{8} - \frac{M_m - M_n}{l_{13}}\right) + \left(\frac{w_{base}\, l_{14}}{8} - \frac{M_j - M_k}{l_{14}}\right) + g_{dec}\, W_2$$

R_n = 35,063 lbs

Span 15, $M_o>M_p$, Span where pump is located:

Location of maximum moment: $x_{max} = l_{15}/2 + [(M_o - M_p)/(w_{base}\, l_{15})]$

Moment due to pump at location: $M_{pump} = (g_{dec}\, W_{21}\, d_b\, x_{max})/l_{15}$

Reaction at o due to pump: $R_{po} = (g_{dec}\, W_{21}\, d_b)/l_{15}$

$$M_{15} = \frac{w_{base}\, l_{15}^2}{8} - \frac{M_o + M_p}{2} + \frac{(M_o - M_p)^2}{2\, w_{base}\, l_{15}^2} + M_{pump}$$

M_{15} = 1,113,236 lbs-in

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$$R_o = \left(\frac{w_{base}\ l_{14}}{8} + \frac{M_n - M_o}{l_{14}}\right) + \left(\frac{w_{base}\ l_{15}}{8} + \frac{M_o - M_p}{l_{15}}\right) + R_{po} + g_{dec}\ W_2$$

R_o = 72,258 lbs

Span 16, $M_p > M_q$:

$$M_{16} = \frac{w_{base}\ l_{16}^2}{8} - \frac{M_p + M_q}{2} + \frac{(M_p - M_q)^2}{2\ w_{base}\ l_{16}^2}$$

M_{16} = 487,945 lbs-in

Reaction at p due to pump: $R_{pp} = (g_{dec}\ W_{21}\ d_a)/l_{15}$

$$R_p = \left(\frac{w_{base}\ l_{15}}{8} - \frac{M_o - M_p}{l_{15}}\right) + R_{pp} + \left(\frac{w_{base}\ l_{16}}{8} + \frac{M_p - M_q}{l_{16}}\right) + g_{dec}\ W_2$$

R_p = 674,229 lbs

Span 17, $M_q < M_r$:

$$M_{17} = \frac{w_{base}\ l_{17}^2}{8} - \frac{M_q + M_r}{2} + \frac{(M_q - M_r)^2}{2\ w_{base}\ l_{17}^2}$$

M_{17} = 428,935 lbs-in

$$R_q = \left(\frac{w_{base}\ l_{16}}{8} - \frac{M_p - M_q}{l_{16}}\right) + \left(\frac{w_{base}\ l_{17}}{8} - \frac{M_q - M_r}{l_{17}}\right) + g_{dec}\ W_2$$

R_q = 35,489 lbs

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Span 18, $M_r>M_s$:

$$M_{18} = \frac{w_{base}\ l_{18}^2}{8} - \frac{M_r + M_s}{2} + \frac{(M_r - M_s)^2}{2\ w_{base}\ l_{18}^2}$$

$$M_{18} = 424{,}740 \text{ lbs-in}$$

$$R_r = \left(\frac{w_{base}\ l_{17}}{8} + \frac{M_q - M_r}{l_{17}}\right) + \left(\frac{w_{base}\ l_{18}}{8} + \frac{M_r - M_s}{l_{18}}\right) + g_{dec}\ W_2$$

$$R_r = 32{,}218 \text{ lbs}$$

Span 19, $M_s<M_t$:

$$M_{19} = \frac{w_{base}\ l_{19}^2}{8} - \frac{M_s + M_t}{2} + \frac{(M_s - M_t)^2}{2\ w_{base}\ l_{19}^2}$$

$$M_{19} = 427{,}028 \text{ lbs-in}$$

$$R_s = \left(\frac{w_{base}\ l_{18}}{8} - \frac{M_r - M_s}{l_{18}}\right) + \left(\frac{w_{base}\ l_{19}}{8} - \frac{M_s - M_t}{l_{19}}\right) + g_{dec}\ W_2$$

$$R_s = 31{,}695 \text{ lbs}$$

Span 20, $M_t<M_u$:

$$M_{20} = \frac{w_{base}\ l_{20}^2}{8} - \frac{M_t + M_u}{2} + \frac{(M_t - M_u)^2}{2\ w_{base}\ l_{20}^2}$$

$$M_{20} = 437{,}154 \text{ lbs-in}$$

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$$R_t = \left(\frac{w_{base}\ l_{19}}{8} + \frac{M_s - M_t}{l_{19}}\right) + \left(\frac{w_{base}\ l_{20}}{8} - \frac{M_t - M_u}{l_{20}}\right) + g_{dec}\ W_2$$

R_t = 31,050 lbs

Span 21, $M_u > M_v$:

$$M_{21} = \frac{w_{base}\ l_{21}^2}{8} - \frac{M_u + M_v}{2} + \frac{(M_u - M_v)^2}{2\ w_{base}\ l_{21}^2}$$

M_{21} = 411,820 lbs-in

$$R_u = \left(\frac{w_{base}\ l_{20}}{8} + \frac{M_t - M_u}{l_{20}}\right) + \left(\frac{w_{base}\ l_{21}}{8} + \frac{(M_u - M_v)}{l_{21}}\right) + g_{dec}\ W_2$$

R_u = 29,771 lbs

Span 22, $M_v < M_w$:

$$M_{22} = \frac{w_{base}\ l_{22}^2}{8} - \frac{M_v + M_w}{2} + \frac{(M_v - M_w)^2}{2\ w_{base}\ l_{22}^2}$$

M_{22} = 147,263 lbs-in

$$R_v = \left(\frac{w_{base}\ l_{21}}{8} - \frac{M_u - M_v}{l_{21}}\right) + \left(\frac{w_{base}\ l_{22}}{8} - \frac{M_v - M_w}{l_{22}}\right) + g_{dec}\ W_{3b}$$

R_v = 31,677 lbs

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Span 23, $M_w > M_x$:

$$M_{23} = \frac{w_{base}\, l_{23}^2}{8} - \frac{M_w + M_x}{2} + \frac{(M_w - M_x)^2}{2\, w_{base}\, l_{23}^2}$$

M_{23} = 190,242 lbs-in

$$R_w = \left(\frac{w_{base}\, l_{22}}{8} + \frac{M_v - M_w}{l_{22}}\right) + \left(\frac{w_{base}\, l_{23}}{8} + \frac{(M_w - M_x)}{l_{23}}\right) + g_{dec}\, W_{3b}$$

R_w = 20,940 lbs

Span 24, $M_x < M_y$:

$$M_{24} = \frac{w_{base}\, l_{24}^2}{8} - \frac{M_x + M_y}{2} + \frac{(M_x - M_y)^2}{2\, w_{base}\, l_{24}^2}$$

M_{24} = 3,703,167 lbs-in

$$R_x = \left(\frac{w_{base}\, l_{23}}{8} - \frac{M_w - M_x}{l_{23}}\right) + \left(\frac{w_{base}\, l_{24}}{8} - \frac{(M_x - M_y)}{l_{24}}\right) + g_{dec}\, W_2$$

R_x = -82,350 lbs

Reaction at Column 25:

$$R_y = \frac{w_{base}\, l_{24}}{8} + \frac{M_x - M_y}{l_{24}} + g_{dec}\, W_{tcap}$$

R_y = 231,485 lbs

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Maximum loading on ring:

Maximum loading on ring at Column 16, R_p. Model as combined loading of Ring loaded as loading smeared over entire volume of the ring Reference 7, pages 176 and 178, Case 22 and opposed by a reactive load transferred by tangential shear Roark Case 24. Also assume ring acts as a curved beam (shown Figures 2 and 3).

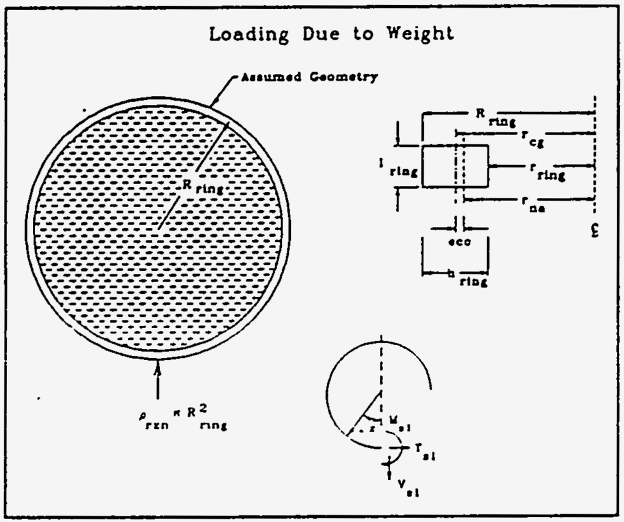

Figure 2

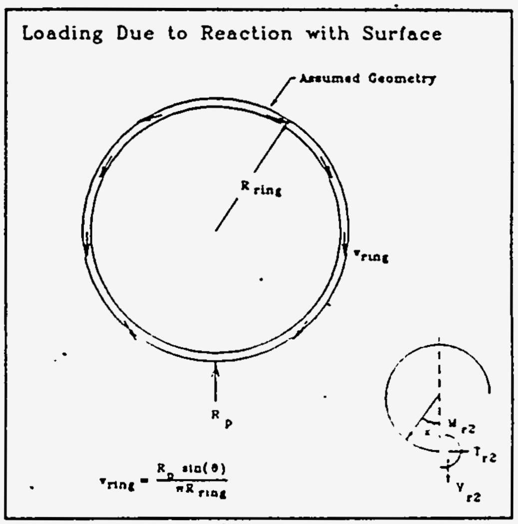

Figure 3

Nominal radius of ring:

OD of ring: $od_{ring} = 5\ \text{ft} + 11.625\ \text{in}$

$R_{ring} = od_{ring}/2$ $R_{ring} = 2.98\ \text{ft}$

Width of ring: $b_{ring} = 1.5\ \text{in}$

Distributed weight of ring throughout cross section:

$w_{ring} = R_p/(\pi\ R_{ring}^2\ b_{ring})$ $w_{ring} = 112\ \text{lbs-in}^3$

Case 20 Maximum Loading at bottom of ring:

$\alpha = 0\ \text{deg}$ $\theta = 0\ \text{deg}$

$u = \cos(\alpha)$ $s = \sin(\theta)$ $c = \cos(\theta)$ $z = \sin(\alpha)$

Maximum moment loading: $M_{1ring} = \tfrac{3}{4}\ w_{ring}\ R_{ring}^3$ $M_{1ring} = 3.84 \times 10^6\ \text{lbs}$

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Circumferential Tension:

$$T_{1ring} = w_{ring} R_{ring}^2 (1 + \tfrac{1}{4} u - \tfrac{1}{2} \pi z + \tfrac{1}{2} \alpha z)$$

$$T_{1ring} = 178{,}845 \text{ lbs/in}$$

Radial Shear:

$$V_{1ring} = w_{ring} R_{ring}^2 (\tfrac{1}{2} \alpha u + \tfrac{1}{4} z - \tfrac{1}{2} \pi u)$$

$$V_{1ring} = -224{,}743 \text{ lbs/in}$$

Case 25, Opposing moment at bottom of ring, $\theta = 0°$, $\alpha = 0°$

Counteracting Moment:

$$M_{2ring} = - [R_p R_{ring} [0.23868 u - \tfrac{1}{2} s + 0.15915 (a z + \theta s + c - u c^2)]]$$

$$M_{2ring} = -5.76 \times 10^6 \text{ lbs-in}$$

Circumferential Tension:

$$T_{2ring} = R_p [0.15915 (\alpha z - u c^2) - 0.07958 u]$$

$$T_{2ring} = -160{,}959 \text{ lbs}$$

Radial Shear:

$$V_{2ring} = - [R_p [0.15915 (\alpha u - \tfrac{1}{2} z + z c^2) - \tfrac{1}{2} u]]$$

$$V_{2ring} = 337{,}115 \text{ lbs}$$

Resultant loading:

Maximum Moment:

$M_{rring} = M_{1ring} b_{ring} + M_{2ring}$ $M_{rring} = 1{,}266$ lbs-in

Circumferential Tension:

$T_{rring} = T_{1ring} b_{ring} + T_{2ring}$ $T_{rring} = 107{,}309$ lbs

Radial Shear:

$V_{rring} = V_{1ring} b_{ring} + V_{2ring}$ $V_{rring} = 0$ lbs

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Geometric parameters of pipe:

Inside radius of ring is id of pipe: $r_{ring} = (od_{pipe} - t_{pipe})/2$

Normal depth of ring including pipe thickness:

$h_{ring} = R_{ring} - r_{ring}$ $h_{pipe} = 4.06$ in

Neutral axis of ring:

$$r_{na} = \frac{h_{ring}}{\ln\left(\frac{R_{ring}}{r_{ring}}\right)}$$

CG of ring:

$r_{cg} = r_{ring} + (h_{ring}/2)$

Eccentricity: $ecc = r_{cg} - r_{na}$

Cross sectional area: $A_{ring} = h_{ring}\, b_{ring}$

Stresses in ring:

Bending stress:

$$\sigma_{bottom} = \frac{M_{rring}\,(r_{na}\; r_{ring})}{A_{ring}\; ecc\; r_{ring}}$$

$\sigma_{bottom} = 320$ psi

Tangential stress:

$\sigma_{tan} = T_{rring}/A_{ring}$ $\sigma_{tan} = 17{,}610$ psi

Maximum shear stress:

$\tau_{ring} = 2\, V_{rring}/A_{ring}$ $\tau_{ring} = 0$ psi

Total stress:

$\sigma_{tot} = \sigma_{bottom} + \sigma_{tan} + \tau_{ring}$ $\sigma_{tot} = 17{,}929$ psi

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ASME allowable from previous data: $s_a = 23{,}270$ psi

Margin of Safety on inner pipe:

$MS_{pipe} = (s_a/\sigma_{tot}) - 1$ $MS_{pipe} = 0.3$ OK

Maximum loading on inner containment pipe between rings:

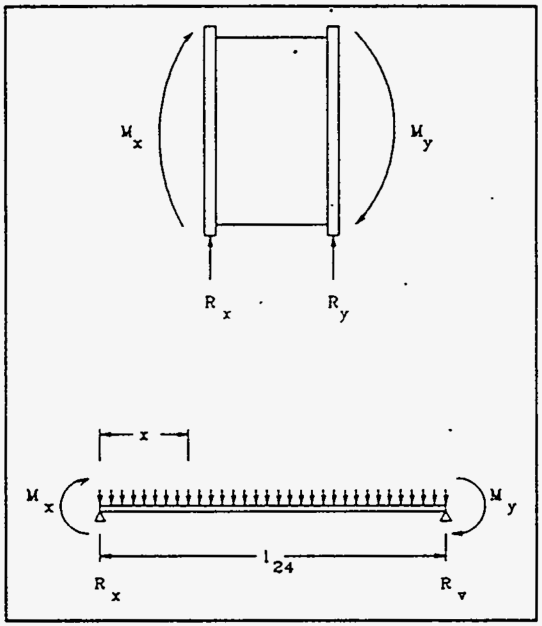

Figure 4

Maximum bending between Columns 24 and 25:

$$\sigma_{bmax} = \frac{M_{24}\left(\frac{od_{pipe}}{2}\right)}{I_{pipe}}$$

$\sigma_{bmax} = 2{,}357$ psi

Short beam criteria applies here, therefore must consider maximum shear.

Maximum shear: $\tau_{ymax} = 2\ R_y/A_{pipe}$ $\tau_{ymax} = 4{,}642$ psi

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Bending at support:

$$\sigma_{by} = \frac{|M_y| \frac{od_{pipe}}{2}}{I_{pipe}}$$

$$\sigma_{by} = 678 \text{ psi}$$

Total stress at pipe section:

$\sigma_{ytot} = \sigma_{bmax} + \tau_{ymax}$ $\sigma_{ytot} = 6{,}998$ psi

Margin of Safety:

$MS_{ypipe} = (s_a/\sigma_{ytot}) - 1$ $MS_{ypipe} = 2.33$ OK

Loading on Inner Blind Flange Plate:

Assuming inside pipe welds carry the entire load determine weld strength.

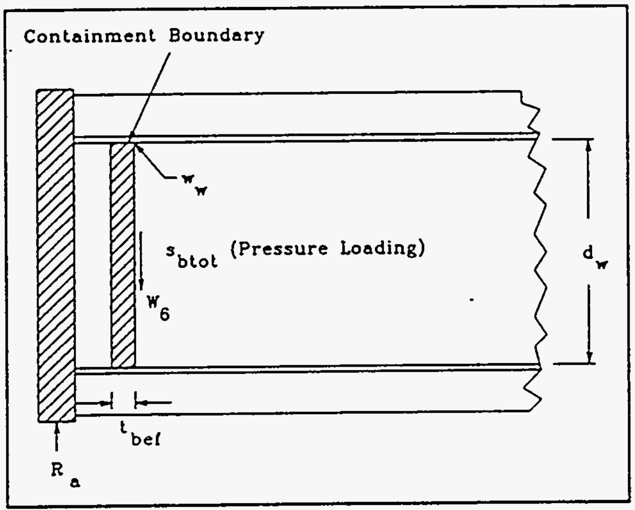

Figure 5

Plate thickness: $t_{bef} = 2.0$ in

From ASME, allowable at joint discontinuities: $1.5\ s_a = 34{,}905$ psi

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Since welds are 100% radiographed assume full strength of fillets.

Weld size, assuming on one weld: $w_w = 0.500$ in

Weld diameter is assumed as same size as pipe: $d_w = id_{pipe}$

Circumference of weld (one side only): $c_w = \pi\ d_w$

Pressure loading from pressure calculations at pipe joint discontinuity:

$$s_{btot} = 10{,}929 \text{ psi}$$

Shear area of weld: $A_w = 0.707\ w_w\ c_w$

Maximum shear due to deflection of pipe during drop:

Weight of inner blind flange: $W_6 = 1{,}800$ lbs

$\tau_{drop} = (2\ g_{dec}\ W_6)/A_w$ $\tau_{drop} = 1{,}719$ psi

Total stress on weld:

$\sigma_{wtot} = \tau_{drop} + s_{btot}$ $\sigma_{wtot} = 12{,}648$ psi

Margin of Safety:

$MS_{befw} = (1.5\ s_a/\sigma_{wtot}) - 1$ $MS_{befw} = 1.76$ OK

Top Cap Loading:

Retaining Ring Loading:

Since fitup tolerance of retaining ring is tighter than for bolts, retaining ring takes up all shear loading from the drop.

Weight of inner top cap: $W_{20} = 1{,}500$ lbs

ID of retaining ring: $id_{itcrr} = 5$ ft + 3 in

Wall thickness: $t_{itcrr} = 0.375$ in

OD of retaining ring: $od_{itcrr} = id_{itcrr} + 2\ t_{itcrr}$

Cross sectional area of ring:

$$A_{itcrr} = \pi\ (od_{itcrr}^2 - id_{itcrr}^2)/4$$

Maximum shearing load on the ring cross section:

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$$\tau_{rrmax} = (2\ g_{dec}\ W_{20})/A_{itcrr}$$

$$\tau_{rrmax} = 1{,}342 \text{ psi}$$

Margin of Safety:

$MS_{rrs} = (s_a/\tau_{rrmax}) - 1$ $MS_{rrs} = 16.34$ OK

Loading on the bolts:

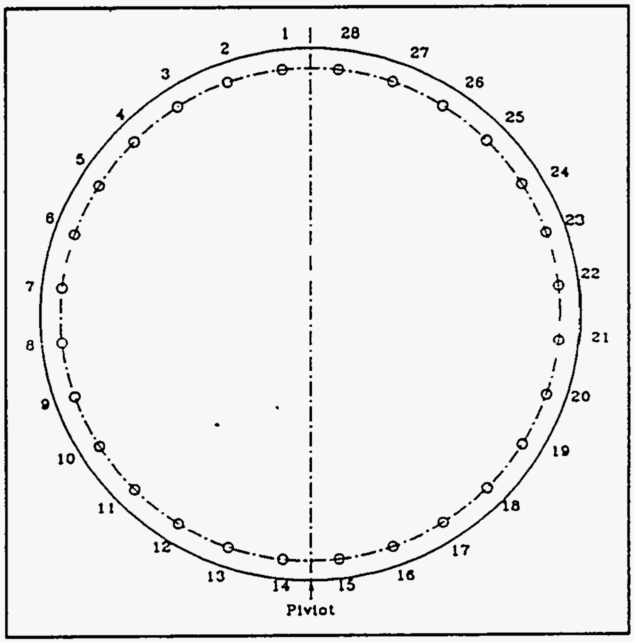

Figure 6

CG of top cap from inner flange face: $cg_{itc} = 1.39$ ft

Bolt parameters:

Number of bolts: $n_{bitc} = 28$

Nominal diameter of bolts: $d_{bitc} = 1$ in

Tensile stress area of each bolt (Reference 12, page 1278):

$$A_b = 0.7854\ (d_{bitc} - 0.9743\ \text{in}/8)^2$$

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Allowable tensile strength of bolts: $\sigma_{bten} = 55{,}000$ psi

Total preload and pressure load per bolt from ASME evaluation:

$$W_{btot} = 19{,}696 \text{ lbs}$$

Angle from vertical flange axis: $\theta_1 = 6.43$ deg

Angle of bolt spacing: $\theta_2 = 12.83$ deg

Diameter of bolt circle: $d_{bc} = 61$ in

Diameter of flange: $d_{flange} = id_{itcrr}$

Distance from Pivot to bolts 14 to 1:

$r_{bc} = d_{bc}/2$ $r_{flange} = d_{flange}/2$

Perpendicular distance:

Distance from pivot to centerline of bolt 14:

$$r_{14} = r_{flange} - r_{bc}\cos(\theta_1)$$

Distance from pivot to centerline of bolt 13:

$$r_{13} = f_{flange} - r_{bc}\cos(\theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 12:

$$r_{12} = r_{flange} - r_{bc}\cos(2\,\theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 11:

$$r_{11} = r_{flange} - r_{bc}\cos(3\,\theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 10:

$$r_{10} = r_{flange} - r_{bc}\cos(4\,\theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 9:

$$r_9 = r_{flange} - r_{bc}\cos(5\,\theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 8:

$$r_8 = r_{flange} - r_{bc}\cos(6\,\theta_2 + \theta_1)$$

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Distance from pivot to centerline of bolt 7:

$$r_7 = r_{flange} + r_{bc} \sin(\theta_1)$$

Distance from pivot to centerline of bolt 6:

$$r_6 = r_{flange} + r_{bc} \sin(\theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 5:

$$r_5 = r_{flange} + r_{bc} \sin(2\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 4:

$$r_4 = r_{flange} + r_{bc} \sin(3\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 3:

$$r_3 = r_{flange} + r_{bc} \sin(4\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 2:

$$r_2 = r_{flange} + r_{bc} \sin(5\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 1:

$$r_1 = r_{flange} + r_{bc} \sin(6\ \theta_2 + \theta_1)$$

By symmetry bolts distances 15 to 28 are equal to 14 to 1, respectively.

Moment due to drop due to eccentric loading of bolts:

$$M_{bitc} = g_{dec} W_{20}\, cg_{itc}$$

Tensile load on bolt 1 (highest loading):

$$F_{bitc1} = \frac{r_1 M_{bitc}}{2\left(\begin{array}{c} r_1^2 + r_2^2 + r_3^2 + r_4^2 + r_5^2 + r_6^2 + r_7^2 + r_8^2 \\ + r_9^2 + r_{10}^2 + r_{11}^2 + r_{12}^2 + r_{13}^2 + r_{14}^2 \end{array}\right)}$$

$$F_{bitc1} = 1{,}285 \text{ lbs}$$

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Total bolt load:

$W_{itcb} = W_{btot} + F_{bitc1}$ $W_{itcb} = 20{,}981$ lbs

Tensile stress on bolt:

$\sigma_{bolt} = W_{itcb}/A_b$ $\sigma_{bolt} = 34{,}637$ psi

Margin of Safety based on bolt ultimate:

$MS_{bolt} = (\sigma_{bten}/\sigma_{bolt}) - 1$ $MS_{bolt} = 0.59$ OK

Outer Shell Loading from lead:

Model longest thinnest section only:

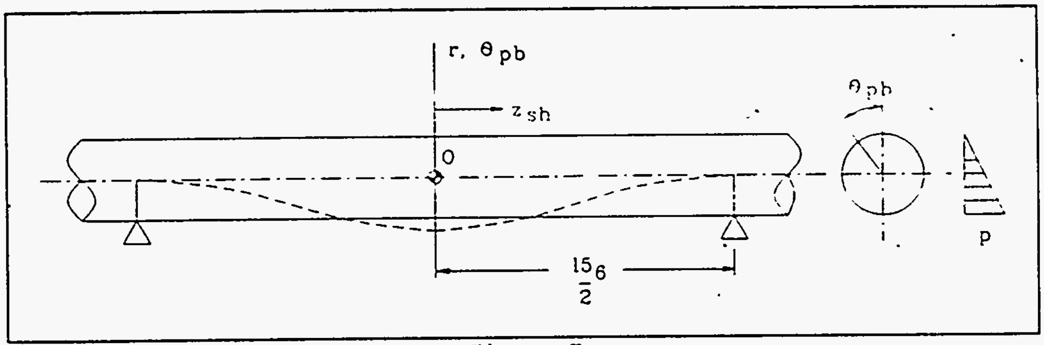

Figure 7

ID of shell: $id_{shell} = 5\text{ ft} + 8\text{ in}$

Wall thickness: $t_{516sh} = 0.3125$ in

OD of shell: $od_{shell} = id_{shell} + 2\,t_{516sh}$

Inner cross sectional void area of shell:

$$A_{crsh} = \pi(id_{shell}^2 - od_{pipe}^2)/4$$

Longest length between supports: $15_6 = 2.5$ ft

Mid point of length: $z_{sh} = 15_6/2$

Gap of void: $gap = (id_{shell} - od_{pipe})/2$ gap = 2 in

Radius of lead: $r_{pb} = od_{pipe}/2 + gap$

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Angle of evaluation: $\theta_{pb} = 180$ deg

Poissin's ratio for carbon steel (Reference 8): $\nu_{cstl} = 0.3$

Density of lead (Reference 13, page 398): $\rho_{pb} = 0.4096\ \text{lbs/in}^3$

Assume 65% density of shot: $\rho_{shot} = 0.65\ \rho_{pb}$

Weight of lead between supports:

$$w_{spb} = A_{crsh}\ \rho_{shot}\ 15_6$$

$$w_{spb} = 3{,}312\ \text{lbs}$$

Assume weight of lead smeared over the entire cross sectional area:

Cross sectional area: $A_{smr} = (\pi/4)od_{shell}^2$

Smear density: $\rho_{smr} = w_{spb}/(A_{smr}\ 15_6)$

Load between supports at angle of evaluation, stress due to lead slump modeled using membrane theory of pipe filled between supports with a flowable material.

Tangential stress:

$$\sigma_t = \frac{g_{dec}\ \rho_{smr}\ r_{pb}^2}{t_{516}sh}\left(1 - \cos(\theta_{pb})\right)$$

$$\sigma_t = 7{,}376\ \text{psi}$$

Longitudinal stress:

$$\sigma_l = \frac{g_{dec}\ \rho_{smr}}{t_{516}sh}\left(\frac{z_{sh}^2}{2}\right)\cos(\theta_{pb}) + \rho_{cstl}\ \sigma_t$$

$$\sigma_l = 1{,}854\ \text{psi}$$

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Shear stress:

$$\sigma_{shr} = \frac{-g_{dec}\,\rho_{smr}}{t_{516}\,sh}\left(\frac{z_{sh}^2}{2}\right)\sin(\theta_{pb})$$

$$\sigma_{shr} = 0 \text{ psi}$$

Total stress at maximum deflection (at center of length):

$$\sigma_{pbtot} = \sigma_t \bullet \sigma_l + \sigma_{shr}$$

$$\sigma_{pbtot} = 9{,}230 \text{ psi}$$

Margin of Safety:

$MS_{pb} = (s_a/\sigma_{pbtot}) - 1$ $MS_{po} = 1.52$ OK

Weld on Stiffener Rings:

Evaluate circumferential fillet welds joining the stiffening rings and end plates to the inner containment pipe. Assume welds are 1/2 inch fillets both sides.

Weld size: $w_{srw} = 0.500$ in

Diameter of weld is OD of pipe: od_{pipe}: 64 in

Largest moment on outer top end plate, model as pipe welded to stiffening ring with no support from outer shell or top cap flange.

Evaluate weld per AWS, Reference 11, page 7.4-7.

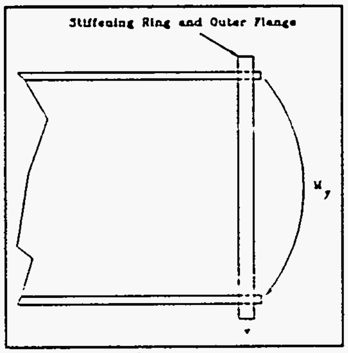

Figure 8

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Treat the welds as a line in bending:

$$S_{weld} = \pi \frac{od_{pipe}^2}{4}$$

Linear Force on welds, assuming welds equally share the load:

$$f_b = \left| \frac{M_y}{2\ S_{weld}} \right|$$

$$f_b = 165 \text{ lbs/in}$$

AWS allowable for fillet welds used in Bridge Construction for ASTM A-36 material with thickness greater than 1 inch using E60 or SAW-1 Electrodes and assuming parallel loading, Reference 10 and Reference 11, page 7.4-8.

$$s_{aws} = 8{,}800 \text{ psi}$$

Allowable line load:

$f_{aws} = s_{aws}\ (0.707\ w_{srw})$ $f_{aws} = 3{,}111$ lbs/in

Margin of Safety:

$MS_{srw} = (f_{aws}/f_b) - 1$ $MS_{srw} = 17.8$ OK

6.4.10 Drop Evaluation Loaded and Fully Shielded (101-SY)

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Checker S. R. Crow S.R.Crow Date 08/31/94

I. Objectives:

The objective of this evaluation is to assess the ability of the 101-SY fully shielded packaging to maintain leak tightness and structural integrity after a 1 foot flat drop onto a horizontal 12 inch thick concrete surface (Reference 1 and 2). Maintenance of leak tightness and structural integrity are demonstrated by confirming the stresses in critical components and at critical locations of the package are adequately below the values established in Reference 8.

II. References:

1. WHC-SD-TP-019, Rev 0, "Packaging Design Criteria Transfer and Disposal of Hydrogen Mixer Pump".
2. WHC, Engineering Change Notice 606676, dated June 27, 1994.
3. American Institute of Steel Construction, Steel Construction Manual, 9th Edition.
4. US-NRC, 10 CFR Part 71, "Packaging and Transportation of Radioactive Materials".
5. WHC Drawing, No. H-2-83734, "Hydrogen Mixer Pump Storage Container".
6. EPRI NP-4830, "The Effect of Target Hardness on the Structural Design of Concrete Storage Pads for Spent Fuel Casks".
7. Roark, Formulas for Stress and Strain, 4th Edition.
8. American Society of Mechanical Engineers, Boiler and Pressure Vessels, Section VIII, Division 2, 1989.
9. American Society of Mechanical Engineers, Boiler and Pressure Vessels, Section VIII, Division 1, 1989.
10. American Welding Society, AWS/ANSI D 1.1, "Structural Welding Code".
11. Blodgett, O. W., Design of Welded Structures, 1976.
12. ASTM, American Society of Testing and Materials, Annual Book of ASTM Standards, Volume 15.08.
13. Industrial Press, Machinery's Handbook, 20th Edition.

III. Results and Conclusions:

As with the results for an unshielded package, results for a fully shielded package show that all components, materials and welds have adequate margins of

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safety to insure that the package will not lose containment in the event of a 1 ft drop. In most cases the stresses are somewhat lower since with the heavier package the deceleration factors are less (shown in the G loading evaluation). This is due primarily to the fundamental axioms in Reference 6. The EPRI report (Reference 6) considers that due to the hardness and stiffness of a cask, the concrete pad will fail absorbing most of the energy of impact. Subsequently, the heavier the cask the more the concrete fails absorbing more energy. This results in lower deceleration loads being transmitted to the package or cask. Consequently, since the fully shielded package is heavier than the unshielded package less deceleration loading is experienced by the fully shielded package which results in lower stress values.

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IV. Engineering Evaluation:

As per the PDC (Reference 1), assume a perfectly flat horizontal drop onto a concrete as specified in the Reference 1. Assume the package impacts on all stiffener rings and exterior flanges simultaneously. This analysis models a fully shielded loaded container.

Model drop loading as a beam with multiple supports using the three moment theorem in AISC, Reference 2. Assume package is uniformly loaded, except for payload and rings. The payload is modeled as a concentrated load with loading at the center of gravity and the rings are modeled as concentrated loads at the supports.

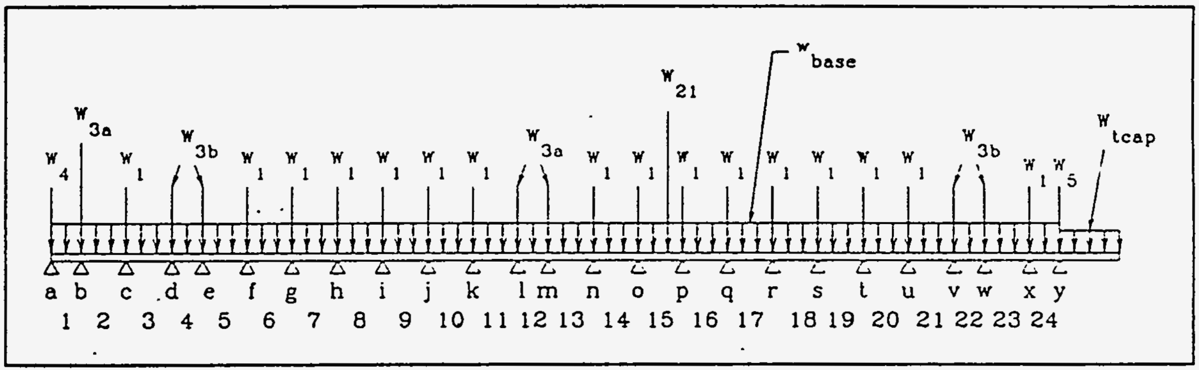

Figure 1

Pipe and shell parameters, Reference 5:

Inner containment pipe:

OD: $od_{pipe} = 64$ in Wall thickness: $t_{pipe} = 0.500$ in

ID: $id_{pipe} = od_{pipe} - (2\ t_{pipe})$

Length of pipe: $l_{pipe} = 52$ ft + 0.75 in

Outer shell thin section:

ID: $id_{shell} = 5$ ft + 8 in Wall thickness: $t_{shell} = 0.3125$ in

OD: $od_{shell1} = id_{shell} + 2\ (t_{shell1})$

Outer shell thick section:

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Wall thickness: $t_{shell2} = 0.5$ in

OD: $od_{shell2} = id_{shell} + 2\,(t_{shell2})$

G loading from EPRI drop data (Reference 6): $g_{dec} = 25.3$

Data from weight and center of gravity calculations:

Weight of shielding: $W_{18b} = 66{,}000$ lbs

Weight of package (except stiffeners and payload) uniformly distributed:

$$W_{base} = 39{,}000 \text{ lbs} + W_{18b}$$

Uniform distributed weight of package:

$$w_{base} = (g_{dec}\, W_{base})/l_{pipe} \qquad w_{base} = 4{,}252 \text{ lbs/in}$$

Weight of stiffener rings:

Bottom end flange: $W_4 = 2{,}600$ lbs

Type 1 stiffener rings: $W_2 = 450$ lbs

Type 2a stiffener rings: $W_{3a} = 525$ lbs

Type 2b stiffener rings: $W_{3b} = 600$ lbs

Weight of payload: $W_{21} = 20{,}000$ lbs

CG of payload from center of bottom flange: $cg_{pay} = 32.56$ ft

Putting it between Columns 15 and 16.

Moment of inertia and cross sectional area of pipe:

Moment of inertia: $I_{pipe} = \pi(od^4_{pipe} - id^4_{pipe})/64$

Cross sectional area: $A_{pipe} = \pi(od^2_{pipe} - id^2_{pipe})/4$

Moment of inertia and cross sectional area of thin outer shell:

Moment of inertia: $I_{os1} = \pi(od^4_{shell1} - id^4_{shell})/64$

Cross sectional area: $A_{os1} = \pi(od^2_{shell1} - id^2_{shell})/4$

Moment of inertia and cross sectional area of thick outer shell:

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Moment of inertia: $I_{os2} = \pi(od^4_{shell2} - id^4_{shell})/64$

Cross sectional area: $A_{os2} = \pi(od^2_{shell2} - id^2_{shell})/4$

Moment of inertia and cross sectional area of composites:

Pipe with thin outer shell:

Moment of inertia: $I_1 = I_{pipe} + I_{os1}$

Cross sectional area: $A_1 = A_{pipe} + A_{os1}$

Pipe with thick outer shell:

Moment of inertia: $I_2 = I_{pipe} + I_{os2}$

Cross sectional area: $A_2 = A_{pipe} + A_{os2}$

Length between centerline of supports:

$l_1 = 9.750$ in

$l_2 = (2\text{ ft} + 10\text{ in}) - l_1$

$l_3 = (4\text{ ft} + 10.250\text{ in}) - (2\text{ ft} + 10\text{ in})$

$l_4 = (5\text{ ft} + 7.750\text{ in}) - (4\text{ ft} + 10.250\text{ in})$

$l_5 = (8\text{ ft} + 3.250\text{ in}) - (5\text{ ft} + 7.750\text{ in})$

$l_6 = (10\text{ ft} + 10.750\text{ in}) - (8\text{ ft} + 3.250\text{ in})$

$l_7 = (13\text{ ft} + 6.25\text{ in}) - (10\text{ ft} + 10.750\text{ in})$

$l_8 = (16\text{ ft} + 1.750\text{ in}) - (13\text{ ft} + 6.25\text{ in})$

$l_9 = (18\text{ ft} + 9.250\text{ in}) - (16\text{ ft} + 1.750\text{ in})$

$l_{10} = (21\text{ ft} + 4.750\text{ in}) - (18\text{ ft} + 9.250\text{ in})$

$l_{11} = (24\text{ ft} + 0.250\text{ in}) - (21\text{ ft} + 4.750\text{ in})$

$l_{12} = (24\text{ ft} + 9.750\text{ in}) - (24\text{ ft} + 0.250\text{ in})$

$l_{13} = (27\text{ ft} + 5.25\text{ in}) - (24\text{ ft} + 9.750\text{ in})$

$l_{14} = (30\text{ ft} + 0.750\text{ in}) - (27\text{ ft} + 5.25\text{ in})$

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l_{15} = (32 ft + 8.250 in) - (30 ft + 0.750 in)

l_{16} = (35 ft + 3.750 in) - (32 ft + 8.250 in)

l_{17} = (37 ft + 11.750 in) - (35 ft + 3.750 in)

l_{18} = (40 ft + 6.750 in) - (37 ft + 11.750 in)

l_{19} = (43 ft + 2.250 in) - (40 ft + 6.750 in)

l_{20} = (45 ft + 9.750 in) - (43 ft + 2.250 in)

l_{21} = (48 ft + 5.25 in) - (45 ft + 9.750 in)

l_{22} = (49 ft + 2.750 in) - (48 ft + 5.25 in)

l_{23} = (51 ft + 2.750 in) - (49 ft + 2.750 in)

l_{24} = (52 ft + 0.750 in) - (51 ft + 2.750 in)

CG of pump locations relative to Column 15 and 16:

Distance from Column 15: $d_a = cg_{pay}$ - (30 ft + 0.750 in)

Distance from Column 16: d_b = (32 ft + 8.25 in) - cg_{pay}

Using the Three Moment Theorem, determine moments at the supports:

End Conditions assuming simply supported:

At bottom end flange end: M_a = 0.0 lbs-in

At top end moments due to top caps exists, model as uniform cantilevered load of combined weight of both inner and outer top caps.

Weight of outer top cap: W_{19} = 1,900 lbs

Weight of inner top cap: W_{20} = 1,500 lbs

Total weight: $W_{tcap} = W_{19} + W_{20}$

Length of outer top cap: l_{tcap} = (2 ft + 1.875 in) + 2.25 in

Assume load is distributed in a triangular shape along the length:

$$M_y = -(1/3\ g_{dec}\ W_{tcap}\ l_{tcap})$$

Constraints: M_a = 0.0 lbs-in $M_y = -(1/3\ g_{dec}\ W_{tcap}\ l_{tcap})$

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Span 1 and 2:

$$M_a \frac{l_1}{I_1} + 2\, M_b \left(\frac{l_1}{I_1} + \frac{l_2}{I_1} \right) + M_c \frac{l_2}{I_1} = -\frac{w_{base}}{4} \left(\frac{l_1^3}{I_1} + \frac{l_2^3}{I_1} \right)$$

Span 2 and 3:

$$M_b \frac{l_2}{I_1} + 2\, M_c \left(\frac{l_2}{I_1} + \frac{l_3}{I_1} \right) + M_d \frac{l_3}{I_1} = -\frac{w_{base}}{4} \left(\frac{l_2^3}{I_1} + \frac{l_3^3}{I_1} \right)$$

Span 3 and 4:

$$M_c \frac{l_3}{I_1} + 2\, M_d \left(\frac{l_3}{I_1} + \frac{l_4}{I_1} \right) + M_e \frac{l_4}{I_1} = -\frac{w_{base}}{4} \left(\frac{l_3^3}{I_1} + \frac{l_4^3}{I_1} \right)$$

Span 4 and 5:

$$M_d \frac{l_4}{I_1} + 2 \cdot M_e \left(\frac{l_4}{I_1} + \frac{l_5}{I_1} \right) + M_f \frac{l_5}{I_1} = -\frac{w_{base}}{4} \left(\frac{l_4^3}{I_1} + \frac{l_5^3}{I_1} \right)$$

Span 5 and 6:

$$M_e \frac{l_5}{I_1} + 2\, M_f \left(\frac{l_5}{I_1} + \frac{l_6}{I_1} \right) + M_g \frac{l_6}{I_1} = -\frac{w_{base}}{4} \left(\frac{l_5^3}{I_1} + \frac{l_6^3}{I_1} \right)$$

Span 6 and 7:

$$M_f \frac{l_6}{I_1} + 2\, M_g \left(\frac{l_6}{I_1} + \frac{l_7}{I_1} \right) + M_h \frac{l_7}{I_1} = -\frac{w_{base}}{4} \left(\frac{l_6^3}{I_1} + \frac{l_7^3}{I_1} \right)$$

Span 7 and 8:, Transition from thin to thick outer shell:

$$M_g \frac{l_7}{I_1} + 2\, M_h \left(\frac{l_7}{I_1} + \frac{l_8}{I_2} \right) + M_i \frac{l_8}{I_2} = -\frac{w_{base}}{4} \left(\frac{l_7^3}{I_1} + \frac{l_8^3}{I_2} \right)$$

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Span 8 and 9:

$$M_h \frac{l_8}{I_2} + 2\ M_i \left(\frac{l_8}{I_2} + \frac{l_9}{I_2} \right) + M_j \frac{l_9}{I_2} = -\frac{w_{base}}{4} \left(\frac{l_8^3}{I_2} + \frac{l_9^3}{I_2} \right)$$

Span 9 and 10:

$$M_i \frac{l_9}{I_2} + 2\ M_j \left(\frac{l_9}{I_2} + \frac{l_{10}}{I_2} \right) + M_k \frac{l_{10}}{I_2} = -\frac{w_{base}}{4} \left(\frac{l_9^3}{I_2} + \frac{l_{10}^3}{I_2} \right)$$

Span 10 and 11:

$$M_j \frac{l_{10}}{I_2} + 2\ M_k \left(\frac{l_{10}}{I_2} + \frac{l_{11}}{I_2} \right) + M_l \frac{l_{11}}{I_2} = -\frac{w_{base}}{4} \left(\frac{l_{10}^3}{I_2} + \frac{l_{11}^3}{I_2} \right)$$

Span 11 and 12:

$$M_k \frac{l_{11}}{I_2} + 2\ M_l \left(\frac{l_{11}}{I_2} + \frac{l_{12}}{I_2} \right) + M_m \frac{l_{12}}{I_2} = -\frac{w_{base}}{4} \left(\frac{l_{11}^3}{I_2} + \frac{l_{12}^3}{I_2} \right)$$

Span 12 and 13:

$$M_l \frac{l_{12}}{I_2} + 2\ M_m \left(\frac{l_{12}}{I_2} + \frac{l_{13}}{I_2} \right) + M_n \frac{l_{13}}{I_2} = -\frac{w_{base}}{4} \left(\frac{l_{12}^3}{I_2} + \frac{l_{13}^3}{I_2} \right)$$

Span 13 and 14:

$$M_m \frac{l_{13}}{I_2} + 2\ M_n \left(\frac{l_{13}}{I_2} + \frac{l_{14}}{I_2} \right) + M_o \frac{l_{14}}{I_2} = -\frac{w_{base}}{4} \left(\frac{l_{13}^3}{I_2} + \frac{l_{14}^3}{I_2} \right)$$

Span 14 and 15:, Transition from thick to thin outer shell and pump cg location:

$$M_n \frac{l_{14}}{I_2} + 2\ M_o \left(\frac{l_{14}}{I_2} + \frac{l_{15}}{I_1} \right) + M_p \frac{l_{15}}{I_1} = -\frac{w_{base}}{4} \left(\frac{l_{14}^3}{I_2} + \frac{l_{15}^3}{I_1} \right) + - \frac{g_{dec}\ W_{21}\ d_1 \left(l_{15}^2 - d_1^2 \right)}{l_{15}\ I_1}$$

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Span 15 and 16:, pump cg location:

$$M_o \frac{l_{15}}{I_1} + 2\,M_p\left(\frac{l_{15}}{I_1} + \frac{l_{16}}{I_1}\right) + M_q\frac{l_{16}}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_{15}^3}{I_1} + \frac{l_{16}^3}{I_1}\right) + -\frac{g_{dec}\,W_{21}\,d_b\left(l_{15}^2 - d_b^2\right)}{l_{15}\,I_1}$$

Span 16 and 17:

$$M_p \frac{l_{16}}{I_1} + 2\,M_q\left(\frac{l_{16}}{I_1} + \frac{l_{17}}{I_1}\right) + M_r\frac{l_{17}}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_{16}^3}{I_1} + \frac{l_{17}^3}{I_1}\right)$$

Span 17 and 18:

$$M_q \frac{l_{17}}{I_1} + 2\,M_r\left(\frac{l_{17}}{I_1} + \frac{l_{18}}{I_1}\right) + M_s\frac{l_{18}}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_{17}^3}{I_1} + \frac{l_{18}^3}{I_1}\right)$$

Span 18 and 19:

$$M_r \frac{l_{18}}{I_1} + 2\,M_s\left(\frac{l_{18}}{I_1} + \frac{l_{19}}{I_1}\right) + M_t\frac{l_{19}}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_{18}^3}{I_1} + \frac{l_{19}^3}{I_1}\right)$$

Span 19 and 20:

$$M_s \frac{l_{19}}{I_1} + 2\,M_t\left(\frac{l_{19}}{I_1} + \frac{l_{20}}{I_1}\right) + M_u\frac{l_{20}}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_{19}^3}{I_1} + \frac{l_{20}^3}{I_1}\right)$$

Span 20 and 21:

$$M_t \frac{l_{20}}{I_1} + 2\,M_u\left(\frac{l_{20}}{I_1} + \frac{l_{21}}{I_1}\right) + M_v\frac{l_{21}}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_{20}^3}{I_1} + \frac{l_{21}^3}{I_1}\right)$$

Span 21 and 22:

$$M_u \frac{l_{21}}{I_1} + 2\,M_v\left(\frac{l_{21}}{I_1} + \frac{l_{22}}{I_1}\right) + M_w\frac{l_{22}}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_{21}^3}{I_1} + \frac{l_{22}^3}{I_1}\right)$$

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Span 22 and 23:

$$M_v \frac{l_{22}}{I_1} + 2\,M_w\left(\frac{l_{22}}{I_1} + \frac{l_{23}}{I_1}\right) + M_x \frac{l_{23}}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_{22}^3}{I_1} + \frac{l_{23}^3}{I_1}\right)$$

Span 23 and 24:

$$M_w \frac{l_{23}}{I_1} + 2\,M_x\left(\frac{l_{23}}{I_1} + \frac{l_{24}}{I_1}\right) + M_y \frac{l_{24}}{I_1} = -\frac{w_{base}}{4}\left(\frac{l_{23}^3}{I_1} + \frac{l_{24}^3}{I_1}\right)$$

	lbs-in		lbs-in
M_a	0	M_b	-149,340
M_c	-246,988	M_d	-112,957
M_e	-258,592	M_f	-376,495
M_g	-345,001	M_h	-353,073
M_i	-353,258	M_j	-343,470
M_k	-382,435	M_l	-236,365
M_m	-285,116	M_n	-270,229
M_o	-743,542	M_p	-451,199
M_q	-333,590	M_r	-358,760
M_s	-342,684	M_t	-347,218
M_u	-378,018	M_v	-250,282
M_w	-179,627	M_x	-49,748
M_y	-806,438		

Maximum moments between supports and reactions at supports:

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Span 1, $M_a < M_b$:

$$M_1 = \frac{w_{base}\ l_1^2}{8} - \frac{M_a + M_b}{2} + \frac{(M_a - M_b)^2}{2\ w_{base}\ l_1^2}$$

$$M_1 = 152{,}784 \text{ lbs-in}$$

$$R_a = \frac{w_{base}\ l_1}{2} - \frac{M_a - M_b}{l_1} + g_{dec}\ W_4$$

$$R_a = 71{,}192 \text{ lbs}$$

Span 2, $M_b < M_c$:

$$M_2 = \frac{w_{base}\ l_2^2}{8} - \frac{M_b + M_c}{2} + \frac{(M_b - M_c)^2}{2\ w_{base}\ l_2^2}$$

$$M_2 = 512{,}633 \text{ lbs-in}$$

$$R_b = \left(\frac{w_{base}\ l_1}{8} + \frac{M_a - M_b}{l_1}\right) + \left(\frac{w_{base}\ l_2}{8} - \frac{M_b - M_c}{l_2}\right) + g_{dec} W_{3a}$$

$$R_b = 42{,}644 \text{ lbs}$$

Span 3, $M_c > M_d$:

$$M_3 = \frac{w_{base}\ l_3^2}{8} - \frac{M_c + M_d}{2} + \frac{(M_c - M_d)^2}{2\ w_{base}\ l_3^2}$$

$$M_3 = 496{,}128 \text{ lbs-in}$$

$$R_c = \left(\frac{w_{base}\ l_2}{8} + \frac{M_b - M_c}{l_2}\right) + \left(\frac{w_{base}\ l_3}{8} + \frac{M_c - M_d}{l_3}\right) + g_{dec}\ W_2$$

$$R_c = 35{,}663 \text{ lbs}$$

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Span 4, $M_d < M_e$:

$$M_4 = \frac{w_{base}\, l_4^2}{8} - \frac{M_d + M_e}{2} + \frac{(M_d - M_e)^2}{2\, w_{base}\, l_4^2}$$

M_4 = 261,378 lbs-in

$$R_d = \left(\frac{w_{base}\, l_3}{8} - \frac{M_c - M_d}{l_3}\right) + \left(\frac{w_{base}\, l_4}{8} - \frac{M_d - M_e}{l_4}\right) + g_{dec}\, W_{3b}$$

R_d = 23,316 lbs

Span 5, $M_e < M_f$:

$$M_5 = \frac{w_{base}\, l_5^2}{8} - \frac{M_e + M_f}{2} + \frac{(M_e - M_f)^2}{2\, w_{base}\, l_5^2}$$

M_5 = 846,584 lbs-in

$$R_e = \left(\frac{w_{base}\, l_4}{8} + \frac{M_d - M_e}{l_4}\right) + \left(\frac{w_{base}\, l_5}{8} - \frac{M_e - M_f}{l_5}\right) + g_{dec}\, W_{3b}$$

R_e = 48,559 lbs

Span 6, $M_f > M_g$:

$$M_6 = \frac{w_{base}\, l_6^2}{8} - \frac{M_f + M_g}{2} + \frac{(M_f - M_g)^2}{2\, w_{base}\, l_6^2}$$

M_6 = 888,259 lbs-in

$$R_f = \left(\frac{w_{base}\, l_5}{8} + \frac{M_e - M_f}{l_5}\right) + \left(\frac{w_{base}\, l_6}{8} - \frac{M_f - M_g}{l_6}\right) + g_{dec}\, W_2$$

R_f = 49,613 lbs

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Span 7, $M_g<M_h$:

$$M_7 = \frac{w_{base}\, l_7^2}{8} - \frac{M_g + M_h}{2} + \frac{(M_g - M_h)^2}{2\, w_{base}\, l_7^2}$$

$$M_7 = 876{,}438 \text{ lbs-in}$$

$$R_g = \left(\frac{w_{base}\, l_6}{8} - \frac{M_f - M_g}{l_6}\right) + \left(\frac{w_{base}\, l_7}{8} - \frac{M_g - M_h}{l_7}\right) + g_{dec}\, W_2$$

$$R_g = 45{,}614 \text{ lbs}$$

Span 8, $M_h<M_i$:

$$M_8 = \frac{w_{base}\, l_8^2}{8} - \frac{M_h + M_i}{2} + \frac{(M_h - M_i)^2}{2\, w_{base}\, l_8^2}$$

$$M_8 = 880{,}559 \text{ lbs-in}$$

$$R_h = \left(\frac{w_{base}\, l_7}{8} + \frac{M_g - M_h}{l_7}\right) + \left(\frac{w_{base}\, l_8}{8} - \frac{M_g - M_h}{l_8}\right) + g_{dec}\, W_2$$

$$R_h = 44{,}870 \text{ lbs}$$

Span 9, $M_i>M_j$:

$$M_9 = \frac{w_{base}\, l_9^2}{8} - \frac{M_i + M_j}{2} + \frac{(M_i - M_j)^2}{2\, w_{base}\, l_9^2}$$

$$M_9 = 875{,}769 \text{ lbs-in}$$

$$R_i = \left(\frac{w_{base}\, l_8}{8} + \frac{M_h - M_i}{l_8}\right) + \left(\frac{w_{base}\, l_9}{8} + \frac{M_i - M_j}{l_9}\right) + g_{dec}\, W_2$$

$$R_i = 44{,}565 \text{ lbs}$$

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Span 10, $M_j < M_k$:

$$M_{10} = \frac{w_{base}\, l_{10}^2}{8} - \frac{M_j + M_k}{2} + \frac{(M_j - M_k)^2}{2\, w_{base}\, l_{10}^2}$$

$$M_{10} = 890{,}526 \text{ lbs-in}$$

$$R_j = \left(\frac{w_{base}\, l_9}{8} - \frac{M_i - M_j}{l_9}\right) + \left(\frac{w_{base}\, l_{10}}{8} - \frac{M_j - M_k}{l_{10}}\right) + g_{dec}\, W_2$$

$$R_j = 43{,}944 \text{ lbs}$$

Span 11, $M_k > M_l$:

$$M_{11} = \frac{w_{base}\, l_{11}^2}{8} - \frac{M_k + M_l}{2} + \frac{(M_k - M_l)^2}{2\, w_{base}\, l_{11}^2}$$

$$M_{11} = 839{,}322 \text{ lbs-in}$$

$$R_k = \left(\frac{w_{base}\, l_{10}}{8} + \frac{M_j - M_k}{l_{10}}\right) + \left(\frac{w_{base}\, l_{11}}{8} + \frac{M_k - M_l}{l_{11}}\right) + g_{dec}\, W_2$$

$$R_k = 41{,}470 \text{ lbs}$$

Span 12, $M_l < M_m$:

$$M_{12} = \frac{w_{base}\, l_{12}^2}{8} - \frac{M_l + M_m}{2} + \frac{(M_l - M_m)^2}{2\, w_{base}\, l_{12}^2}$$

$$M_{12} = 311{,}806 \text{ lbs-in}$$

$$R_l = \left(\frac{w_{base}\, l_{11}}{8} - \frac{M_k - M_l}{l_{11}}\right) + \left(\frac{w_{base}\, l_{12}}{8} - \frac{M_l - M_m}{l_{12}}\right) + g_{dec}\, W_{3a}$$

$$R_l = 34{,}580 \text{ lbs}$$

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Span 13, $M_m > M_n$:

$$M_{13} = \frac{w_{base}\, l_{13}^2}{8} - \frac{M_m + M_n}{2} + \frac{(M_m - M_n)^2}{2\, w_{base}\, l_{13}^2}$$

$$M_{13} = 805{,}092 \text{ lbs-in}$$

$$R_m = \left(\frac{w_{base}\, l_{12}}{8} + \frac{M_l - M_m}{l_{12}}\right) + \left(\frac{w_{base}\, l_{13}}{8} + \frac{M_m - M_n}{l_{13}}\right) + g_{dec}\, W_{3a}$$

$$R_m = 39{,}734 \text{ lbs}$$

Span 14, $M_n < M_o$:

$$M_{14} = \frac{w_{base}\, l_{14}^2}{8} - \frac{M_n + M_o}{2} + \frac{(M_n - M_o)^2}{2\, w_{base}\, l_{14}^2}$$

$$M_{14} = 1{,}060{,}827 \text{ lbs-in}$$

$$R_n = \left(\frac{w_{base}\, l_{13}}{8} - \frac{M_m - M_n}{l_{13}}\right) + \left(\frac{w_{base}\, l_{14}}{8} - \frac{M_j - M_k}{l_{14}}\right) + g_{dec}\, W_2$$

$$R_n = 44{,}106 \text{ lbs}$$

Span 15, $M_o > M_p$, Span where pump is located:

Location of maximum moment: $x_{max} = l_{15}/2 + [(M_o - M_p)/(w_{base}\, l_{15})]$

Moment due to pump at location: $M_{pump} = (g_{dec}\, W_{21}\, d_b\, x_{max})/l_{15}$

Reaction at o due to pump: $R_{po} = (g_{dec}\, W_{21}\, d_b)/l_{15}$

$$M_{15} = \frac{w_{base}\, l_{15}^2}{8} - \frac{M_o + M_p}{2} + \frac{(M_o - M_p)^2}{2\, w_{base}\, l_{15}^2} + M_{pump}$$

$$M_{15} = 1{,}468{,}339 \text{ lbs-in}$$

$$R_o = \left(\frac{w_{base}\, l_{14}}{8} + \frac{M_n - M_o}{l_{14}}\right) + \left(\frac{w_{base}\, l_{15}}{8} + \frac{M_o - M_p}{l_{15}}\right) + R_{po} + g_{dec}\, W_2$$

$$R_o = 75{,}193 \text{ lbs}$$

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Span 16, $M_p > M_q$:

$$M_{16} = \frac{w_{base}\, l_{16}^2}{8} - \frac{M_p + M_q}{2} + \frac{(M_p - M_q)^2}{2\, w_{base}\, l_{16}^2}$$

$$M_{16} = 921{,}427 \text{ lbs-in}$$

Reaction at p due to pump: $R_{pp} = (g_{dec}\, W_{21}\, d_a)/l_{15}$

$$R_p = \left(\frac{w_{base}\, l_{15}}{8} - \frac{M_o - M_p}{l_{15}}\right) + R_{pp} + \left(\frac{w_{base}\, l_{16}}{8} + \frac{M_p - M_q}{l_{16}}\right) + g_{dec}\, W_2$$

$$R_p = 531{,}840 \text{ lbs}$$

Span 17, $M_q < M_r$:

$$M_{17} = \frac{w_{base}\, l_{17}^2}{8} - \frac{M_q + M_r}{2} + \frac{(M_q - M_r)^2}{2\, w_{base}\, l_{17}^2}$$

$$M_{17} = 890{,}516 \text{ lbs-in}$$

$$R_q = \left(\frac{w_{base}\, l_{16}}{8} - \frac{M_p - M_q}{l_{16}}\right) + \left(\frac{w_{base}\, l_{17}}{8} - \frac{M_q - M_r}{l_{17}}\right) + g_{dec}\, W_2$$

$$R_q = 48{,}083 \text{ lbs}$$

Span 18, $M_r > M_s$:

$$M_{18} = \frac{w_{base}\, l_{18}^2}{8} - \frac{M_r + M_s}{2} + \frac{(M_r - M_s)^2}{2\, w_{base}\, l_{18}^2}$$

$$M_{18} = 861{,}537 \text{ lbs-in}$$

$$R_r = \left(\frac{w_{base}\, l_{17}}{8} + \frac{M_q - M_r}{l_{17}}\right) + \left(\frac{w_{base}\, l_{18}}{8} + \frac{M_r - M_s}{l_{18}}\right) + g_{dec}\, W_2$$

$$R_r = 45{,}138 \text{ lbs}$$

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Span 19, $M_s < M_t$:

$$M_{19} = \frac{w_{base}\, l_{19}^2}{8} - \frac{M_s + M_t}{2} + \frac{(M_s - M_t)^2}{2\, w_{base}\, l_{19}^2}$$

$$M_{19} = 872{,}347 \text{ lbs-in}$$

$$R_s = \left(\frac{w_{base}\, l_{18}}{8} - \frac{M_r - M_s}{l_{18}}\right) + \left(\frac{w_{base}\, l_{19}}{8} - \frac{M_s - M_t}{l_{19}}\right) + g_{dec}\, W_2$$

$$R_s = 44{,}979 \text{ lbs}$$

Span 20, $M_t < M_u$:

$$M_{20} = \frac{w_{base}\, l_{20}^2}{8} - \frac{M_t + M_u}{2} + \frac{(M_t - M_u)^2}{2\, w_{base}\, l_{20}^2}$$

$$M_{20} = 890{,}124 \text{ lbs-in}$$

$$R_t = \left(\frac{w_{base}\, l_{19}}{8} + \frac{M_s - M_t}{l_{19}}\right) + \left(\frac{w_{base}\, l_{20}}{8} - \frac{M_t - M_u}{l_{20}}\right) + g_{dec}\, W_2$$

$$R_t = 44{,}036 \text{ lbs}$$

Span 21, $M_u > M_v$:

$$M_{21} = \frac{w_{base}\, l_{21}^2}{8} - \frac{M_u + M_v}{2} + \frac{(M_u - M_v)^2}{2\, w_{base}\, l_{21}^2}$$

$$M_{21} = 843{,}477 \text{ lbs-in}$$

$$R_u = \left(\frac{w_{base}\, l_{20}}{8} + \frac{M_t - M_u}{l_{20}}\right) + \left(\frac{w_{base}\, l_{21}}{8} + \frac{(M_u + M_v)}{l_{21}}\right) + g_{dec}\, W_2$$

$$R_u = 41{,}793 \text{ lbs}$$

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Span 22, $M_v > M_w$:

$$M_{22} = \frac{w_{base}\, l_{22}^2}{8} - \frac{M_v + M_w}{2} + \frac{(M_v - M_w)^2}{2\; w_{base}\, l_{22}^2}$$

M_{22} = 269,428 lbs-in

$$R_v = \left(\frac{w_{base}\, l_{21}}{8} - \frac{M_u - M_v}{l_{21}}\right) + \left(\frac{w_{base}\, l_{22}}{8} + \frac{M_v - M_w}{l_{22}}\right) + g_{dec}\, W_{3b}$$

R_v = 33,590 lbs

Span 23, $M_w > M_x$:

$$M_{23} = \frac{w_{base}\, l_{23}^2}{8} - \frac{M_w + M_x}{2} + \frac{(M_w - M_x)^2}{2\; w_{base}\, l_{23}^2}$$

M_{23} = 424,283 lbs-in

$$R_w = \left(\frac{w_{base}\, l_{22}}{8} + \frac{M_v - M_w}{l_{22}}\right) + \left(\frac{w_{base}\, l_{23}}{8} + \frac{(M_w - M_x)}{l_{23}}\right) + g_{dec}\, W_{3b}$$

R_w = 20,137 lbs

Span 24, $M_x < M_y$:

$$M_{24} = \frac{w_{base}\, l_{24}^2}{8} - \frac{M_x + M_y}{2} + \frac{(M_x - M_y)^2}{2\; w_{base}\, l_{24}^2}$$

M_{24} = 1,154,534 lbs-in

$$R_x = \left(\frac{w_{base}\, l_{23}}{8} - \frac{M_w - M_x}{l_{23}}\right) + \left(\frac{w_{base}\, l_{24}}{8} - \frac{(M_x - M_y)}{l_{24}}\right) + g_{dec}\, W_2$$

R_x = -40,801 lbs

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Reaction at Column 25:

$$R_y = \frac{w_{base}\, l_{24}}{8} + \frac{M_x - M_y}{l_{24}} + g_{dec}\, W_{tcap}$$

$$R_y = 167{,}004 \text{ lbs}$$

Maximum loading on ring:

Maximum loading on ring at Column 16, R_p. Model as combined loading of Ring loaded as loading smeared over entire volume of the ring Reference 7, pages 176 and 178; Case 22 and opposed by a reactive load transferred by tangential shear Roark Case 24. Also assume ring acts as a curved beam (shown Figures 2 and 3).

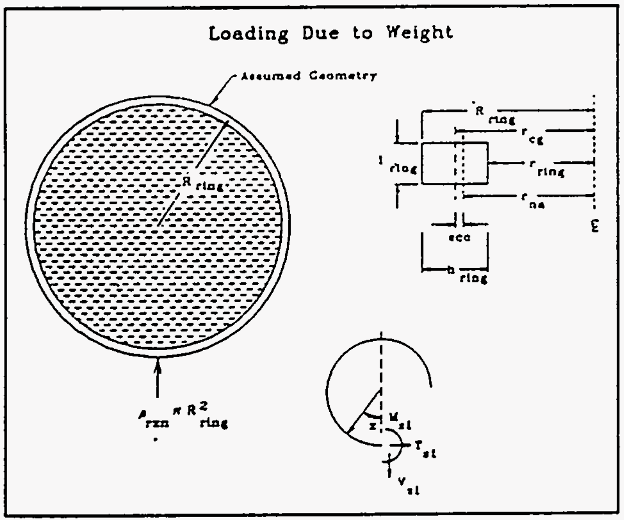

Figure 2

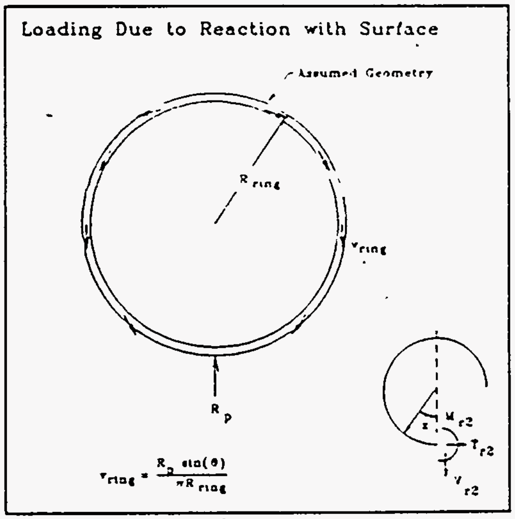

Figure 3

Nominal radius of ring:

OD of ring: $od_{ring} = 5 \text{ ft} + 11.625 \text{ in}$

$R_{ring} = od_{ring}/2$ $R_{ring} = 2.98 \text{ ft}$

Width of ring: $b_{ring} = 1.5 \text{ in}$

Distributed weight of ring throughout cross section:

$w_{ring} = R_p/(\pi\, R^2_{ring}\, b_{ring})$ $w_{ring} = 88 \text{ lbs/in}^3$

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Case 20 Maximum Loading at bottom of ring:

$\alpha = 0$ deg $\theta = 0$ deg

$u = \cos(\alpha)$ $s = \sin(\theta)$ $c = \cos(\theta)$ $z = \sin(\alpha)$

Maximum moment loading: $M_{1ring} = 3/4\ w_{ring}\ R^3_{ring}$ $M_{1ring} = 3.03 \times 10^6$ lbs

Circumferential Tension:

$T_{1ring} = w_{ring}\ R^2_{ring}\ (1 + 1/4\ u - 1/2\ \pi\ z + 1/2\ \alpha\ z)$

$T_{1ring} = 141{,}075$ lbs/in

Radial Shear:

$V_{1ring} = w_{ring}\ R^2_{ring}\ (1/2\ \alpha\ u + 1/4\ z - 1/2\ \pi\ u)$

$V_{1ring} = -177{,}280$ lbs/in

Case 25, Opposing moment at bottom of ring, $\theta = 0°$, $\alpha = 0°$

Counteracting Moment:

$M_{2ring} = -\ [R_p\ R_{ring}\ [0.23868\ u - 1/2\ s + 0.15915\ (a\ z + \theta\ s + c - u\ c^2)]]$

$M_{2ring} = -4.55 \times 10^6$ lbs-in

Circumferential Tension:

$T_{2ring} = R_p\ [0.15915\ (\alpha\ z - u\ c^2) - 0.07958\ u]$

$T_{2ring} = -126{,}966$ lbs

Radial Shear:

$V_{2ring} = -\ [R_p\ [0.15915\ (\alpha\ u - 1/2\ z + z\ c^2) - 1/2\ u]]$

$V_{2ring} = 265{,}920$ lbs

Resultant loading:

Maximum Moment:

$M_{rring} = M_{1ring}\ b_{ring} + M_{2ring}$ $M_{rring} = 998$ lbs-in

Circumferential Tension:

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$T_{rring} = T_{1ring}\, b_{ring} + T_{2ring}$ $T_{rring} = 84{,}646$ lbs

Radial Shear:

$V_{rring} = V_{1ring}\, b_{ring} + V_{2ring}$ $V_{rring} = 0$ lbs

Geometric parameters of pipe:

Inside radius of ring is id of pipe: $r_{ring} = (od_{pipe} - t_{pipe})/2$

Normal depth of ring including pipe thickness:

$h_{ring} = R_{ring} - r_{ring}$ $h_{ring} = 4.06$ in

Neutral axis of ring:

$$r_{na} = \frac{h_{ring}}{\ln\left(\frac{R_{ring}}{r_{ring}}\right)}$$

CG of ring:

$r_{cg} = r_{ring} + (h_{ring}/2)$

Eccentricity: $ecc = r_{cg} - r_{na}$

Cross sectional area: $A_{ring} = h_{ring}\, b_{ring}$

Stresses in ring:

Bending stress:

$$\sigma_{bottom} = \frac{M_{rring}\,(r_{na} - r_{ring})}{A_{ring}\; ecc\; r_{ring}}$$

$\sigma_{bottom} = 252$ psi

Tangential stress:

$\sigma_{tan} = T_{rring}/A_{ring}$ $\sigma_{tan} = 13{,}891$ psi

Maximum shear stress:

$\tau_{ring} = 2\, V_{rring}/A_{ring}$ $\tau_{ring} = 0$ psi

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Total stress:

$$\sigma_{tot} = \sigma_{bottom} + \sigma_{tan} + \tau_{ring} \qquad \sigma_{tot} = 14{,}143 \text{ psi}$$

ASME allowable from previous data: $s_a = 23{,}270$ psi

Margin of Safety on inner pipe:

$$MS_{pipe} = (s_a/\sigma_{tot}) - 1 \qquad MS_{pipe} = 0.65 \qquad \text{OK}$$

Maximum Loading on inner containment pipe between rings:

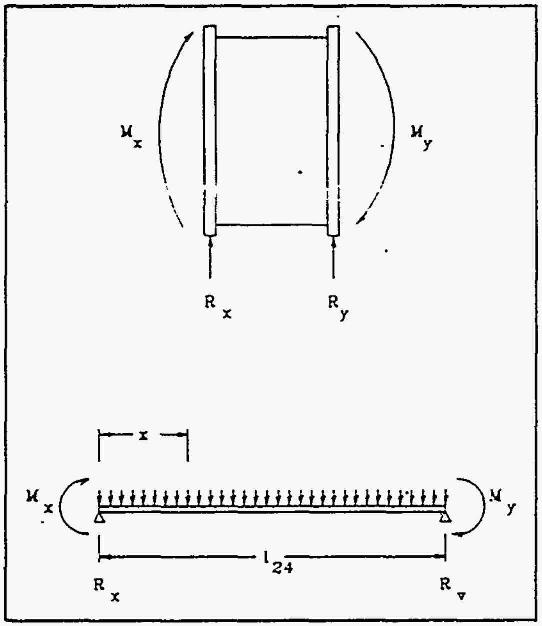

Figure 4

Maximum bending between Columns 15 and 16:

$$\sigma_{bmax} = \frac{M_{15}\left(\frac{od_{pipe}}{2}\right)}{I_{pipe}}$$

$$\sigma_{bmax} = 935 \text{ psi}$$

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Short beam criteria applies here, therefore must consider maximum shear at support.

Maximum shear: $\tau_{ymax} = 2\ R_y/A_{pipe}$ $\tau_{ymax} = 3{,}349$ psi

Bending at support:

$$\sigma_{by} = \frac{|M_y|\ \frac{od_{pipe}}{2}}{I_{pipe}}$$

$$\sigma_{by} = 513 \text{ psi}$$

Total stress at pipe section:

$\sigma_{ytot} = \sigma_{bmax} + \tau_{ymax}$ $\sigma_{ytot} = 4{,}283$ psi

Margin of Safety:

$MS_{ypipe} = (s_a/\sigma_{ytot}) - 1$ $MS_{ypipe} = 4.43$ OK

Loading on Inner Blind Flange Plate:

Assuming inside pipe welds carry the entire load determine weld strength.

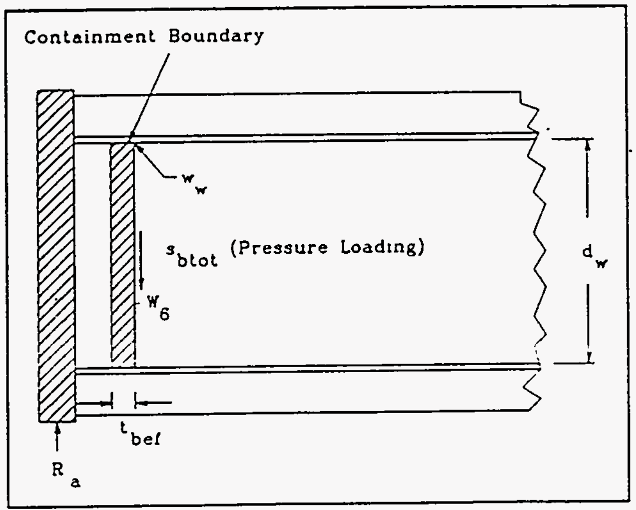

Figure 5

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Plate thickness: $t_{bef} = 2.0$ in

From ASME, allowable at joint discontinuities: $1.5\ s_a = 34{,}905$ psi

Since welds are 100% radiographed assume full strength of fillets.

Weld size, assuming on one weld: $w_w = 0.500$ in

Weld diameter is assumed as same size as pipe: $d_w = id_{pipe}$

Circumference of weld (one side only): $c_w = \pi\ d_w$

Pressure loading form pressure calculations at pipe joint discontinuity:

$$s_{btot} = 10{,}929 \text{ psi}$$

Shear area of weld: $A_w = 0.707\ w_w\ c_w$

Maximum shear due deflection of pipe during drop:

Weight of inner blind flange: $W_6 = 1{,}800$ lbs

$\tau_{drop} = (2\ g_{dec} \cdot W_6)/A_w$ $\tau_{drop} = 1{,}302$ psi

Total stress on weld:

$\sigma_{wtot} = \tau_{drop} + s_{btot}$ $\sigma_{wtot} = 12{,}231$ psi

Margin of Safety:

$MS_{befw} = (1.5\ s_a/\sigma_{wtot}) - 1$ $MS_{befw} = 1.85$ OK

Top Cap Loading:

Retaining Ring Loading:

Since fitup tolerance of retaining ring is tighter than for bolts, retaining ring takes up all shear loading from the drop.

Weight of inner top cap: $W_{20} = 1{,}500$ lbs

ID of retaining ring: $id_{itcrr} = 5$ ft + 3 in

Wall thickness: $t_{itcrr} = 0.375$ in

OD of retaining ring: $od_{itcrr} = id_{itcrr} + 2(t_{itcrr})$

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Cross sectional area of ring:

$$A_{itcrr} = \pi\,(od^2_{itcrr} - id^2_{itcrr})/4$$

Maximum shearing load on the ring cross section:

$$\tau_{rrmax} = (2\,g_{dec}\,W_{20})/A_{itcrr}$$

$$\tau_{rrmax} = 1{,}017 \text{ psi}$$

Margin of Safety:

$MS_{rrs} = (s_a/\tau_{rrmax}) - 1$ $MS_{rrs} = 21.89$ OK

Loading on the bolts:

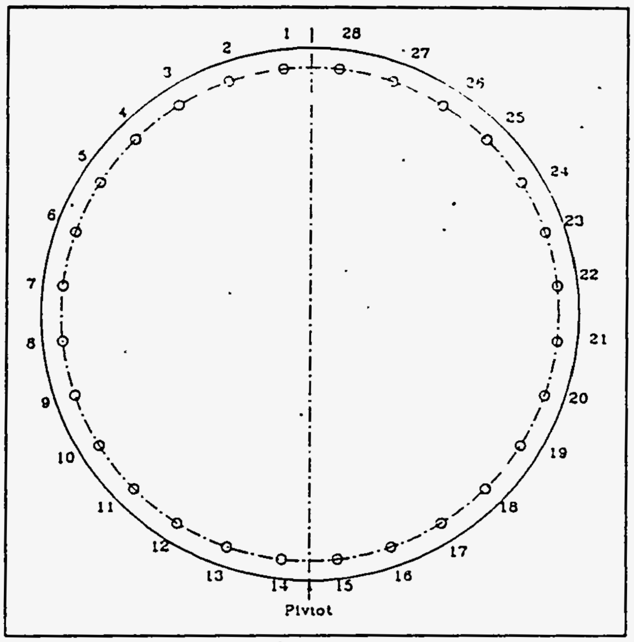

Figure 6

CG of top cap from inner flange face: $cg_{itc} = 1.39$ ft

Bolt parameters:

Number of bolts: $n_{bitc} = 28$

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Nominal diameter of bolts: $d_{bitc} = 1$ in

Tensile stress area of each bolt (Reference ASTM, page 1278):

$$A_b = 0.7854\ (d_{bitc} - 0.9743\ \text{in}/8)^2$$

Allowable tensile strength of bolts: $\sigma_{bten} = 55{,}000$ psi

Total preload and pressure load per bolt from ASME evaluation:

$$W_{btot} = 19{,}696\ \text{lbs}$$

Angle from vertical flange axis: $\theta_1 = 6.43$ deg

Angle of bolt spacing: $\theta_2 = 12.83$ deg

Diameter of bolt circle: $d_{bc} = 61$ in

Diameter of flange: $d_{flange} = id_{itcrr}$

Distance from Pivot to bolts 14 to 8:

$r_{bc} = d_{bc}/2$ $r_{flange} = d_{flange}/2$

Perpendicular distance:

Distance from pivot to centerline of bolt 14:

$$r_{14} = r_{flange} - r_{bc}\cos(\theta_1)$$

Distance from pivot to centerline of bolt 13:

$$r_{13} = r_{flange} - r_{bc}\cos(\theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 12:

$$r_{12} = r_{flange} - r_{bc}\cos(2\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 11:

$$r_{11} = r_{flange} - r_{bc}\cos(3\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 10:

$$r_{10} = r_{flange} - r_{bc}\cos(4\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 9:

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$$r_9 = r_{flange} - r_{bc} \cos(5\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 8:

$$r_8 = r_{flange} - r_{bc} \cos(6\ \theta_2 + \theta_1)$$

Distance from Pivot to bolts 7 to 1:

Distance from pivot to centerline of bolt 7:

$$r_7 = r_{flange} + r_{bc} \sin(\theta_1)$$

Distance from pivot to centerline of bolt 6:

$$r_6 = r_{flange} + r_{bc} \sin(\theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 5:

$$r_5 = r_{flange} + r_{bc} \sin(2\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 4:

$$r_4 = r_{flange} + r_{bc} \sin(3\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 3:

$$r_3 = r_{flange} + r_{bc} \sin(4\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 2:

$$r_2 = r_{flange} + r_{bc} \sin(5\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 1:

$$r_1 = r_{flange} + r_{bc} \sin(6\ \theta_2 + \theta_1)$$

By symmetry bolts 15 to 28 are equal to 14 to 1, respectively.

Moment due to drop due to eccentric loading of bolts:

$$M_{bitc} = g_{dec}\ W_{20}\ cg_{itc}$$

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Tensile load on bolt 1 (highest loading):

$$F_{bitc1} = \frac{r_1 M_{bitc}}{2\left(\begin{array}{l} r_1^2 + r_2^2 + r_3^2 + r_4^2 + r_5^2 + r_6^2 + r_7^2 + r_8^2 \\ \quad + r_9^2 + r_{10}^2 + r_{11}^2 + r_{12}^2 + r_{13}^2 + r_{14}^2 \end{array}\right)}$$

$$F_{bitc1} = 960 \text{ lbs}$$

Total bolt load:

$W_{itcb} = W_{btot} + F_{bitc1}$ $W_{itcb} = 20{,}656$ lbs

Tensile stress on bolt:

$\sigma_{bolt} = W_{itcb}/A_b$ $\sigma_{bolt} = 34{,}100$ psi

Margin of Safety based on bolt ultimate:

$MS_{bolt} = (\sigma_{bten}/\sigma_{bolt}) - 1$ $MS_{bolt} = 0.61$ OK

Outer Shell Loading from lead:

Model longest thinnest section only:

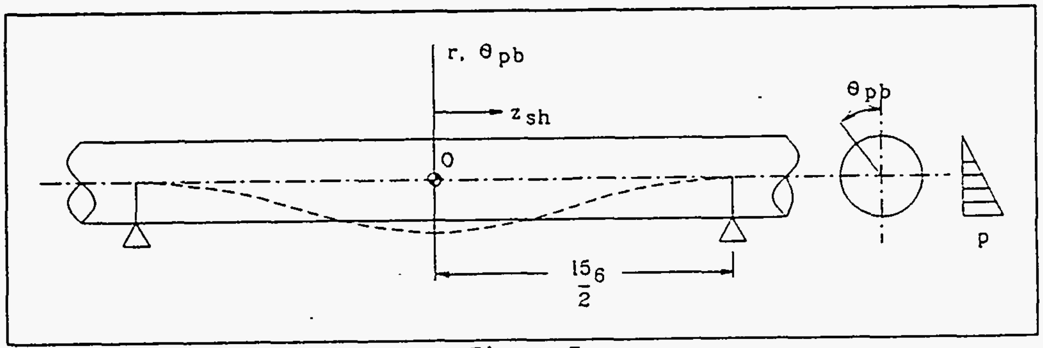

Figure 7

ID of shell: $id_{shell} = 5 \text{ ft} + 8 \text{ in}$

Wall thickness: $t_{516sh} = 0.3125 \text{ in}$

OD of shell: $od_{shell} = id_{shell} + 2(t_{516sh})$

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Inner cross sectional void area of shell:

$$A_{crsh} = \pi(id^2_{shell} - od^2_{pipe})/4$$

Longest length between supports: $15_6 = 2.5$ ft

Mid point of length: $z_{sh} = 15_6/2$

Gap of void: $gap = (id_{shell} - od_{pipe})/2$ $gap = 2$ in

Radius of lead: $r_{pb} = od_{pipe}/2 + gap$

Angle of evaluation: $\theta_{pb} = 180$ deg

Poisson's ratio for carbon steel (Reference 8): $\nu_{cstl} = 0.3$

Density of lead (Reference 13, page 398): $\rho_{pb} = 0.4096$ lbs/in^3

Assume 65% density of shot: $\rho_{shot} = 0.65\ \rho_{pb}$

Weight of lead between supports:

$$w_{spb} = A_{crsh}\ \rho_{shot}\ 15_6$$

$$w_{spb} = 3{,}312 \text{ lbs}$$

Assume weight of lead smeared over the entire cross sectional area:

Cross sectional area: $A_{smr} = \pi/4\ od^2_{shell}$

Smear density: $\rho_{smr} = w_{spb}/(A_{smr}\ 15_6)$

Load between supports at angle of evaluation, stress due to lead slump modeled using membrane theory of pipe filled between supports with a flowable material.

Tangential stress:

$$\sigma_t = \frac{g_{dec}\ \rho_{smr}\ r^2_{pb}}{t_{516}\, sh}\,(1 - \cos(\theta_{pb}))$$

$$\sigma_t = 5{,}587 \text{ psi}$$

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Longitudinal stress:

$$\sigma_l = \frac{g_{dec}\,\rho_{smr}}{t_{516}\,sh}\left(\frac{z_{sh}^2}{2}\right)\cos(\theta_{pb}) + \nu_{cscl}\,\sigma_c$$

$$\sigma_l = 1{,}404 \text{ psi}$$

Shear stress:

$$\sigma_{shr} = \frac{-g_{dec}\,\rho_{smr}}{t_{516}\,sh}\left(\frac{z_{sh}^2}{2}\right)\sin(\theta_{pb})$$

$$\sigma_{shr} = 0 \text{ psi}$$

Total stress at maximum deflection (at center of length):

$$\sigma_{pbtot} = \sigma_c + \sigma_l + \sigma_{shr}$$

$$\sigma_{pbtot} = 6{,}992 \text{ psi}$$

Margin of Safety:

$MS_{pb} = (s_a/\sigma_{pbtot}) - 1$ $MS_{pb} = 2.33$ OK

Weld on Stiffener Rings:

Evaluate circumferential fillet welds joining the stiffening rings and end plates to the inner containment pipe. Assume welds are 1/2 inch fillets both sides.

Weld size: $w_{srw} = 0.500$ in

Diameter of weld is OD of pipe: od_{pipe}: 64 in

Largest moment on outer top end plate, model as pipe welded to stiffening ring with no support from outer shell or top cap flange.

Evaluate weld per AWS, Reference 11, page 7.4-7.

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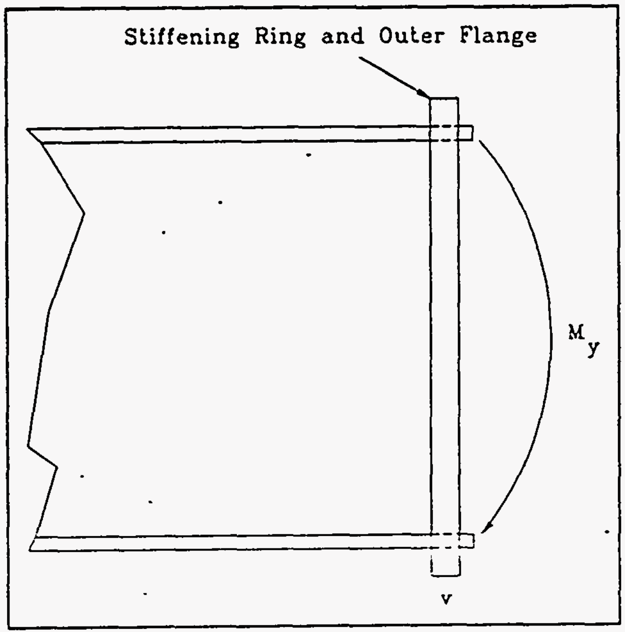

Figure 8

Treat the welds as a line in bending:

$$S_{weld} = \pi \frac{od_{pipe}^2}{4}$$

Linear Force on welds, assuming welds equally share the load:

$$f_b = \left| \frac{M_y}{2\ S_{weld}} \right|$$

$$f_b = 125 \text{ lbs/in}$$

AWS allowable for fillet welds used in Bridge Construction for ASTM A-36 material with thickness greater than 1 inch using E60 or SAW-1 Electrodes and assuming parallel loading, Reference 10 and Reference 11, page 7.4-8.

$$s_{aws} = 8{,}800 \text{ psi}$$

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Allowable line load:

$f_{aws} = s_{aws}\ (0.707\ w_{srw})$ $\qquad f_{aws} = 3{,}111$ lbs/in

Margin of Safety:

$MS_{srw} = (f_{aws}/f_b) - 1$ $\qquad MS_{srw} = 23.82$ OK

6.4.11 Drop Evaluation Loaded and Partially Shielded (101-SY)

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Checker S. R. Crow Date 08/31/94

I. Objectives:

The objective of this evaluation is to assess the ability of the 101-SY partially shielded packaging (shielding up to Column 14) to maintain leak tightness and structural integrity after a 1 foot flat drop onto a horizontal 12 inch thick concrete surface (Reference 1 and 2). Maintenance of leak tightness and structural integrity are demonstrated by confirming the stresses in critical components and at critical locations of the package are adequately below the values established in Reference 8.

II. References:

1. WHC-SD-TP-019, Rev 0, *Packaging Design Criteria Transfer and Disposal of Hydrogen Mixer Pump.*
2. WHC, *Engineering Change Notice 606676*, dated June 27, 1994.
3. American Institute of Steel Construction, *Steel Construction Manual, 9th Edition.*
4. US-NRC, 10 CFR Part 71, *Packaging and Transportation of Radioactive Materials.*
5. WHC Drawing, No. H-2-83734, *Hydrogen Mixer Pump Storage Container.*
6. EPRI NP-4830, *The Effect of Target Hardness on the Structural Design of Concrete Storage Pads for Spent Fuel Casks.*
7. Roark, *Formulas for Stress and Strain*, 4th Edition.
8. American Society of Mechanical Engineers, *Boiler and Pressure Vessels, Section VIII, Division 2, 1989.*
9. American Society of Mechanical Engineers, *Boiler and Pressure Vessels, Section VIII, Division 1, 1989.*
10. American Welding Society, AWS/ANSI D 1.1, *Structural Welding Code.*
11. Blodgett, O. W., *Design of Welded Structures*, 1976.
12. ASTM, American Society of Testing and Materials, *Annual Book of ASTM Standards, Volume 15.08.*
13. Industrial Press, *Machinery's Handbook, 20th Edition.*

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III. Results and Conclusions:

As with the results for an unshielded package, results for a partially shielded package show that all components, materials and welds have adequate margins of safety to insure that the package will not lose containment in the event of a 1 ft drop. In most cases the stresses are somewhat lower, than the unshielded package, since with the heavier package the deceleration factors are less (shown in the G loading evaluation). This is due primarily to the fundamental axioms in Reference 6. The EPRI report (Reference 6) considers that due to the hardness and stiffness of a cask, the concrete pad will fail absorbing most of the energy of impact. Subsequently, the heavier the cask the more the concrete fails absorbing more energy. This results in lower deceleration loads being transmitted to the package or cask with increasing weight. Consequently, since the partially shielded package is heavier than the unshielded package less deceleration loading is experienced by the package which results in lower stress values.

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Checker S. R. Crow SRC Date 08/31/94

IV. Engineering Evaluation:

As per the PDC (Reference 1), assume a perfectly flat horizontal drop onto a concrete as specified in the Reference 1. Assume the package impacts on all stiffener rings and exterior flanges simultaneously. This analysis models a partially shielded and loaded container.

Model drop loading as a beam with multiple supports using the three moment theorem in AISC, Reference 2. Assume package is uniformly loaded, except for payload and rings. The payload is modeled as a concentrated load with loading at the center of gravity and the rings are modeled as concentrated loads at the supports.

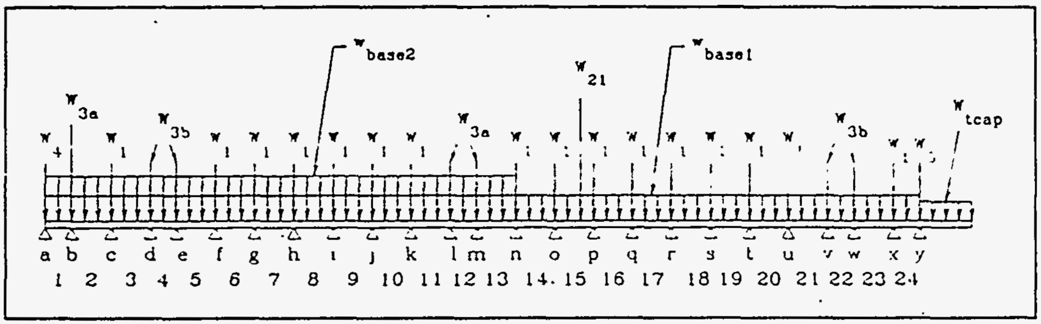

Figure 1

Pipe and shell parameters from H-2-83734, Reference 2:

Inner containment pipe:

OD: $od_{pipe} = 64$ in Wall thickness: $t_{pipe} = 0.500$ in

ID: $id_{pipe} = od_{pipe} - 2(t_{pipe})$

Length of pipe: $l_{pipe} = 52$ ft + 0.75 in

Outer shell thin section:

ID: $id_{shell} = 5$ ft + 8 in Wall thickness: $t_{shell1} = 0.3125$ in

OD: $od_{shell1} = id_{shell} + 2\ t_{shell1}$

Outer shell thick section:

Wall thickness: $t_{shell2} = 0.5$ in

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OD: $od_{shell2} = id_{shell} + 2(t_{shell2})$

G loading from EPRI drop data (Reference 6): $g_{dec} = 32.3$

Data from weight and center of gravity calculations:

Weight of shielding up Column 14: $W_{18a} = 32{,}000$ lbs

Length of shielding: $l_{sh} = (30 \text{ ft} + 0.75 \text{ in}) - 1.75 \text{ in}$

Weight of package (except stiffeners and payload) uniformly distributed:

From Column 14: $W_{base1} = 39{,}000$ lbs

Up to Column 14: $W_{base2} = 39{,}000 \text{ lbs} + W_{18a}$

Uniform distributed weight of package:

Up to Column 14: $w_{base2} = g_{dec} (W_{base1}/l_{pipe} + W_{18a}/l_{sh})$ $w_{base2} = 4{,}895$ lbs/in

From Column 14: $w_{base1} = (g_{dec} W_{base1})/l_{pipe}$ $w_{base} = 2{,}016$ lbs/in

Weight of stiffener rings:

Bottom end flange: $W_4 = 2{,}600$ lbs

Type 1 stiffener rings: $W_2 = 450$ lbs

Type 2a stiffener rings: $W_{3a} = 525$ lbs

Type 2b stiffener rings: $W_{3b} = 600$ lbs

Weight of payload: $W_{21} = 20{,}000$ lbs

CG of payload from center of bottom flange: $cg_{pay} = 32.56$ ft
Putting it between Columns 15 and 16.

Moment of inertia and cross sectional area of pipe:

Moment of inertia: $I_{pipe} = \pi(od^4_{pipe} - id^4_{pipe})/64$

Cross sectional area: $A_{pipe} = \pi(od^2_{pipe} - id^2_{pipe})/4$

Moment of inertia and cross sectional area of thin outer shell:

Moment of inertia: $I_{os1} = \pi(od^4_{shell1} - id^4_{shell})/64$

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Cross sectional area: $A_{os1} = \pi(od^2_{shell1} - id^2_{shell})/4$

Moment of inertia and cross sectional area of thick outer shell:

Moment of inertia: $I_{os2} = \pi(od^4_{shell2} - id^4_{shell})/64$

Cross sectional area: $A_{os2} = \pi(od^2_{shell2} - id^2_{shell})/4$

Moment of inertia and cross sectional area of composites:

Pipe with thin outer shell:

Moment of inertia: $I_1 = I_{pipe} + I_{os1}$

Cross sectional area: $A_1 = A_{pipe} + A_{os1}$

Pipe with thick outer shell:

Moment of inertia: $I_2 = I_{pipe} + I_{os2}$

Cross sectional area: $A_2 = A_{pipe} + A_{os2}$

Length between centerline of supports:

$l_1 = 9.750 \text{ in}$

$l_2 = (2 \text{ ft} + 10 \text{ in}) - l_1$

$l_3 = (4 \text{ ft} + 10.250 \text{ in}) - (2 \text{ ft} + 10 \text{ in})$

$l_4 = (5 \text{ ft} + 7.750 \text{ in}) - (4 \text{ ft} + 10.250 \text{ in})$

$l_5 = (8 \text{ ft} + 3.250 \text{ in}) - (5 \text{ ft} + 7.750 \text{ in})$

$l_6 = (10 \text{ ft} + 10.750 \text{ in}) - (8 \text{ ft} + 3.250 \text{ in})$

$l_7 = (13 \text{ ft} + 6.25 \text{ in}) - (10 \text{ ft} + 10.750 \text{ in})$

$l_8 = (16 \text{ ft} + 1.750 \text{ in}) - (13 \text{ ft} + 6.25 \text{ in})$

$l_9 = (18 \text{ ft} + 9.250 \text{ in}) - (16 \text{ ft} + 1.750 \text{ in})$

$l_{10} = (21 \text{ ft} + 4.750 \text{ in}) - (18 \text{ ft} + 9.250 \text{ in})$

$l_{11} = (24 \text{ ft} + 0.250 \text{ in}) - (21 \text{ ft} + 4.750 \text{ in})$

$l_{12} = (24 \text{ ft} + 9.750 \text{ in}) - (24 \text{ ft} + 0.250 \text{ in})$

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$l_{13} = (27\ \text{ft} + 5.25\ \text{in}) - (24\ \text{ft} + 9.750\ \text{in})$

$l_{14} = (30\ \text{ft} + 0.750\ \text{in}) - (27\ \text{ft} + 5.25\ \text{in})$

$l_{15} = (32\ \text{ft} + 8.250\ \text{in}) - (30\ \text{ft} + 0.750\ \text{in})$

$l_{16} = (35\ \text{ft} + 3.750\ \text{in}) - (32\ \text{ft} + 8.250\ \text{in})$

$l_{17} = (37\ \text{ft} + 11.750\ \text{in}) - (35\ \text{ft} + 3.750\ \text{in})$

$l_{18} = (40\ \text{ft} + 6.750\ \text{in}) - (37\ \text{ft} + 11.750\ \text{in})$

$l_{19} = (43\ \text{ft} + 2.250\ \text{in}) - (40\ \text{ft} + 6.750\ \text{in})$

$l_{20} = (45\ \text{ft} + 9.750\ \text{in}) - (43\ \text{ft} + 2.250\ \text{in})$

$l_{21} = (48\ \text{ft} + 5.25\ \text{in}) - (45\ \text{ft} + 9.750\ \text{in})$

$l_{22} = (49\ \text{ft} + 2.750\ \text{in}) - (48\ \text{ft} + 5.25\ \text{in})$

$l_{23} = (51\ \text{ft} + 2.750\ \text{in}) - (49\ \text{ft} + 2.750\ \text{in})$

$l_{24} = (52\ \text{ft} + 0.750\ \text{in}) - (51\ \text{ft} + 2.750\ \text{in})$

CG of pump locations relative to Column 15 and 16:

Distance from Column 15: $d_a = cg_{pay} - (30\ \text{ft} + 0.750\ \text{in})$

Distance from Column 16: $d_b = (32\ \text{ft} + 8.25\ \text{in}) - cg_{pay}$

Using the Three Moment Theorem, determine moments at the supports:

End Conditions assuming simply supported:

At bottom end flange end: $M_a = 0.0\ \text{lbs-in}$

At top end moments due to top caps exists, model as uniform cantilevered load of combined weight of both inner and outer top caps.

Weight of outer top cap: $W_{19} = 1{,}900\ \text{lbs}$

Weight of inner top cap: $W_{20} = 1{,}500\ \text{lbs}$

Total weight: $W_{tcap} = W_{19} + W_{20}$

Length of outer top cap: $l_{tcap} = (2\ \text{ft} + 1.875\ \text{in}) + 2.25\ \text{in}$

Assume load is distributed in a triangular shape along the length:

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$$M_y = -\left(1/3\ g_{dec}\ W_{tcap}\ l_{tcap}\right)$$

Constraints: $M_a = 0.0$ lbs-in $M_y = -\left(1/3\ g_{dec}\ W_{tcap}\ l_{tcap}\right)$

Span 1 and 2:

$$M_a \frac{l_1}{I_1} + 2\ M_b \left(\frac{l_1}{I_1} + \frac{l_2}{I_1}\right) + M_c \frac{l_2}{I_1} = -\frac{w_{base2}}{4}\left(\frac{l_1^3}{I_1} + \frac{l_2^3}{I_1}\right)$$

Span 2 and 3:

$$M_b \frac{l_2}{I_1} + 2\ M_c \left(\frac{l_2}{I_1} + \frac{l_3}{I_1}\right) + M_d \frac{l_3}{I_1} = -\frac{w_{base2}}{4}\left(\frac{l_2^3}{I_1} + \frac{l_3^3}{I_1}\right)$$

Span 3 and 4:

$$M_c \frac{l_3}{I_1} + 2\ M_d \left(\frac{l_3}{I_1} + \frac{l_4}{I_1}\right) + M_e \frac{l_4}{I_1} = -\frac{w_{base2}}{4}\left(\frac{l_3^3}{I_1} + \frac{l_4^3}{I_1}\right)$$

Span 4 and 5:

$$M_d \frac{l_4}{I_1} + 2\ M_e \left(\frac{l_4}{I_1} + \frac{l_5}{I_1}\right) + M_f \frac{l_5}{I_1} = -\frac{w_{base2}}{4}\left(\frac{l_4^3}{I_1} + \frac{l_5^3}{I_1}\right)$$

Span 5 and 6:

$$M_e \frac{l_5}{I_1} + 2\ M_f \left(\frac{l_5}{I_1} + \frac{l_6}{I_1}\right) + M_g \frac{l_6}{I_1} = -\frac{w_{base2}}{4}\left(\frac{l_5^3}{I_1} + \frac{l_6^3}{I_1}\right)$$

Span 6 and 7:

$$M_f \frac{l_6}{I_1} + 2\ M_g \left(\frac{l_6}{I_1} + \frac{l_7}{I_1}\right) + M_h \frac{l_7}{I_1} = -\frac{w_{base2}}{4}\left(\frac{l_6^3}{I_1} + \frac{l_7^3}{I_1}\right)$$

Span 7 and 8, Transition from thin to thick outer shell:

$$M_g \frac{l_7}{I_1} + 2\ M_h \left(\frac{l_7}{I_1} + \frac{l_8}{I_2}\right) + M_i \frac{l_8}{I_2} = -\frac{w_{base2}}{4}\left(\frac{l_7^3}{I_1} + \frac{l_8^3}{I_2}\right)$$

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Span 8 and 9:

$$M_h \frac{l_8}{I_2} + 2\, M_i \left(\frac{l_8}{I_2} + \frac{l_9}{I_2}\right) + M_j \frac{l_9}{I_2} = -\frac{w_{base2}}{4}\left(\frac{l_8^3}{I_2} + \frac{l_9^3}{I_2}\right)$$

Span 9 and 10:

$$M_i \frac{l_9}{I_2} + 2\, M_j \left(\frac{l_9}{I_2} + \frac{l_{10}}{I_2}\right) + M_k \frac{l_{10}}{I_2} = -\frac{w_{base2}}{4}\left(\frac{l_9^3}{I_2} + \frac{l_{10}^3}{I_2}\right)$$

Span 10 and 11:

$$M_j \frac{l_{10}}{I_2} + 2\, M_k \left(\frac{l_{10}}{I_2} + \frac{l_{11}}{I_2}\right) + M_l \frac{l_{11}}{I_2} = -\frac{w_{base2}}{4}\left(\frac{l_{10}^3}{I_2} + \frac{l_{11}^3}{I_2}\right)$$

Span 11 and 12:

$$M_k \frac{l_{11}}{I_2} + 2\, M_l \left(\frac{l_{11}}{I_2} + \frac{l_{12}}{I_2}\right) + M_m \frac{l_{12}}{I_2} = -\frac{w_{base2}}{4}\left(\frac{l_{11}^3}{I_2} + \frac{l_{12}^3}{I_2}\right)$$

Span 12 and 13:

$$M_l \frac{l_{12}}{I_2} + 2\, M_m \left(\frac{l_{12}}{I_2} + \frac{l_{13}}{I_2}\right) + M_n \frac{l_{13}}{I_2} = -\frac{w_{base2}}{4}\left(\frac{l_{12}^3}{I_2} + \frac{l_{13}^3}{I_2}\right)$$

Span 13 and 14:

$$M_m \frac{l_{13}}{I_2} + 2\, M_n \left(\frac{l_{13}}{I_2} + \frac{l_{14}}{I_2}\right) + M_o \frac{l_{14}}{I_2} = -\frac{w_{base2}}{4}\left(\frac{l_{13}^3}{I_2} + \frac{l_{14}^3}{I_2}\right)$$

Span 14 and 15, Transition from thick to thin outer shell and pump cg location:

$$M_n \frac{l_{14}}{I_2} + 2\, M_o \left(\frac{l_{14}}{I_2} + \frac{l_{15}}{I_1}\right) + M_p \frac{l_{15}}{I_1} = -\frac{1}{4}\left(\frac{w_{base2}\, l_{14}^3}{I_2} + \frac{w_{base1}\, l_{15}^3}{I_1}\right) + \\ - \frac{g_{dec}\, W_{21}\, d_a \left(l_{15}^2 - d_a^2\right)}{l_{15}\, I_1}$$

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Span 15 and 16, pump cg location:

$$M_o \frac{l_{15}}{I_1} + 2 M_p \left(\frac{l_{15}}{I_1} + \frac{l_{16}}{I_1}\right) + M_q \frac{l_{16}}{I_1} = -\frac{w_{basel}}{4}\left(\frac{l_{15}^3}{I_1} + \frac{l_{16}^3}{I_1}\right) + -\frac{g_{dec}\, W_{21}\, d_b \left(l_{15}^2 - d_b^2\right)}{l_{15}\, I_1}$$

Span 16 and 17:

$$M_p \frac{l_{16}}{I_1} + 2 M_q \left(\frac{l_{16}}{I_1} + \frac{l_{17}}{I_1}\right) + M_r \frac{l_{17}}{I_1} = -\frac{w_{basel}}{4}\left(\frac{l_{16}^3}{I_1} + \frac{l_{17}^3}{I_1}\right)$$

Span 17 and 18:

$$M_q \frac{l_{17}}{I_1} + 2 M_r \left(\frac{l_{17}}{I_1} + \frac{l_{18}}{I_1}\right) + M_s \frac{l_{18}}{I_1} = -\frac{w_{basel}}{4}\left(\frac{l_{17}^3}{I_1} + \frac{l_{18}^3}{I_1}\right)$$

Span 18 and 19:

$$M_r \frac{l_{18}}{I_1} + 2 M_s \left(\frac{l_{18}}{I_1} + \frac{l_{19}}{I_1}\right) + M_t \frac{l_{19}}{I_1} = -\frac{w_{basel}}{4}\left(\frac{l_{18}^3}{I_1} + \frac{l_{19}^3}{I_1}\right)$$

Span 19 and 20:

$$M_s \frac{l_{19}}{I_1} + 2 M_t \left(\frac{l_{19}}{I_1} + \frac{l_{20}}{I_1}\right) + M_u \frac{l_{20}}{I_1} = -\frac{w_{basel}}{4}\left(\frac{l_{19}^3}{I_1} + \frac{l_{20}^3}{I_1}\right)$$

Span 20 and 21:

$$M_t \frac{l_{20}}{I_1} + 2 M_u \left(\frac{l_{20}}{I_1} + \frac{l_{21}}{I_1}\right) + M_v \frac{l_{21}}{I_1} = -\frac{w_{basel}}{4}\left(\frac{l_{20}^3}{I_1} + \frac{l_{21}^3}{I_1}\right)$$

Span 21 and 22:

$$M_u \frac{l_{21}}{I_1} + 2 M_v \left(\frac{l_{21}}{I_1} + \frac{l_{22}}{I_1}\right) + M_w \frac{l_{22}}{I_1} = -\frac{w_{basel}}{4}\left(\frac{l_{21}^3}{I_1} + \frac{l_{22}^3}{I_1}\right)$$

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Span 22 and 23:

$$M_v \frac{l_{22}}{I_1} + 2\, M_w \left(\frac{l_{22}}{I_1} + \frac{l_{23}}{I_1} \right) + M_x \frac{l_{23}}{I_1} = -\frac{w_{base1}}{4} \left(\frac{l_{22}^3}{I_1} + \frac{l_{23}^3}{I_1} \right)$$

Span 23 and 24:

$$M_w \frac{l_{23}}{I_1} + 2\, M_x \left(\frac{l_{23}}{I_1} + \frac{l_{24}}{I_1} \right) + M_y \frac{l_{24}}{I_1} = -\frac{w_{base1}}{4} \left(\frac{l_{23}^3}{I_1} + \frac{l_{24}^3}{I_1} \right)$$

	lbs-in		lbs-in
M_a	0	M_b	-171,934
M_c	-284,357	M_d	-130,047
M_e	-297,716	M_f	-433,459
M_g	-397,198	M_h	-406,497
M_i	-406,682	M_j	-395,521
M_k	-439,982	M_l	-273,298
M_m	-319,179	M_n	-334,384
M_o	-772,032	M_p	-267,615
M_q	-143,906	M_r	-173,979
M_s	-161,566	M_t	-164,557
M_u	-180,557	M_v	-113,565
M_w	-125,034	M_x	85,646
M_y	-1×10^6		

Maximum moments between supports and reactions at supports:

Span 1, $M_a < M_b$:

$$M_1 = \frac{w_{base2}\, l_1^2}{8} - \frac{M_a + M_b}{2} + \frac{(M_a - M_b)^2}{2\, w_{base2}\, l_1^2}$$

M_1 = 175,900 lbs-in

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$$R_a = \frac{w_{base2}\ l_1}{2} - \frac{M_a - M_b}{l_1} + g_{dec}\ W_4$$

$$R_a = 90{,}211 \text{ lbs}$$

Span 2, $M_b < M_c$:

$$M_2 = \frac{w_{base2}\ l_2^2}{8} - \frac{M_b + M_c}{2} + \frac{(M_b - M_c)^2}{2\ w_{base2}\ l_2^2}$$

$$M_2 = 590{,}194 \text{ lbs-in}$$

$$R_b = \left(\frac{w_{base2}\ l_1}{8} + \frac{M_a - M_b}{l_1}\right) + \left(\frac{w_{base2}\ l_2}{8} - \frac{M_b - M_c}{l_2}\right) + g_{dec} W_{3a}$$

$$R_b = 50{,}761 \text{ lbs}$$

Span 3, $M_c > M_d$:

$$M_3 = \frac{w_{base2}\ l_3^2}{8} - \frac{M_c + M_d}{2} + \frac{(M_c - M_d)^2}{2\ w_{base2}\ l_3^2}$$

$$M_3 = 571{,}191 \text{ lbs-in}$$

$$R_c = \left(\frac{w_{base2}\ l_2}{8} + \frac{M_b - M_c}{l_2}\right) + \left(\frac{w_{base2}\ l_3}{8} + \frac{M_c - M_d}{l_3}\right) + g_{dec}\ W_2$$

$$R_c = 42{,}486 \text{ lbs}$$

Span 4, $M_d < M_e$:

$$M_4 = \frac{w_{base2}\ l_4^2}{8} - \frac{M_d + M_e}{2} + \frac{(M_d - M_e)^2}{2\ w_{base2}\ l_4^2}$$

$$M_4 = 300{,}923 \text{ lbs-in}$$

$$R_d = \left(\frac{w_{base2}\ l_3}{8} - \frac{M_c - M_d}{l_3}\right) + \left(\frac{w_{base2}\ l_4}{8} - \frac{M_d - M_e}{l_4}\right) + g_{dec}\ W_{3b}$$

$$R_d = 28{,}747 \text{ lbs}$$

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Span 5, $M_e<M_f$:

$$M_5 = \frac{w_{base2}\, l_5^2}{8} - \frac{M_e + M_f}{2} + \frac{(M_e - M_f)^2}{2\, w_{base2}\, l_5^2}$$

$M_5 =$ 974,671 lbs-in

$$R_e = \left(\frac{w_{base2}\, l_4}{8} + \frac{M_d - M_e}{l_4}\right) + \left(\frac{w_{base2}\, l_5}{8} - \frac{M_e - M_f}{l_5}\right) + g_{dec}\, W_{3b}$$

$R_e =$ 57,809 lbs

Span 6, $M_f>M_g$:

$$M_6 = \frac{w_{base2}\, l_6^2}{8} - \frac{M_f + M_g}{2} + \frac{(M_f - M_g)^2}{2\, w_{base2}\, l_6^2}$$

$M_6 = 1 \times 10^6$ lbs-in

$$R_f = \left(\frac{w_{base2}\, l_5}{8} + \frac{M_e - M_f}{l_5}\right) + \left(\frac{w_{base2}\, l_6}{8} - \frac{M_f - M_g}{l_6}\right) + g_{dec}\, W_2$$

$R_f =$ 58,547 lbs

Span 7, $M_g<M_h$:

$$M_7 = \frac{w_{base2}\, l_7^2}{8} - \frac{M_g + M_h}{2} + \frac{(M_g - M_h)^2}{2\, w_{base2}\, l_7^2}$$

$M_7 = 1 \times 10^6$ lbs-in

$$R_g = \left(\frac{w_{base2}\, l_6}{8} - \frac{M_f - M_g}{l_6}\right) + \left(\frac{w_{base2}\, l_7}{8} - \frac{M_g - M_h}{l_7}\right) + g_{dec}\, W_2$$

$R_g =$ 53,942 lbs

Span 8, $M_h < M_i$:

$$M_8 = \frac{w_{base2}\, l_8^2}{8} - \frac{M_h + M_i}{2} + \frac{(M_h - M_i)^2}{2\, w_{base2}\, l_8^2}$$

$$M_8 = 1 \times 10^6 \text{ lbs-in}$$

$$R_h = \left(\frac{w_{base2}\, l_7}{8} + \frac{M_g - M_h}{l_7}\right) + \left(\frac{w_{base2}\, l_8}{8} - \frac{M_g - M_h}{l_8}\right) + g_{dec}\, W_2$$

$$R_h = 53{,}087 \text{ lbs}$$

Span 9, $M_i > M_j$:

$$M_9 = \frac{w_{base2}\, l_9^2}{8} - \frac{M_i + M_j}{2} + \frac{(M_i - M_j)^2}{2\, w_{base2}\, l_9^2}$$

$$M_9 = 1 \times 10^6 \text{ lbs-in}$$

$$R_i = \left(\frac{w_{base2}\, l_8}{8} + \frac{M_h - M_i}{l_8}\right) + \left(\frac{w_{base2}\, l_9}{8} + \frac{M_i - M_j}{l_9}\right) + g_{dec}\, W_2$$

$$R_i = 52{,}738 \text{ lbs}$$

Span 10, $M_j < M_k$:

$$M_{10} = \frac{w_{base2}\, l_{10}^2}{8} - \frac{M_j + M_k}{2} + \frac{(M_j - M_k)^2}{2\, w_{base2}\, l_{10}^2}$$

$$M_{10} = 1 \times 10^6 \text{ lbs-in}$$

$$R_j = \left(\frac{w_{base2}\, l_9}{8} - \frac{M_i - M_j}{l_9}\right) + \left(\frac{w_{base2}\, l_{10}}{8} - \frac{M_j - M_k}{l_{10}}\right) + g_{dec}\, W_2$$

$$R_j = 52{,}029 \text{ lbs}$$

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Span 11, $M_k > M_l$:

$$M_{11} = \frac{w_{base2}\, l_{11}^2}{8} - \frac{M_k + M_l}{2} + \frac{(M_k - M_l)^2}{2\, w_{base2}\, l_{11}^2}$$

M_{11} = 966,687 lbs-in

$$R_k = \left(\frac{w_{base2}\, l_{10}}{8} + \frac{M_j - M_k}{l_{10}} \right) + \left(\frac{w_{base2}\, l_{11}}{8} + \frac{M_k - M_l}{l_{11}} \right) + g_{dec}\, W_2$$

R_k = 49,206 lbs

Span 12, $M_l < M_m$:

$$M_{12} = \frac{w_{base2}\, l_{12}^2}{8} - \frac{M_l + M_m}{2} + \frac{(M_l - M_m)^2}{2\, w_{base2}\, l_{12}^2}$$

M_{12} = 353,847 lbs-in

$$R_l = \left(\frac{w_{base2}\, l_{11}}{8} - \frac{M_k - M_l}{l_{11}} \right) + \left(\frac{w_{base2}\, l_{12}}{8} - \frac{M_l - M_m}{l_{12}} \right) + g_{dec}\, W_{3a}$$

R_l = 42,509 lbs

Span 13, $M_m > M_n$:

$$M_{13} = \frac{w_{base2}\, l_{13}^2}{8} - \frac{M_m + M_n}{2} + \frac{(M_m - M_n)^2}{2\, w_{base2}\, l_{13}^2}$$

M_{13} = 933,992 lbs-in

$$R_m = \left(\frac{w_{base2}\, l_{12}}{8} + \frac{M_l - M_m}{l_{12}} \right) + \left(\frac{w_{base2}\, l_{13}}{8} + \frac{M_m - M_n}{l_{13}} \right) + g_{dec}\, W_{3a}$$

R_m = 46,393 lbs

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Span 14, $M_n < M_o$:

$$M_{14} = \frac{w_{base2}\, l_{14}^2}{8} - \frac{M_n + M_o}{2} + \frac{(M_n - M_o)^2}{2\ w_{base2}\, l_{14}^2}$$

$$M_{14} = 1{,}180{,}111 \text{ lbs-in}$$

$$R_n = \left(\frac{w_{base2}\, l_{13}}{8} - \frac{M_m - M_n}{l_{13}}\right) + \left(\frac{w_{base2}\, l_{14}}{8} - \frac{M_j - M_k}{l_{14}}\right) + g_{dec}\, W_2$$

$$R_n = 51{,}192 \text{ lbs}$$

Span 15, $M_o > M_p$, Span where pump is located:

Location of maximum moment: $x_{max} = l_{15}/2 + [(M_o - M_p)/(w_{base}\ l_{15})]$

Moment due to pump at location: $M_{pump} = (g_{dec}\ W_{21}\ d_b\ x_{max})/l_{15}$

Reaction at o due to pump: $R_{po} = (g_{dec}\ W_{21}\ d_b)/l_{15}$

$$M_{15} = \frac{w_{base1}\, l_{15}^2}{8} - \frac{M_o + M_p}{2} + \frac{(M_o - M_p)^2}{2\ w_{base1}\, l_{15}^2} + M_{pump}$$

$$M_{15} = 1{,}078{,}497 \text{ lbs-in}$$

$$R_o = \left(\frac{w_{base2}\, l_{14}}{8} + \frac{M_n - M_o}{l_{14}}\right) + \left(\frac{w_{base1}\, l_{15}}{8} + \frac{M_o - M_p}{l_{15}}\right) + R_{po} + g_{dec}\, W_2$$

$$R_o = 71{,}008 \text{ lbs}$$

Span 16, $M_p > M_q$:

$$M_{16} = \frac{w_{base1}\, l_{16}^2}{8} - \frac{M_p + M_q}{2} + \frac{(M_p - M_q)^2}{2\ w_{base1}\, l_{16}^2}$$

$$M_{16} = 459{,}673 \text{ lbs-in}$$

Reaction at p due to pump: $R_{pp} = (g_{dec}\ W_{21}\ d_a)/l_{15}$

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$$R_p = \left(\frac{w_{basel}\ l_{15}}{8} - \frac{M_o - M_p}{l_{15}}\right) + R_{pp} + \left(\frac{w_{basel}\ l_{16}}{8} + \frac{M_p - M_q}{l_{16}}\right) + g_{dec}\ W_2$$

$$R_p = 657{,}122 \text{ lbs}$$

Span 17, $M_q > M_r$:

$$M_{17} = \frac{w_{basel}\ l_{17}^2}{8} - \frac{M_q + M_r}{2} + \frac{(M_q - M_r)^2}{2\ w_{basel}\ l_{17}^2}$$

$$M_{17} = 417{,}251 \text{ lbs-in}$$

$$R_q = \left(\frac{w_{basel}\ l_{16}}{8} - \frac{M_p - M_q}{l_{16}}\right) + \left(\frac{w_{basel}\ l_{17}}{8} - \frac{M_q - M_r}{l_{17}}\right) + g_{dec}\ W_2$$

$$R_q = 33{,}527 \text{ lbs}$$

Span 18, $M_r > M_s$:

$$M_{18} = \frac{w_{basel}\ l_{18}^2}{8} - \frac{M_r + M_s}{2} + \frac{(M_r - M_s)^2}{2\ w_{basel}\ l_{18}^2}$$

$$M_{18} = 410{,}023 \text{ lbs-in}$$

$$R_r = \left(\frac{w_{basel}\ l_{17}}{8} - \frac{M_q - M_r}{l_{17}}\right) + \left(\frac{w_{basel}\ l_{18}}{8} + \frac{M_r - M_s}{l_{18}}\right) + g_{dec}\ W_2$$

$$R_r = 30{,}953 \text{ lbs}$$

Span 19, $M_s < M_t$:

$$M_{19} = \frac{w_{basel}\ l_{19}^2}{8} - \frac{M_s + M_t}{2} + \frac{(M_s - M_t)^2}{2\ w_{basel}\ l_{19}^2}$$

$$M_{19} = 413{,}151 \text{ lbs-in}$$

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$$R_s = \left(\frac{w_{basel}\ l_{18}}{8} - \frac{M_r - M_s}{l_{18}}\right) + \left(\frac{w_{basel}\ l_{19}}{8} - \frac{M_s - M_t}{l_{19}}\right) + g_{dec}\ W_2$$

R_s = 30,593 lbs

Span 20, $M_t<M_u$:

$$M_{20} = \frac{w_{basel}\ l_{20}^2}{8} - \frac{M_t + M_u}{2} + \frac{(M_t - M_u)^2}{2\ w_{basel}\ l_{20}^2}$$

M_{20} = 422,708 lbs-in

$$R_t = \left(\frac{w_{basel}\ l_{19}}{8} + \frac{M_s - M_t}{l_{19}}\right) + \left(\frac{w_{basel}\ l_{20}}{8} - \frac{M_t - M_u}{l_{20}}\right) + g_{dec}\ W_2$$

R_t = 30,001 lbs

Span 21, $M_u>M_v$:

$$M_{21} = \frac{w_{basel}\ l_{21}^2}{8} - \frac{M_u + M_v}{2} + \frac{(M_u - M_v)^2}{2\ w_{basel}\ l_{21}^2}$$

M_{21} = 398,270 lbs-in

$$R_u = \left(\frac{w_{basel}\ l_{20}}{8} + \frac{M_t - M_u}{l_{20}}\right) + \left(\frac{w_{basel}\ l_{21}}{8} + \frac{(M_u + M_v)}{l_{21}}\right) + g_{dec}\ W_2$$

R_u = 28,795 lbs

Span 22, $M_v<M_w$:

$$M_{22} = \frac{w_{basel}\ l_{22}^2}{8} - \frac{M_v + M_w}{2} + \frac{(M_v - M_w)^2}{2\ w_{basel}\ l_{22}^2}$$

M_{22} = 142,407 lbs-in

$$R_v = \left(\frac{w_{basel}\ l_{21}}{8} - \frac{M_u - M_v}{l_{21}}\right) + \left(\frac{w_{basel}\ l_{22}}{8} - \frac{M_v - M_w}{l_{22}}\right) - g_{dec}\ W_{3b}$$

R_v = 30,633 lbs

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Span 23, $M_w > M_x$:

$$M_{23} = \frac{w_{base1}\, l_{23}^2}{8} - \frac{M_w + M_x}{2} + \frac{(M_w - M_x)^2}{2\, w_{base1}\, l_{23}^2}$$

$$M_{23} = 183{,}978 \text{ lbs-in}$$

$$R_w = \left(\frac{w_{base1}\, l_{22}}{8} + \frac{M_v - M_w}{l_{22}}\right) + \left(\frac{w_{base1}\, l_{23}}{8} + \frac{(M_w - M_x)}{l_{23}}\right) + g_{dec}\, W_{3b}$$

$$R_w = 20{,}252 \text{ lbs}$$

Span 24, $M_x < M_y$:

$$M_{24} = \frac{w_{base1}\, l_{24}^2}{8} - \frac{M_x + M_y}{2} + \frac{(M_x - M_y)^2}{2\, w_{base1}\, l_{24}^2}$$

$$M_{24} = 3{,}581{,}211 \text{ lbs-in}$$

$$R_x = \left(\frac{w_{base1}\, l_{23}}{8} - \frac{M_w - M_x}{l_{23}}\right) + \left(\frac{w_{base1}\, l_{24}}{8} - \frac{(M_x - M_y)}{l_{24}}\right) + g_{dec}\, W_2$$

$$R_x = -79{,}638 \text{ lbs}$$

Reaction at Column 25:

$$R_y = \frac{w_{base1}\, l_{24}}{8} + \frac{M_x - M_y}{l_{24}} + g_{dec}\, W_{tcap}$$

$$R_y = 223{,}861 \text{ lbs}$$

Maximum loading on ring:

Maximum loading on ring at Column 15, R_p. Model as combined loading of Ring loaded as loading smeared over entire volume of the ring Reference 7, pages 176 and 178, Case 22 and opposed by a reactive load transferred by tangential shear Case 24. Also assume ring acts as a curved beam (shown Figures 2 and 3).

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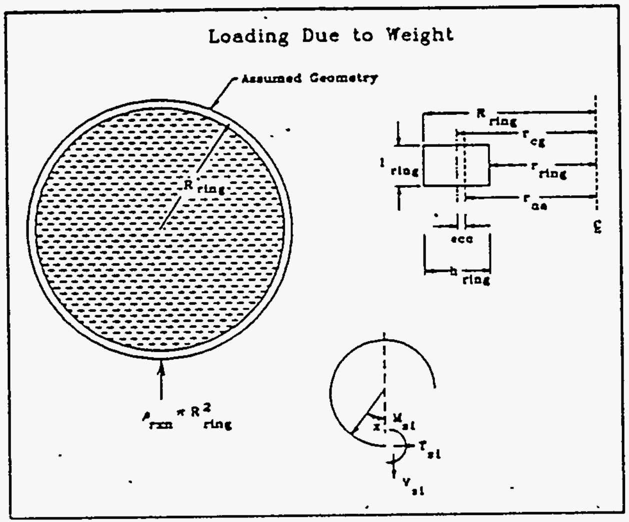

Figure 2

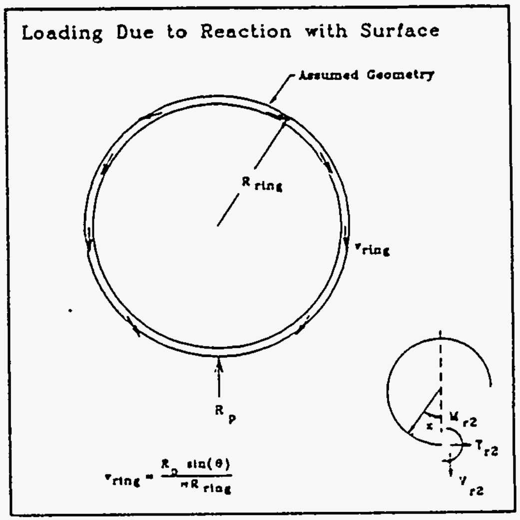

Figure 3

Nominal radius of ring:

OD of ring: od_{ring} = 5 ft + 11.625 in

$R_{ring} = od_{ring}/2$ $\qquad R_{ring} = 2.98$ ft

Width of ring: b_{ring} = 1.5 in

Distributed weight of ring throughout cross section:

$w_{ring} = R_p/(\pi R^2_{ring}\ b_{ring})$ $\qquad w_{ring} = 109$ lbs/in^3

Case 20 Maximum Loading at bottom of ring:

$\alpha = 0$ deg $\qquad \theta = 0$ deg

$u = \cos(\alpha)$ $\qquad s = \sin(\theta)$ $\qquad c = \cos(\theta)$ $\qquad z = \sin(\alpha)$

Maximum moment loading: $M_{1ring} = \frac{3}{4}\ w_{ring}\ R_{ring}^{\ 3}$ $\qquad M_{1ring} = 3.75 \times 10^6$ lbs

Circumferential Tension:

$T_{1ring} = w_{ring}\ R_{ring}^{\ 2}\ (1 + 1/4\ u - 1/2\ \pi\ z + 1/2\ \alpha\ z)$

T_{1ring} = 174,307 lbs/in

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Radial Shear:

$$V_{1ring} = w_{ring} R^2_{ring} (1/2\ \alpha\ u + 1/4\ z - 1/2\ \pi\ u)$$

$$V_{1ring} = -219{,}041 \text{ lbs/in}$$

Case 25, Opposing moment at bottom of ring, $\theta = 0°$, $\alpha = 0°$:

Counteracting Moment:

$$M_{2ring} = -[R_p R_{ring} [0.23868\ u - 1/2\ s + 0.15915\ (a\ z + \theta\ s + c - u\ c^2)]]$$

$$M_{2ring} = -5.62 \times 10^6 \text{ lbs-in}$$

Circumferential Tension:

$$T_{2ring} = R_p [0.15915\ (\alpha\ z - u\ c^2) - 0.07958\ u]$$

$$T_{2ring} = -156{,}875 \text{ lbs}$$

Radial Shear:

$$V_{2ring} = -[R_p [0.15915\ (\alpha\ u - 1/2\ z + z\ c^2) - 1/2\ u]]$$

$$V_{2ring} = 328{,}561 \text{ lbs}$$

Resultant loading:

Maximum Moment:

$M_{rring} = M_{1ring}\ b_{ring} + M_{2ring}$ $M_{rring} = 1{,}233$ lbs-in

Circumferential Tension:

$T_{rring} = T_{1ring}\ b_{ring} + T_{2ring}$ $T_{rring} = 104{,}586$ lbs

Radial Shear:

$V_{rring} = V_{1ring}\ b_{ring} + V_{2ring}$ $V_{rring} = 0$ lbs

Geometric parameters of pipe:

Inside radius of ring is id of pipe: $r_{ring} = (od_{pipe} - t_{pipe})/2$

Normal depth of ring including pipe thickness:

$h_{ring} = R_{ring} - r_{ring}$ $h_{ring} = 4.06$ in

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Neutral axis of ring:

$$r_{na} = \frac{h_{ring}}{\ln\left(\frac{R_{ring}}{r_{ring}}\right)}$$

CG of ring:

$$r_{cg} = r_{ring} + (h_{ring}/2)$$

Eccentricity: $ecc = r_{cg} - r_{na}$

Cross sectional area: $A_{ring} = h_{ring}\, b_{ring}$

Stresses in ring:

Bending stress:

$$\sigma_{bottom} = \frac{M_{rring}\,(r_{na}\; r_{ring})}{A_{ring}\; ecc\; r_{ring}}$$

$$\sigma_{bottom} = 311 \text{ psi}$$

Tangential stress:

$\sigma_{tan} = T_{rring}/A_{ring}$ $\sigma_{tan} = 17{,}163$ psi

Maximum shear stress:

$\tau_{ring} = 2\, V_{rring}/A_{ring}$ $\tau_{ring} = 0$ psi

Total stress:

$\sigma_{tot} = \sigma_{bottom} + \sigma_{tan} + \tau_{ring}$ $\sigma_{tot} = 17{,}474$ psi

ASME allowable from previous data: $s_a = 23{,}270$ psi

Margin of Safety on inner pipe:

$MS_{pipe} = (s_a/\sigma_{tot}) - 1$ $MS_{pipe} = 0.33$ OK

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Maximum Loading on inner containment pipe between rings:

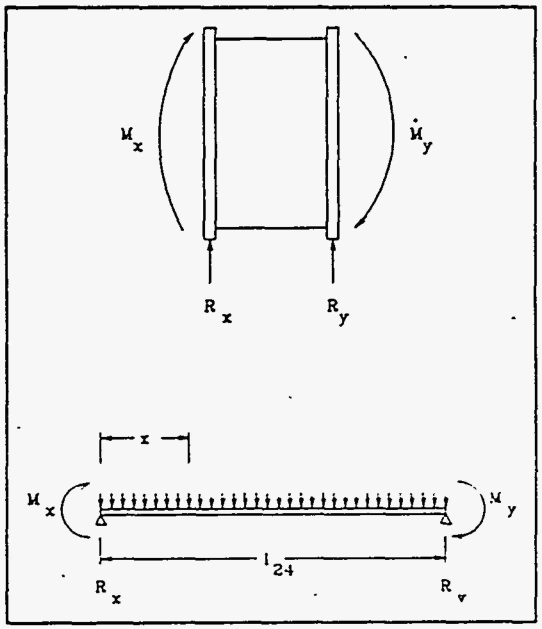

Figure 4

Maximum bending between Columns 24 and 25:

$$\sigma_{bmax} = \frac{M_{24}\left(\frac{od_{pipe}}{2}\right)}{I_{pipe}}$$

$$\sigma_{bmax} = 2{,}279 \text{ psi}$$

Short beam criteria applies here, therefore must consider maximum shear at support.

Maximum shear: $\tau_{ymax} = 2\ R_y/A_{pipe}$ $\tau_{ymax} = 4{,}489$ psi

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Bending at support:

$$\sigma_{by} = \frac{|M_y| \frac{od_{pipe}}{2}}{I_{pipe}}$$

$$\sigma_{by} = 655 \text{ psi}$$

Total stress at pipe section:

$\sigma_{ytot} = \sigma_{bmax} + \tau_{ymax}$ $\sigma_{ytot} = 6{,}768$ psi

Margin of Safety:

$MS_{ypipe} = (s_a/\sigma_{ytot}) - 1$ $MS_{ypipe} = 2.44$ OK

Loading on Inner Blind Flange Plate:

Assuming inside pipe welds carry the entire load determine weld strength.

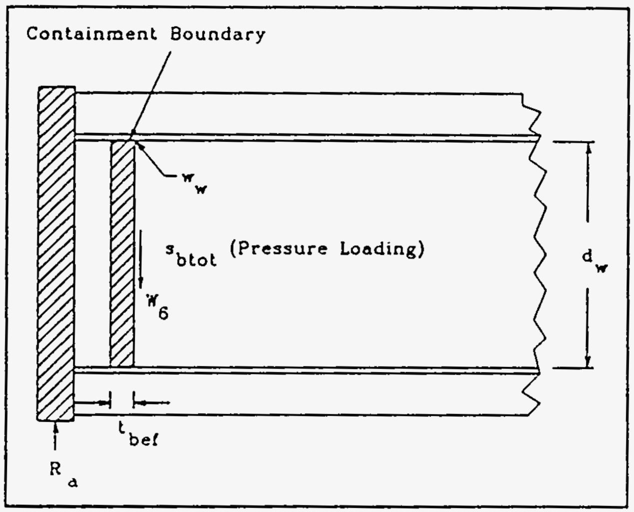

Figure 5

Plate thickness: $t_{bef} = 2.0$ in

From ASME, allowable at joint discontinuities: $1.5\ s_a = 34{,}905$ psi

Since welds are 100% radiographed assume full strength of fillets.

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Weld size, assuming on one weld: $w_w = 0.500$ in

Weld diameter is assumed as same size as pipe: $d_w = id_{pipe}$

Circumference of weld (one side only): $c_w = \pi(d_w)$

Pressure loading form pressure calculations at pipe joint discontinuity:

$$s_{btot} = 10{,}929 \text{ psi}$$

Shear area of weld: $A_w = 0.707\ w_w\ c_w$

Maximum shear due deflection of pipe during drop:

Weight of inner blind flange: $W_6 = 1{,}800$ lbs

$\tau_{drop} = (2\ g_{dec}\ W_6)/A_w$ $\tau_{drop} = 1{,}662$ psi

Total stress on weld:

$\sigma_{wtot} = \tau_{drop} + s_{btot}$ $\sigma_{wtot} = 12{,}591$ psi

Margin of Safety:

$MS_{befw} = (1.5\ s_a/\sigma_{wtot}) - 1$ $MS_{befw} = 1.77$ OK

Top Cap Loading:

Retaining Ring Loading:

Since fitup tolerance of retaining ring is tighter than for bolts, retaining ring takes up all shear loading from the drop.

Weight of inner top cap: $W_{20} = 1{,}500$ lbs

ID of retaining ring: $id_{itcrr} = 5$ ft + 3 in

Wall thickness: $t_{itcrr} = 0.375$ in

OD of retaining ring: $od_{itcrr} = id_{itcrr} + 2\ t_{itcrr}$

Cross sectional area of ring:

$$A_{itcrr} = \pi\ (od^2_{itcrr} - id^2_{itcrr})/4$$

Maximum shearing load on the ring cross section:

$$\tau_{rrmax} = (2\ g_{dec}\ W_{20})/A_{itcrr}$$

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$$\tau_{rrmax} = 1{,}298 \text{ psi}$$

Margin of Safety:

$MS_{rrs} = (s_a/\tau_{rrmax}) - 1$ $MS_{rrs} = 16.93$ OK

Loading on the bolts:

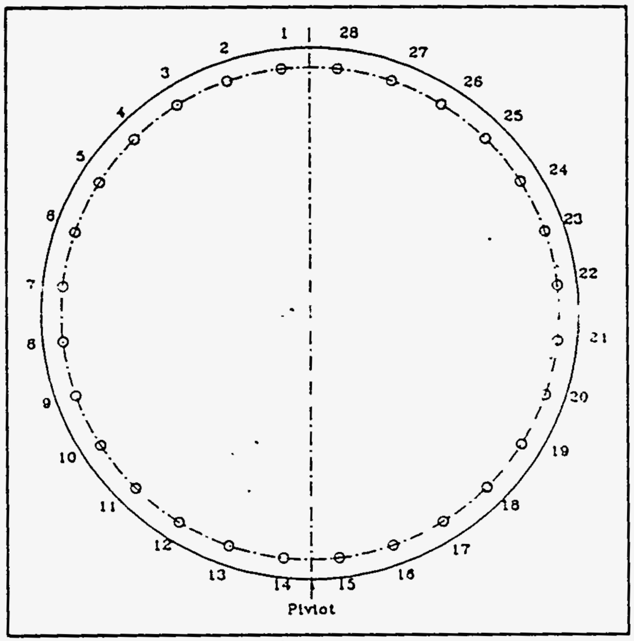

Figure 6

CG of top cap from inner flange face: $cg_{itc} = 1.39$ ft

Bolt parameters:

Number of bolts: $n_{bitc} = 28$

Nominal diameter of bolts: $d_{bitc} = 1$ in

Tensile stress area of each bolt (Reference ASTM, page 1278):

$$A_b = 0.7854\,(d_{bitc} - 0.9743 \text{ in}/8)^2$$

Allowable tensile strength of bolts: $\sigma_{bten} = 55{,}000$ psi

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Checker S. R. Crow Date 08/31/94

Total preload and pressure load per bolt from ASME evaluation:

$$W_{btot} = 19{,}696 \text{ lbs}$$

Angle from vertical flange axis: $\theta_1 = 6.43$ deg

Angle of bolt spacing: $\theta_2 = 12.83$ deg

Diameter of bolt circle: $d_{bc} = 61$ in

Diameter of flange: $d_{flange} = id_{itcrr}$

Distance from Pivot to bolts 14 to 8:

$$r_{bc} = d_{bc}/2 \qquad r_{flange} = d_{flange}/2$$

Perpendicular distance:

Distance from pivot to centerline of bolt 14:

$$r_{14} = r_{flange} - r_{bc}\cos(\theta_1)$$

Distance from pivot to centerline of bolt 13:

$$r_{13} = r_{flange} - r_{bc}\cos(\theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 12:

$$r_{12} = r_{flange} - r_{bc}\cos(2\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 11:

$$r_{11} = r_{flange} - r_{bc}\cos(3\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 10:

$$r_{10} = r_{flange} - r_{bc}\cos(4\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 9:

$$r_9 = r_{flange} - r_{bc}\cos(5\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 8:

$$r_8 = r_{flange} - r_{bc}\cos(6\ \theta_2 + \theta_1)$$

Distance from Pivot to bolts 7 to 1:

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Distance from pivot to centerline of bolt 7:

$$r_7 = r_{flange} + r_{bc}\ \sin(\theta_1)$$

Distance from pivot to centerline of bolt 6:

$$r_6 = r_{flange} + r_{bc}\ \sin(\theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 5:

$$r_5 = r_{flange} + r_{bc}\ \sin(2\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 4:

$$r_4 = r_{flange} + r_{bc}\ \sin(3\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 3:

$$r_3 = r_{flange} + r_{bc}\ \sin(4\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 2:

$$r_2 = r_{flange} + r_{bc}\ \sin(5\ \theta_2 + \theta_1)$$

Distance from pivot to centerline of bolt 1:

$$r_1 = r_{flange} + r_{bc}\ \sin(6\ \theta_2 + \theta_1)$$

By symmetry bolts 15 to 28 are equal to 14 to 1, respectively.

Moment due to drop due to eccentric loading of bolts:

$$M_{bitc} = g_{dec}\ W_{20}\ cg_{itc}$$

Tensile load on bolt 1 (highest loading):

$$F_{bitc1} = \frac{r_1\ M_{bitc}}{2\left(\begin{array}{l} r_1^2 + r_2^2 + r_3^2 + r_4^2 + r_5^2 + r_6^2 + r_7^2 + r_8^2 \\ \quad + r_9^2 + r_{10}^2 + r_{11}^2 + r_{12}^2 + r_{13}^2 + r_{14}^2 \end{array}\right)}$$

$$F_{bitc1} = 1{,}225 \text{ lbs}$$

Total bolt load:

$$W_{itcb} = W_{btot} + F_{bitc1} \qquad W_{itcb} = 20{,}921 \text{ lbs}$$

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Checker S. R. Crow Date 08/31/94

Tensile stress on bolt:

$\sigma_{bolt} = W_{itcb}/A_b$ $\sigma_{bolt} = 34{,}538$ psi

Margin of Safety based on bolt ultimate:

$MS_{bolt} = (\sigma_{bten}/\sigma_{bolt}) - 1$ $MS_{bolt} = 0.59$ OK

Outer Shell Loading from lead:

Model longest thinnest section only:

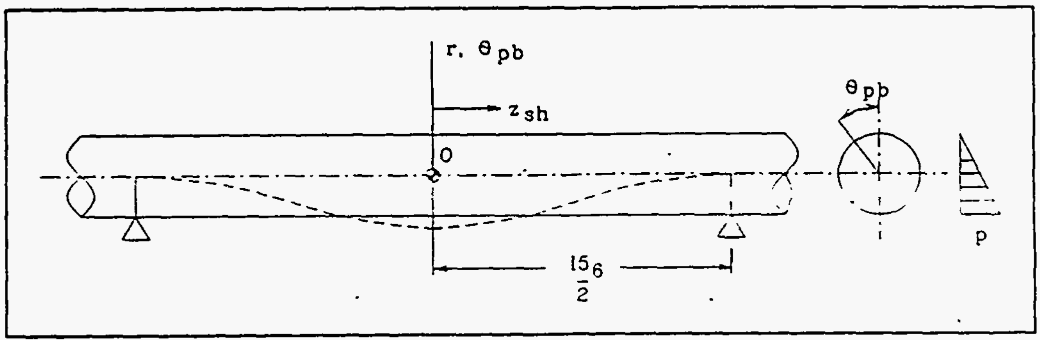

Figure 7

ID of shell: $id_{shell} = 5\text{ ft} + 8\text{ in}$

Wall thickness: $t_{516sh} = 0.3125$ in

OD of shell: $od_{shell} = id_{shell} + 2(t_{516sh})$

Inner cross sectional void area of shell:

$$A_{crsh} = \pi(id^2_{shell} - od^2_{pipe})/4$$

Longest length between supports: $15_6 = 2.5$ ft

Mid point of length: $z_{sh} = 15_6/2$

Gap of void: $gap = (id_{shell} - od_{pipe})/2$ $gap = 2$ in

Radius of lead: $r_{pb} = od_{pipe}/2 + gap$

Angle of evaluation: $\theta_{pb} = 180$ deg

Poisson's ratio for carbon steel (Reference 8): $\nu_{cstl} = 0.3$

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Density of lead (Reference 13, page 398): $\rho_{pb} = 0.4096$ lbs/in^3

Assume 65% density of shot: $\rho_{shot} = 0.65\ \rho_{pb}$

Weight of lead between supports:

$$w_{spb} = A_{crsh}\ \rho_{shot}\ 15_6$$

$$w_{spb} = 3{,}312 \text{ lbs}$$

Assume weight of lead smeared over the entire cross sectional area:

Cross sectional area: $A_{smr} = \pi/4\ od_{shell}^2$

Smear density: $\rho_{smr} = w_{spb}/(A_{smr}\ 15_6)$

Load between supports at angle of evaluation, stress due to lead slump modeled using membrane theory of pipe filled between supports with a flowable material.

Tangential stress:

$$\sigma_t = \frac{g_{dec}\ \rho_{smr}\ r_{pb}^2}{t_{516} sh}\left(1 - \cos(\theta_{pb})\right)$$

$$\sigma_t = 7{,}133 \text{ psi}$$

Longitudinal stress:

$$\sigma_l = \frac{g_{dec}\ \rho_{smr}}{t_{516} sh}\left(\frac{z_{sh}^2}{2}\right)\cos(\theta_{pb}) + \nu_{cstl}\ \sigma_t$$

$$\sigma_l = 1{,}793 \text{ psi}$$

Shear stress:

$$\sigma_{shr} = \frac{-g_{dec}\ \rho_{smr}}{t_{516} sh}\left(\frac{z_{sh}^2}{2}\right)\sin(\theta_{pb})$$

$$\sigma_{shr} = 0 \text{ psi}$$

Total stress at maximum deflection (at center of length):

$$\sigma_{pbtot} = \sigma_t + \sigma_l + \sigma_{shr}$$

$$\sigma_{pbtot} = 8{,}926 \text{ psi}$$

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Originator S. S. Shiraga Date 08/01/94
Checker S. R. Crow Date 08/31/94

Margin of Safety:

$MS_{pb} = (s_a/\sigma_{pbtot}) - 1$ $MS_{pb} = 1.61$ OK

Weld on Stiffener Rings:

Evaluate circumferential fillet welds joining the stiffening rings and end plates to the inner containment pipe. Assume welds are 1/2 inch fillets both sides.

Weld size: $w_{srw} = 0.500$ in

Diameter of weld is OD of pipe: od_{pipe}: 64 in

Largest moment on outer top end plate, model as pipe welded to stiffening ring with no support from outer shell or top cap flange.

Evaluate weld per AWS, Reference 11, page 7.4-7.

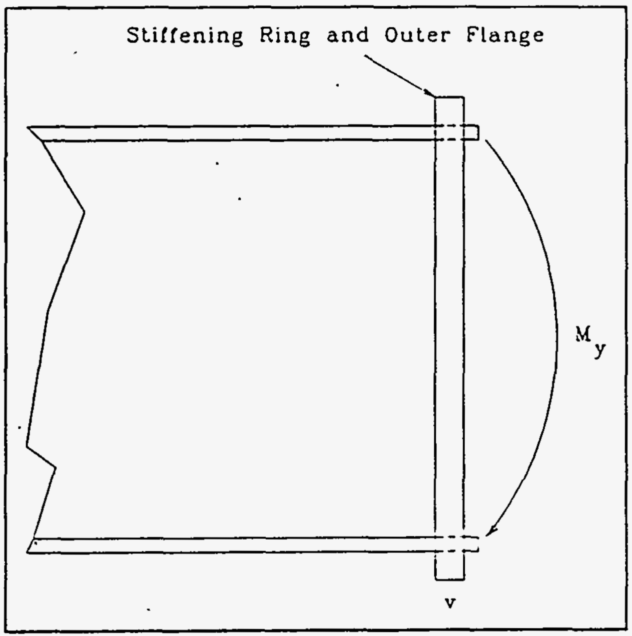

Figure 8

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Checker S. R. Crow Date 08/31/94

Treat the welds as a line in bending:

$$S_{weld} = \pi \frac{od_{pipe}^2}{4}$$

Linear Force on welds, assuming welds equally share the load:

$$f_b = \left|\frac{M_y}{2\ S_{weld}}\right|$$

$$f_b = 160 \text{ lbs/in}$$

AWS allowable for fillet welds used in Bridge Construction for ASTM A-36 material with thickness greater than 1 inch using E60 or SAW-1 Electrodes and assuming parallel loading, Reference 10 and Reference 11, page 7.4-8.

$$s_{aws} = 8{,}800 \text{ psi}$$

Allowable line load:

$f_{aws} = s_{aws}\ (0.707\ w_{srw})$ $f_{aws} = 3{,}111$ lbs/in

Margin of Safety:

$MS_{srw} = (f_{aws}/f_b) - 1$ $MS_{srw} = 18.44$ OK

6.5 TIEDOWN ANALYSIS

DON'T SAY IT --- *Write It!*

DATE: 7/25/94

TO: Richard F. Carlstrom G2-02

FROM: Harold E. Adkins, Jr. G2-03
Telephone: 376-9703

cc:
J. W. Thornton G2-03
S. R. Crow G2-03
M. J. Ostrom H5-68
T. C. Mackey S2-03
C. E. Brewer S3-15

SUBJECT: 101-SY TRANSPORT PACKAGING TIEDOWN ANALYSIS

The 101-SY tiedown analysis has been completed based on a tiedown configuration which is shown in figure 1. All analysis was based on a fully lead shielded 101-SY package containing a 19,427 lb payload (approximate total weight = 138,800 lbs).

The results of the analysis indicate that the cables for this tiedown configuration must have a minimum load capability of 15,430 lbs for each of the sixteen (16) cable legs. These cable legs are approximately 81 inches in length. To remain consistent with the analysis performed on the rip-out capability of the container tiedown tabs, shackles with a pin diameter of 1-5/8 inches, must be used. It is suggested by the analyst to implement a double jaw end turnbuckle to minimize exposure time and to aid in pre-tensioning the tiedowns. These such devices must meet or exceed the working load limit of the cables they are being used with. It is important for interested parties to note that all of the tiedown components mentioned above are available through McMaster-Carr supply company and photocopies of these components are attached at the end of the analysis. Pre-tensioning procedures are left to the discretion of the rigging crew responsible.

An important note that should be brought to the readers attention is as follows. In light of the fact that the container stiffness exceeds that of the main transport trailer and the manner in which the container is being restrained (tie-downs), a low-cycle fatigue failure analysis of the main transport trailer is recommended.

The analysis, consisting of hand calculations, were checked by S. R. Crow and are attached.

54-3000-101 (12/92) GEF014

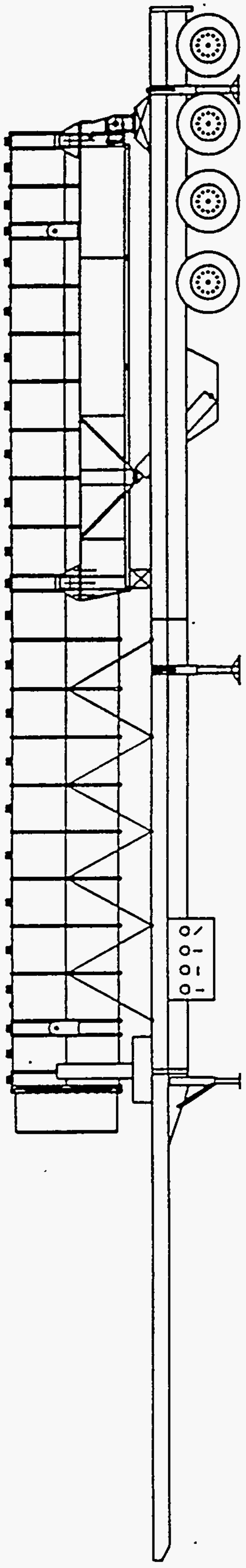

FIGURE 1. TILT-TRAILER TIEDOWN CONFIGURATION.

DESIGN CALCULATIONS

(1) Drawing ______ (2) Doc. No. ______ (3) Page 1 of 16
(4) Building General (5) Rev. Zero (6) Job No. N2B6D
(7) Subject 101-SY TILT-TRAILER TIEDOWN ANALYSIS
(8) Originator Harold E. Adkins, Jr. Date 7/25/94
(9) Checker Stan R. Crow Date 7-25-94
(10)

101-SY TILT-TRAILER TIEDOWN ANALYSIS

Phase I of bearing load analysis:

- Determine bearing load capability of container strongback-attachment points

Assumptions:

- To meet the requirements of 10 CFR 71.45 (b)(1), only the rigid mount points that mate with the strongback are considered for calculating critical bearing stress. This will give a conservative approximation considering the fact that the container will also be tied down using cables that directly attach from container tiedown points to the trailer.

$W_c = 138800 \cdot lbf$	Maximum weight of fully shielded container (Shielded to column line 25 w/Lead on Drawing # H-2-83734) & (19,427 lbf payload - pump) - Calculation of this value attached at the end of this analysis
$W_s = 30000 \cdot lbf$	Maximum weight of strongback
$S_y = 36000 \cdot psi$	Yield Strength of ASTM A-36 (From ASME Section VIII, Div 1)
$S_u = 58000 \cdot psi$	Ultimate Strength of ASTM A-36 (From ASME Section VIII, Div 1)

Critical Bearing Stress Of Strongback Mounting Points:

$F_{pcr} / F_y = l_e / d$ (C-J3-1 AISC - Steel Construction)

$l_e := 4.5 \cdot in$	Minimum distance from free edge (including ring thickness)
$d := 2.257 \cdot in$	Minimum accountable bolt diameter for a 2.5 inch diameter bolt (From "AN INTRODUCTION TO THE DESIGN AND BEHAVIOR OF BOLTED JOINTS" - John H. Bickford)
$F_y := S_y$	ASTM A-36 yield strength
$F_{pcr} := \frac{F_y \cdot l_e}{d}$	Critical bearing stress
$F_{pcr} = 7.178 \cdot 10^4 \cdot psi$	
$t_{lug} := 2.0 \cdot in$	Thickness of attachment lug

DESIGN CALCULATIONS

(1) Drawing ______ (2) Doc. No. ______ (3) Page 2 of 16

(4) Building General (5) Rev. Zero (6) Job No. ______

(7) Subject 101-SY TILT-TRAILER TIEDOWN ANALYSIS

(8) Originator Harold E. Adkins, Jr. Date 7/25/94

(9) Checker Stan R. Crow Date 7-25-94

(10)

$a_{lug} := t_{lug} \cdot d$ Projected stress area

$Load_{max} := F_{pcr} \cdot a_{lug}$ Maximum load capability

$Load_{max} = 3.24 \cdot 10^5 \cdot lbf$

- From 10 CFR 71.45 (b)(1), the attachment points on the container must be capable of withstanding w/o exceeding yield:

  - 10 X weight Longitudinal
  - 5 X weight Lateral
  - 2 X weight Vertical

$G_{Long} := 10$ $G_{Lat} := 5$ $G_{Vert} := 2$

Longitudinal Loading Case:

$N_{Long} := 4$ Number of effective longitudinal load bearing points (Strongback mount points)

$Load_{Long} := \frac{G_{Long} \cdot W_c}{N_{Long}}$ $Load_{Long} = 3.47 \cdot 10^5 \cdot lbf$

$MS_{Long} := \left(\frac{Load_{max}}{Load_{Long}} - 1 \right)$

$MS_{Long} = -0.066$

Alternate Assumption: (More realistic)

- For the longitudinal load case, the load capabilty of the tiedown points on the container can be incorporated.
- The trailer and strongback are rigid fixtures.
- Aggregate load condition.

Critical Bearing Stress Of Tiedown Points:

DESIGN CALCULATIONS

(1) Drawing ____ (2) Doc. No. ____ (3) Page 3 of 16

(4) Building General (5) Rev. Zero (6) Job No ____

(7) Subject 101-SY TILT-TRAILER TIEDOWN ANALYSIS

(8) Originator Harold E. Adkins, Jr. Date 7/25/94

(9) Checker Stan R. Crow Date 7-25-94

(10)

$F_{pcr} / F_y = l_e / d$ (C-J3-1 AISC - Steel Construction)

$l_e := 2.156 \cdot in$	Minimum distance from free edge (including ring thickness)
$d := \left(1 + \frac{5}{8}\right) \cdot in$	Hardware diameter
$F_y := S_y$	ASTM A-36 yield strength
$F_{pcr} := \frac{F_y \cdot l_e}{d}$	Critical bearing stress
$F_{pcr} = 4.776 \cdot 10^4 \cdot psi$	
$t_{lug} = 1.5 \cdot in$	Thickness of attachment lug
$a_{lug} := t_{lug} \cdot d$	Projected stress area
$Load_{Max} := F_{pcr} \cdot a_{lug}$	Maximum load capability
$Load_{Max} = 1.164 \cdot 10^5 \cdot lbf$	

$M_{Long} := 8$ Number of effective longitudinal load bearing points (Tiedown points)

$Load_{Long} := \frac{G_{Long} \cdot W_c}{N_{Long} + M_{Long}}$ $Load_{Long} = 1.157 \cdot 10^5 \cdot lbf$

$MS_1 = \left(\frac{Load_{max}}{Load_{Long}} - 1\right)$ $MS_1 = 1.801$ (Strongback mount points)

$MS_2 = \left(\frac{Load_{Max}}{Load_{Long}} - 1\right)$ $MS_2 = 0.007$ (Tiedown points)

* All of these points would behave in an aggregate fashion anyway.

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Vertical Loading Case:

$l_e := 4.094 \cdot in$ Minimum distance from free edge

$d := 2.0 \cdot in$ Hardware diameter

$F_y := 36000 \cdot psi$ ASTM A-36 yield strength

$F_{pcr} := \frac{F_y \cdot l_e}{d}$ Critical bearing stress

$F_{pcr} = 7.369 \cdot 10^4 \cdot psi$

$t_{lug} := 2.0 \cdot in$ Thickness of attachment lug

$a_{lug} = t_{lug} \cdot d$ Projected stress area

$Load_{max} := F_{pcr} \cdot a_{lug}$ Maximum load capability

$Load_{max} = 2.948 \cdot 10^5 \cdot lbf$

$N_{Vert} := 4$ Number of effective vertical load bearing points

$Load_{Vert} := \frac{G_{Vert} \cdot W_c}{N_{Vert}}$ $Load_{Vert} = 6.94 \cdot 10^4 \cdot lbf$

$$MS_{Vert} = \left(\frac{Load_{max}}{Load_{Vert}} - 1 \right)$$

$MS_{Vert} = 3.247$

Lateral Loading Case:

- For the lateral case, in light of the fact that the container is fixed in the strongback, only a shear load on the connecting welds of two of the attachment points will be considered This load will be applied to the welds connecting the mounting plates to the stiffening rings

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$\text{weld}_{\text{eff}} := 0.3$ Weld efficiency based on AWS D1.1 (Shear load)

$$\text{Area}_{\text{weld}} := (2)\cdot(2)\cdot\left[\left(11+\frac{5}{8}\right)\cdot 1\right]\cdot\left(\text{weld}_{\text{eff}}\right)\cdot \text{in}^2$$

$$\sigma_{\text{weld}} := \frac{G_{\text{Lat}}\cdot W_c}{\text{Area}_{\text{weld}}}$$

$$\sigma_{\text{weld}} = 4.975\cdot 10^{4}\cdot\text{psi}$$

$$\text{MS}_{\text{Lat}} := \left(\frac{S_u}{\sigma_{\text{weld}}} - 1\right)$$

$$\text{MS}_{\text{Lat}} = 0.166$$

Stiffening Ring Weld Strength:

- Determine stress in stiffening ring welds.

The stiffening rings were welded to the 64" diameter pipe using a 5/16" weld on both sides of the ring as per AWS D1.1. The allowable load on the fillet welds shall be equal to the product of the weld area (based on minimum leg dimension) the allowable stress value in shear of the material being welded and a joint efficiency of 30 % of ultimate.

- Taking only the attachment point stiffening ring welds into account.

$N_{\text{weld}} := 2$ Number of welds per stiffening ring

$$\text{weld}_{\text{leg}} := \frac{5}{16}\cdot\text{in}$$

$$\text{pipe}_{\text{diam}} := 64.0\cdot\text{in}$$

$$\text{Ring}_{\text{weld}} := N_{\text{weld}}\cdot\left[\frac{\pi}{4}\cdot\left[\left[\text{pipe}_{\text{diam}} + 2\cdot\left(\text{weld}_{\text{leg}}\right)\right]^2 - \text{pipe}_{\text{diam}}^{\;2}\right]\right]$$ Stiffening ring weld

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$$End_{weld} := \left[\frac{\pi}{4}\cdot\left[\left[pipe_{diam} + 2\cdot\left(weld_{leg}\right)\right]^2 - pipe_{diam}{}^2\right]\right]$$ End-cap weld

$$weld_{eff} \equiv 0.3$$

$$Area_{Weld} := \left(weld_{eff}\right)\cdot\left[(3)\cdot Ring_{weld} + End_{weld}\right]$$

$$\sigma weld_{long} := \frac{G_{Long}\cdot W_c}{Area_{Weld}} \qquad MS_{Long} = \left(\frac{S_u}{\sigma weld_{long}} - 1\right) \qquad MS_{Long} = 4.541$$

$$\sigma weld_{lat} = \frac{G_{Lat}\cdot W_c}{Area_{Weld}} \qquad MS_{Lat} = \left(\frac{S_u}{\sigma weld_{lat}} - 1\right) \qquad MS_{Lat} = 10.081$$

$$\sigma weld_{vert} := \frac{G_{Vert}\cdot W_c}{Area_{Weld}} \qquad MS_{Vert} = \left(\frac{S_u}{\sigma weld_{vert}} - 1\right) \qquad MS_{Vert} = 26.703$$

The purpose for these above calculations is to show that the strongback attachments are able to carry portions of the tiedown load if needed.

Phase II of bearing load analysis:

- Determine bearing load capability of stiffening ring tiedown tabs

Assumptions:

- To meet the requirements of 10 CFR 71.45 (b)(1), only points at which the cables attach to the container will be analyzed using moment combinations taking in to account the weight of the strongback at its CG wise location. The pivot point will be the pivot-pins on the
- Four attachment points per side will be used [Eight cables per side in a "V" configuration as shown in figure 1 (TILT-TRAILER TIEDOWN CONFIGURATION) presented before this analysis]
- The container is fully shielded to column line 25 in reference to drawing number H-2-83734
- The container behaves as a rigid body.

- From 10 CFR 71.45 (b)(1), the attachment points on the container must be capable of withstanding w/o exceeding yield:

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- 10 X weight Longitudinal
- 5 X weight Lateral
- 2 X weight Vertical

$G_{Long} := 10 \quad G_{Lat} := 5 \quad G_{Vert} := 2$

Longitudinal Loading Case:

This load case was analyzed and it was determined that the attachment points were adequate. The load case results are presented in Phase I above.

Vertical Loading Case:

Using the free-body diagram on the next page (Section A) and implementing a summation of moments and forces, the maximum subjected force to the tiedown lugs is determined to be.

$\text{Vertload}_{max} = 34816 \cdot \text{lbf}$

$\text{Load}_{Max} = 1.164 \cdot 10^5 \cdot \text{lbf}$ Critical bearing load capability of tiedown points from above

$$MS_{vert} := \left(\frac{\text{Load}_{Max}}{\text{Vertload}_{max}} - 1 \right)$$

$MS_{vert} = 2.344$

Lateral Loading Case:

This loading case will be ignored due to two facts. The strongback connections provided on the container alone were found to be adequate in reference to withstanding the total subjected load. These results are shown in phase I of this analysis. Also, a lateral restraint/support device will be provided on the trailer coming in contact with the container at column line 24. This is shown in figure 1 (TILT-TRAILER TIEDOWN CONFIGURATION) presented before this analysis. However, the stiffening ring welds needs to be check for the possibility of failure. This verification follows.

Using a summation of moments around the strongback pivot-pin,

$$\text{Moment}_{sum} = 0 = G_{Lat} * (\text{Length}_{CGcont} * W_c + \text{Length}_{CGstrongback} * W_s) - \text{Length}_{latload} * \text{Force}_{Lat}$$

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(9) Checker DLCrow Date 7-25-94

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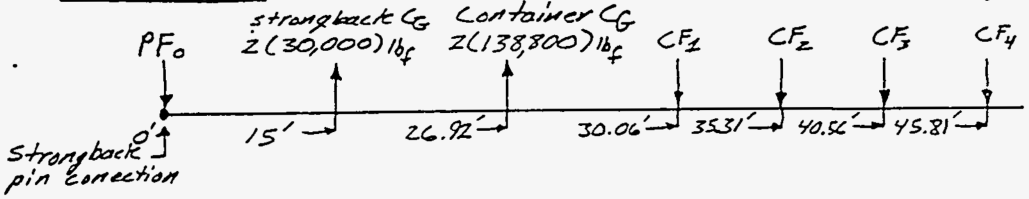
Section A - Vertical Rip-out - 2G Loading



$$\Sigma F = 0 = 2(30{,}000 + 138{,}800) - [PF_0 + CF_1 + CF_2 + CF_3 + CF_4]$$

$$\Sigma M_o = 0 = 2[(30{,}000)(15) + (138{,}800)(26.92)] - [(CF_1)(30.06) + (CF_2)(35.31) + (CF_3)(40.56) + (CF_4)(45.81)]$$

Where,

$$CF_2 = \left(\frac{30.06}{35.31}\right) CF_1 \quad , \quad CF_3 = \left(\frac{30.06}{40.56}\right) CF_1$$

$$\& \; CF_4 = \left(\frac{30.06}{45.81}\right) CF_1 \qquad PF_0 = 111{,}395 \text{ lbf}$$

$CF_1 = 69{,}631$ lbf

$CF_2 = 59{,}278$ lbf

$CF_3 = 51{,}605$ lbf

$CF_4 = 45{,}691$ lbf

- But, we have 2 attachment points on the container at $CF_\#$ locations.

$$\text{Vertload}_{max} = \left(\frac{69{,}631}{2}\right) \text{lbf} \; @ \; CF_1$$

$$\text{Vertload}_{max} = \underline{\underline{34{,}816 \text{ lbf}}}$$

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where

$G_{Lat} = 5$ Lateral G-load value based on 10 CFR 71 45 (b)(1)

$W_c = 1.388 \cdot 10^5 \cdot lbf$ Total container weight

$W_s = 3 \cdot 10^4 \cdot lbf$ Strongback weight

$Length_{CGcont} := 26.918 \cdot ft$ Distance from pivot-pin to container CG

$Length_{CGstrongback} := 15.0 \cdot ft$ Distance from pivot-pin to strongback CG

$Length_{latload} = 51.23 \cdot ft$ Distance from pivot-pin to column line 24 (where lateral load restraint/support device comes in contact with container stiffening ring

$$Force_{Lat} := \frac{G_{Lat} \cdot \left(Length_{CGcont} \cdot W_c + Length_{CGstrongback} \cdot W_s\right)}{Length_{latload}}$$

$Force_{Lat} = 4.086 \cdot 10^5 \cdot lbf$

The stiffening rings were welded to the 64" diameter pipe using a 5/16" weld on both sides of the ring as per AWS D1.1. The allowable load on the fillet welds shall be equal to the product of the weld area (based on minimum leg dimension) the allowable stress value in shear of the material being welded and a joint efficiency of 30 % of ultimate.

- Taking only the attachment point stiffening ring welds into account,

$N_{weld} = 2$ Number of welds per stiffening ring

$weld_{leg} = 0.313 \cdot in$

$pipe_{diam} = 64 \cdot in$

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$$\text{Ring}_{\text{weld}} := N_{\text{weld}} \cdot \left[\frac{\pi}{4} \cdot \left[\left[\text{pipe}_{\text{diam}} + 2 \cdot \left(\text{weld}_{\text{leg}}\right)\right]^2 - \text{pipe}_{\text{diam}}{}^2\right]\right]$$ Area of stiffening ring welds

$$\text{weld}_{\text{eff}} = 0.3$$

$$\text{Area}_{\text{Weld}} := \left(\text{weld}_{\text{eff}}\right) \cdot \text{Ring}_{\text{weld}}$$

$$\sigma_{\text{weld}} := \frac{\text{Force}_{\text{Lat}}}{\text{Area}_{\text{Weld}}}$$

$$\sigma_{\text{weld}} = 1.079 \cdot 10^4 \cdot \text{psi}$$

$$\text{MS}_{\text{Weld}} = \left(\frac{S_u}{\sigma_{\text{weld}}} - 1\right)$$

$$\text{MS}_{\text{Weld}} = 4.378$$

Cable Analysis:

- Determine the minimum load carrying capability that the cables must display

Assumptions:

- The container, trailer and strongback behave as rigid bodies.
- The pivot point will be the pivot-pins on the strongback.
- The elevational difference between the pins and the CG of the container is of no significance.
- The tiedown system must be capable of retaining the payload when subjected to a 1.5 G acceleration in the lateral, longitudinal, or vertical direction.

Longitudinal Loading Case:

- If we assume a yield strength of 108,000 psi for the AISI 4340 3 inch diameter steel strongback pivot-pins (which is highly conservative), the maximum load carrying capability (in shear) of the two pin is,

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$Acc := 1.5$	Subjected G-load
$N_{shear} := 4$	Number of shear planes
$Diam_{pin} := 3 \cdot in$	Pivot-pin Diameter
$Area_{pin} := \frac{\pi}{4} \cdot Diam_{pin}^{2}$	X-sectional area of pin
$Sy_{pin} := 108000 \cdot psi$	Yield Strength of pin
$\tau_{pin} = \frac{Sy_{pin}}{2}$	Shear capability of pin

$LOAD_{max} = N_{shear} \cdot \tau_{pin} \cdot Area_{pin}$

$LOAD_{max} = 1.527 \cdot 10^{6} \cdot lbf$

- If the pivot-pins are relied upon to restrain the load of the container and strongback, and considered as the tiedown system in the longitudinal loading direction,

$W_c = 1.388 \cdot 10^{5} \cdot lbf$	Total container weight
$W_s = 3 \cdot 10^{4} \cdot lbf$	Strongback weight

$LOAD_{lat} := Acc \cdot (W_c + W_s)$

$$MS_{pin} = \left(\frac{LOAD_{max}}{LOAD_{lat}} - 1 \right)$$

$MS_{pin} = 5.03$

- Now to check the strength of the strongback/container interface bolts to assure restraint capability.

$N_{Shear} := 4$	Number of shear planes

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$Diam_{bolt} := 2.257 \cdot in$	Minimum accountable bolt diameter for a 2 5 inch diameter bolt (From "AN INTRODUCTION TO THE DESIGN AND BEHAVIOR OF BOLTED JOINTS" - John H. Bickford)
$Area_{bolt} := \frac{\pi}{4} \cdot Diam_{bolt}^2$	X-sectional area of each bolt
$Sy_{bolt} := 58000 \cdot psi$	Yield Strength of bolts - ASTM A-449, Type1 (From ASME Section VIII, Div. 1)
$\tau_{bolt} := \frac{Sy_{bolt}}{2}$	Shear capability of each bolt

$$LOAD_{Max} = N_{Shear} \cdot \tau_{bolt} \cdot Area_{bolt}$$

$$LOAD_{Max} = 4.641 \cdot 10^5 \cdot lbf$$

$$LOAD_{Lat} := Acc \cdot \left(W_c + W_s\right)$$

$$MS_{bolt} = \left(\frac{LOAD_{Max}}{LOAD_{Lat}} - 1\right)$$

$MS_{bolt} = 0.833$ → Obviously, the pivot-pins will restrain the load

Lateral Loading Case:

The transport trailer to be used is again shown in figure 1. It has been equipped with a lateral restraint/support device which is shown supporting the container at the tractor-end of the trailer. It was specified that the trailer manufacturer must design and build this device to withstand a 150,000 lb force acting laterally. This device in conjunction with the pivot-pin platform, was meant to provide container restraint in the lateral direction.

- Keeping in mind that the pivot-pin platform must withstand a load subjected to it by a wind-loaded, unshielded 72,927 lb container (including payload), the platform structure is assumed to be adequate for providing its portion of lateral restraint.

- Now to check if the lateral restraint/support device can withstand the subjected loads.

Using a summation of moments around the strongback pivot-pin,

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$$\text{Moment}_{\text{sum}} = 0 = G_{\text{Lat}} * (\text{Length}_{\text{CGcont}} * W_c + \text{Length}_{\text{CGstrongback}} * W_s) - \text{Length}_{\text{latload}} * \text{Load}_{\text{subjected}}$$

where

$\text{Load}_{\text{capability}} := 150000 \cdot \text{lbf}$	Load capability of lateral restraint/support device
$G_{\text{Lat}} := 1.5$	Lateral G-load value
$W_c = 1.388 \cdot 10^5 \cdot \text{lbf}$	Total container weight
$W_s = 3 \cdot 10^4 \cdot \text{lbf}$	Strongback weight
$\text{Length}_{\text{CGcont}} = 26.918 \cdot \text{ft}$	Distance from pivot-pin to container CG
$\text{Length}_{\text{CGstrongback}} := 15.0 \cdot \text{ft}$	Distance from pivot-pin to strongback CG
$\text{Length}_{\text{latload}} := 51.23 \cdot \text{ft}$	Distance from pivot-pin to column line 24 (where lateral load restraint/support device comes in contact with container stiffening ring

$$\text{Load}_{\text{subjected}} := \frac{G_{\text{Lat}} \cdot (\text{Length}_{\text{CGcont}} \cdot W_c + \text{Length}_{\text{CGstrongback}} \cdot W_s)}{\text{Length}_{\text{latload}}}$$

$$\text{Load}_{\text{subjected}} = 1.226 \cdot 10^5 \cdot \text{lbf}$$

$$\text{MS}_{\text{restraint}} = \left(\frac{\text{Load}_{\text{capability}}}{\text{Load}_{\text{subjected}}} - 1 \right)$$

$$\text{MS}_{\text{restraint}} = 0.224$$

Vertical Loading Case:

Using a free-body diagram and implementing a summation of moments and forces, the maximum subjected load at a cable connection can be determined. Taking all cable angles in to consideration, this value can then be used to determine the maximum cable load. These calculations follow. (Section B)

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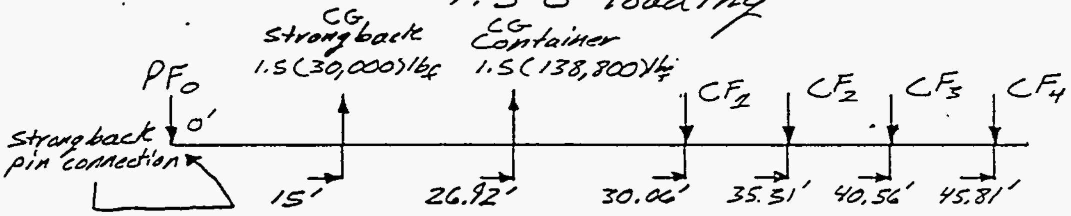
(9) Checker J.L. Crow Date 7-25-94

(10) Section B - Vertical Cable Connection Load - 1.5 G loading



$$\sum F = 0 = 1.5(30{,}000 + 138{,}800) - [PF_0 + CF_1 + CF_2 + CF_3 + CF_4]$$

$$\sum M = 0 = 1.5[(30{,}000)(15) + (138{,}800)(26.92)] - [(CF_1)(30.06) + (CF_2)(35.31) + (CF_3)(40.56) + (CF_4)(45.81)]$$

where,

$$CF_2 = \left(\frac{30.06}{35.31}\right) CF_1 \, , \quad CF_3 = \left(\frac{30.06}{40.56}\right) CF_1$$

$$+ \; CF_4 = \left(\frac{30.06}{45.81}\right) CF_1$$

$$\left\{ \begin{array}{l} CF_1 = 52{,}223 \text{ lb}_f \\ CF_2 = 44{,}459 \text{ lb}_f \\ CF_3 = 38{,}704 \text{ lb}_f \\ CF_4 = 34{,}268 \text{ lb}_f \end{array} \right. \qquad PF_0 = 83{,}546 \text{ lb}_f$$

- But, we have 2 attachment points on the container at $CF_\#$ locations and 2 cables connecting to these attachment points.

$$\text{Vertload}_{max} = \left(\frac{52{,}223}{(2)(2)}\right) \text{ lb}_f \;@\; CF_1$$

$$\text{Vertload}_{max} = \underline{\underline{13{,}056 \text{ lb}_f}}$$ load acting vertically on cables @ CF_1.

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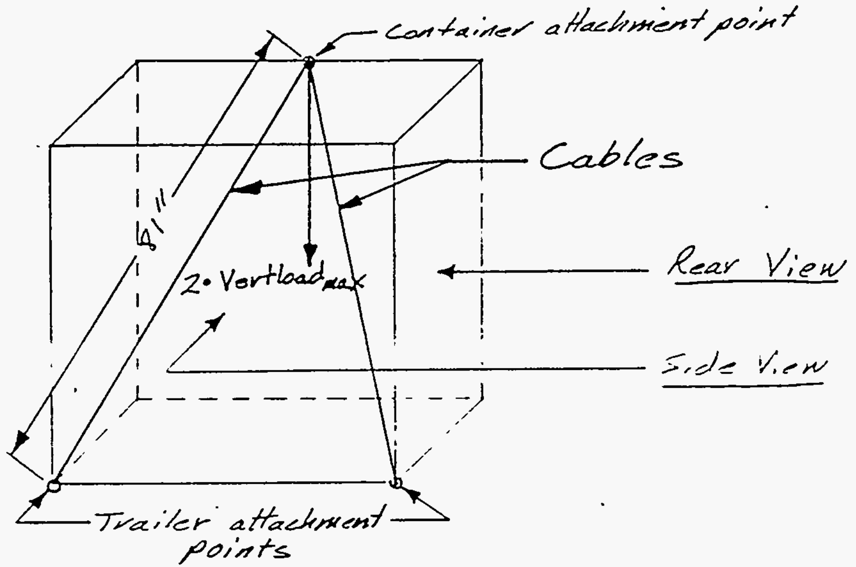
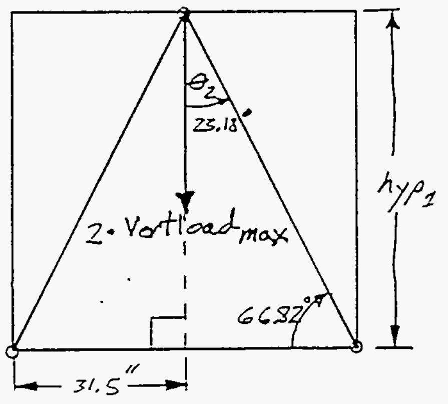
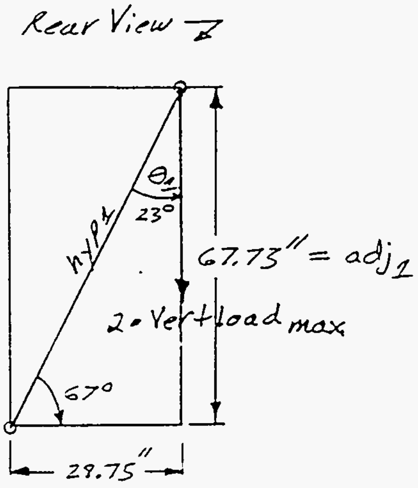
(10) Section B (Continued)

Cable Configuration







$\text{Vertload}_{max} = 13{,}056\ \text{lb}_f$ (from above)

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From Section B it is shown that,

$$adj_1 := 67.73 \cdot in$$

$$Vertload_{max} := 13056 \cdot lbf$$

$$\theta_1 := 23 \cdot deg$$

$$\theta_2 := 23.18 \cdot deg$$

$$Cable_{leg} := \frac{adj_1}{(\cos(\theta_1)) \cdot (\cos(\theta_2))}$$

each cable leg length is

$$Cable_{leg} = 80.041 \cdot in$$

and the maximum subjected cable load, that each particular cable leg must withstand, is

$$MaxLoad_{cable} := \frac{Vertload_{max}}{(\cos(\theta_1)) \cdot (\cos(\theta_2))}$$

$$MaxLoad_{cable} = 1.543 \cdot 10^4 \cdot lbf$$

All cable material and cabling apparatus must be chosen to meet or exceed this value.

101-SY CG Calculations for various shielding conditions

Analysis by: Tim Saffell
Date: July 18, 1994

Weight of Container(no shielding, no pump)

$w_{cont} := 53500 \cdot lbf$ (Weight plus 800 lbf for the additional saddle plate support)

$CG_{noshield} := 311.54 \cdot in$ (of container wo/pump from Ansys)

$w_{pump} := 19427 \cdot lbf$

$w_{pay} := w_{cont} + w_{pump}$

$w_{pay} = 7.293 \cdot 10^{4} \cdot lbf$ (no shielding)

Annulus Area for Shielding

$A_{ann} := \frac{\pi}{4} \cdot \left(68^2 - 64^2\right) \cdot in^2$ $\qquad$ $A_{ann} = 2.88 \cdot ft^2$

Lengths for shielding

$l_{14} := 27 \cdot ft + 5.25 \cdot in - 12 \cdot 1.5 \cdot in - 1.75 \cdot in$ $\qquad$ $l_{14} = 25.792 \cdot ft$

$l_{full} := 52 \cdot ft + .75 \cdot in - 23 \cdot 1.5 \cdot in - 1.75 \cdot in$ $\qquad$ $l_{full} = 49.042 \cdot ft$

Mass of shielding(lead shielding, density=0.270 lbf/in^3) $\qquad$ $\rho := 0.27 \frac{lbf}{in^3}$

$W_{14} := l_{14} \cdot A_{ann} \cdot \rho$ $\qquad$ $W_{14} = 3.465 \cdot 10^{4} \cdot lbf$

$W_{full} := l_{full} \cdot A_{ann} \cdot \rho$ $\qquad$ $W_{full} = 6.589 \cdot 10^{4} \cdot lbf$

Moments

$$M_{tot14} := w_{cont} \cdot CG_{noshield} + W_{14} \cdot \frac{l_{14} + 12 \cdot 1.5 \cdot in + 1.75 \cdot in}{2} + w_{pump} \cdot 390.75 \cdot in$$

$$M_{totfull} := w_{cont} \cdot CG_{noshield} + W_{full} \cdot \frac{l_{full} + 23 \cdot 1.5 \cdot in + 1.75 \cdot in}{2} + w_{pump} \cdot 390.75 \cdot in$$

Total Weight

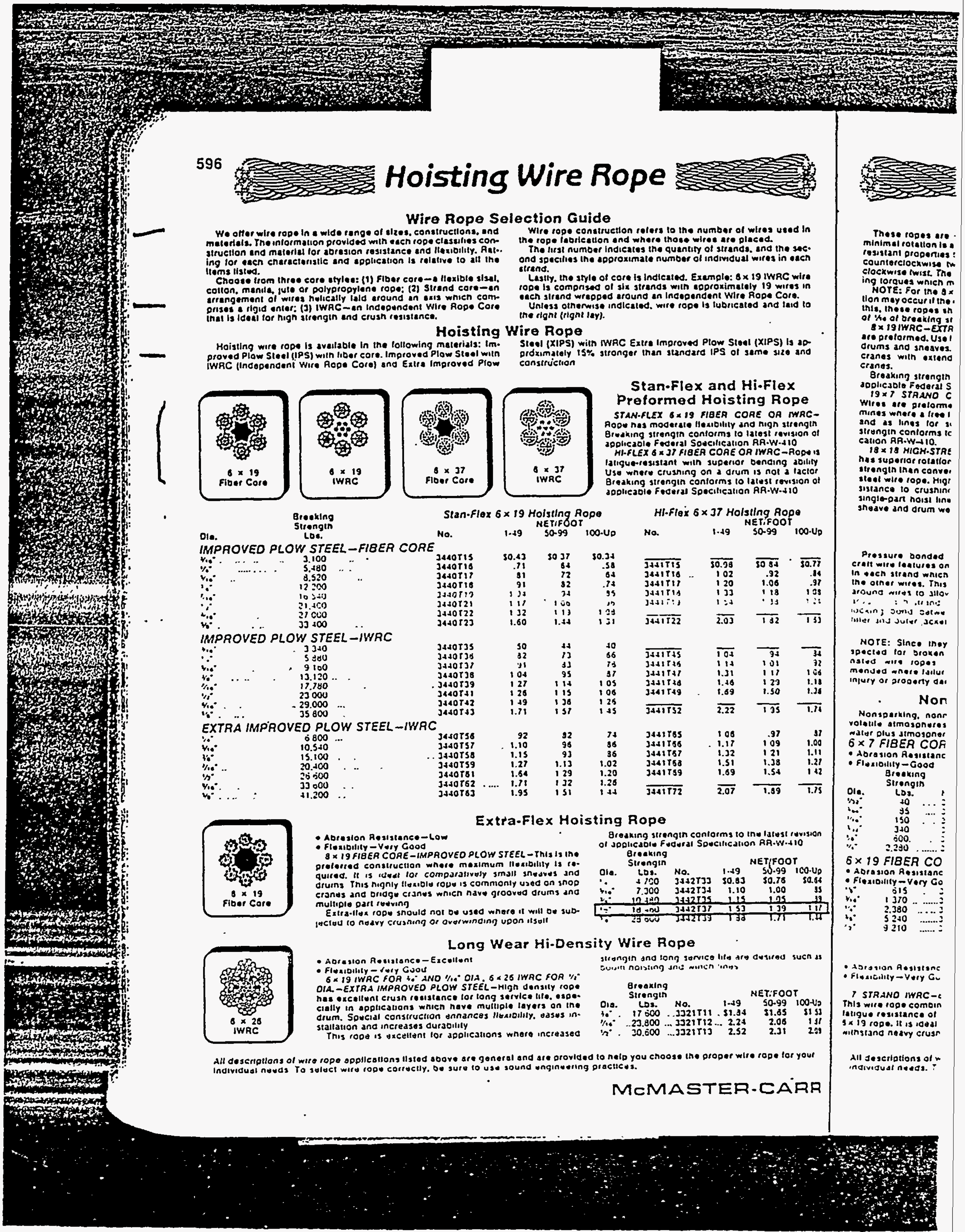
$w_{14} := w_{cont} + W_{14} + w_{pump}$ $\qquad$ $w_{14} = 1.076 \cdot 10^{5} \cdot lbf$

$w_{full} := w_{cont} + W_{full} + w_{pump}$ $\qquad$ $w_{full} = 1.388 \cdot 10^{5} \cdot lbf$

CGs

$CG_{14} := \frac{M_{tot14}}{w_{14}}$ $\qquad$ $CG_{14} = 23.21 \cdot ft$

$CG_{full} := \frac{M_{totfull}}{w_{full}}$ $\qquad$ $CG_{full} = 26.918 \cdot ft$



Hoisting Wire Rope

Wire Rope Selection Guide

We offer wire rope in a wide range of sizes, constructions, and materials. The information provided with each rope classifies construction and material for abrasion resistance and flexibility. Rating for each characteristic and application is relative to all the items listed.

Choose from three core styles: (1) Fiber core—a flexible sisal, cotton, manila, jute or polypropylene rope; (2) Strand core—an arrangement of wires helically laid around an axis which comprises a rigid enter; (3) IWRC—an Independent Wire Rope Core that is ideal for high strength and crush resistance.

Wire rope construction refers to the number of wires used in the rope fabrication and where those wires are placed.

The first number indicates the quantity of strands, and the second specifies the approximate number of individual wires in each strand.

Lastly, the style of core is indicated. Example: 6 × 19 IWRC wire rope is comprised of six strands with approximately 19 wires in each strand wrapped around an Independent Wire Rope Core.

Unless otherwise indicated, wire rope is lubricated and laid to the *right (right lay)*.

Hoisting Wire Rope

Hoisting wire rope is available in the following materials: Improved Plow Steel (IPS) with fiber core. Improved Plow Steel with IWRC (Independent Wire Rope Core) and Extra Improved Plow Steel (XIPS) with IWRC Extra Improved Plow Steel (XIPS) is approximately 15% stronger than standard IPS of same size and construction

Stan-Flex and Hi-Flex Preformed Hoisting Rope

STAN-FLEX 6 × 19 FIBER CORE OR IWRC—Rope has moderate flexibility and high strength. Breaking strength conforms to latest revision of applicable Federal Specification RR-W-410

HI-FLEX 6 × 37 FIBER CORE OR IWRC—Rope is fatigue-resistant with superior bending ability. Use where crushing on a drum is not a factor. Breaking strength conforms to latest revision of applicable Federal Specification RR-W-410

Dia.	Breaking Strength Lbs.	*Stan-Flex 6 × 19 Hoisting Rope* No.	NET/FOOT 1-49	50-99	100-Up	*Hi-Flex 6 × 37 Hoisting Rope* No.	NET/FOOT 1-49	50-99	100-Up
IMPROVED PLOW STEEL—FIBER CORE									
3/16"	3,100	3440T15	$0.43	$0.37	$0.34	—	—	—	—
1/4"	5,480	3440T16	.71	.64	.58	3441T15	$0.98	$0.84	$0.77
5/16"	8,520	3440T17	.81	.72	.64	3441T16	1.02	.92	.84
3/8"	12,200	3440T18	.91	.82	.74	3441T17	1.20	1.06	.97
7/16"	16,540	3440T19	1.04	.94	.85	3441T18	1.33	1.18	1.08
1/2"	21,400	3440T21	1.17	1.06	.95	3441T19	1.54	1.38	1.24
9/16"	27,000	3440T22	1.32	1.13	1.08	—	—	—	—
5/8"	33,400	3440T23	1.60	1.44	1.31	3441T22	2.03	1.82	1.63
IMPROVED PLOW STEEL—IWRC									
3/16"	3,340	3440T35	.50	.44	.40	—	—	—	—
1/4"	5,880	3440T36	.82	.73	.66	3441T45	1.04	.94	.84
5/16"	9,160	3440T37	.91	.83	.75	3441T46	1.14	1.01	.92
3/8"	13,120	3440T38	1.04	.95	.87	3441T47	1.31	1.17	1.06
7/16"	17,780	3440T39	1.27	1.14	1.05	3441T48	1.46	1.29	1.18
1/2"	23,000	3440T41	1.28	1.15	1.06	3441T49	1.69	1.50	1.38
9/16"	29,000	3440T42	1.49	1.36	1.26	—	—	—	—
5/8"	35,800	3440T43	1.71	1.57	1.45	3441T52	2.22	1.95	1.74
EXTRA IMPROVED PLOW STEEL—IWRC									
1/4"	6,800	3440T56	.92	.82	.74	3441T65	1.08	.97	.87
5/16"	10,540	3440T57	1.10	.96	.86	3441T66	1.17	1.09	1.00
3/8"	15,100	3440T58	1.15	.93	.86	3441T67	1.32	1.21	1.11
7/16"	20,400	3440T59	1.27	1.13	1.02	3441T68	1.51	1.38	1.27
1/2"	26,600	3440T61	1.64	1.29	1.20	3441T69	1.69	1.54	1.42
9/16"	33,600	3440T62	1.71	1.32	1.26	—	—	—	—
5/8"	41,200	3440T63	1.95	1.51	1.44	3441T72	2.07	1.89	1.75

Extra-Flex Hoisting Rope

- Abrasion Resistance—Low
- Flexibility—Very Good

8 × 19 FIBER CORE—IMPROVED PLOW STEEL—This is the preferred construction where maximum flexibility is required. It is *ideal for comparatively small sheaves* and drums. This highly flexible rope is commonly used on shop cranes and bridge cranes which have grooved drums and multiple part reeving

Extra-flex rope should not be used where it will be subjected to heavy crushing or overwinding upon itself

Breaking strength conforms to the latest revision of applicable Federal Specification RR-W-410

Dia.	Breaking Strength Lbs.	No.	NET/FOOT 1-49	50-99	100-Up
1/4"	4,700	3442T33	$0.83	$0.76	$0.64
5/16"	7,300	3442T34	1.10	1.00	.85
3/8"	10,380	3442T35	1.15	1.05	.93
1/2"	18,400	3442T37	1.53	1.39	1.17
5/8"	28,600	3442T39	1.88	1.71	1.44

Long Wear Hi-Density Wire Rope

- Abrasion Resistance—Excellent
- Flexibility—Very Good

6 × 19 IWRC FOR 3/8" AND 7/16" DIA., 6 × 26 IWRC FOR 1/2" DIA.—EXTRA IMPROVED PLOW STEEL—High density rope has excellent crush resistance for long service life, especially in applications which have multiple layers on the drum. Special construction enhances flexibility, eases installation and increases durability

This rope is excellent for applications where increased strength and long service life are desired such as boom hoisting and winch lines

Dia.	Breaking Strength Lbs.	No.	NET/FOOT 1-49	50-99	100-Up
3/8"	17,600	3321T11	$1.84	$1.65	$1.53
7/16"	23,800	3321T12	2.24	2.06	1.87
1/2"	30,600	3321T13	2.52	2.31	2.09

All descriptions of wire rope applications listed above are general and are provided to help you choose the proper wire rope for your individual needs. To select wire rope correctly, be sure to use sound engineering practices.

McMASTER-CARR

These ropes are
minimal rotation is a
resistant properties
counterclockwise tw
clockwise twist. The
ing torques which m
NOTE: For the 8 ×
tion may occur if the
this, these ropes sh
of ⅕ of breaking st
8 × 19 IWRC—EXTR
are preformed. Use
drums and sheaves.
cranes with extend
cranes.
Breaking strength
applicable Federal S
19 × 7 STRAND C
Wires are preforme
mines where a free
and as lines for s
strength conforms to
cation RR-W-410.
18 × 18 HIGH-STRE
has superior rotatio
strength than conve
steel wire rope. High
sistance to crushin
single-part hoist line
sheave and drum we

Pressure bonded
craft wire features on
in each strand which
the other wires. This
around wires to allov
locking bond betwe
filler and outer jacket

NOTE: Since they
spected for broken
nated wire ropes
mended where failur
injury or property da

Non

Nonsparking, nonr
volatile atmospheres
water plus atmospher
6 × 7 FIBER COR
- Abrasion Resistanc
- Flexibility—Good

Dia.	Breaking Strength Lbs.
1/32"	40
3/64"	85
1/16"	150
3/32"	340
1/8"	600
1/4"	2,280

6 × 19 FIBER CO
- Abrasion Resistanc
- Flexibility—Very Go

1/8"	615
3/16"	1,370
1/4"	2,380
3/8"	5,240
1/2"	9,210

- Abrasion Resistanc
- Flexibility—Very Go

7 STRAND IWRC—
This wire rope combin
fatigue resistance of
6 × 19 rope. It is ideal
withstand heavy crush

All descriptions of w
individual needs. T

Anchor & Twisted Shackles

Shackle Information

Shackles are excellent for attaching and suspending rope and chain rigging lines. Only shackle pins that fit properly should be used. Substitutes are not intended to withstand the bending that is normally applied to the pin

Shackles should never be pulled at an angle—this greatly reduces the capacity. Instead, fittings and hoist lines should be centered on the pin with suitable washers or spacers.

Choose from three shackle styles:

ANCHOR—Open throat design allows free line movement without undue wear. Wide bow allows ample clearance for thimbles and turnbuckles.

CHAIN—Also known as O-Style. Flat-throat design restricts movement of rigging chain lines. This reduces chain wear and prevents kinking and fouling.

TWISTED—Spiral design accommodates two-plane movement.

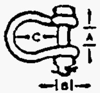
Shackles come with one of three pin styles:

SCREW PINS—Shackles with captive screw pins need no special tools to assemble. Slip a screwdriver blade or hand punch through pin eye and tighten. CAUTION: Screw pin shackles should not be used where load shifting might unscrew the shackle pin.

BOLT PINS—Also known as safety shackles. Bolt pins with threaded ends accommodate nuts as well as locking cotter pins.

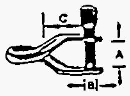
LOOSE PINS—Unthreaded pins are locked with cotter pins except Type 305 stainless steel.

Anchor Shackle with Screw Pin



Anchor Shackle with Bolt Pin

Anchor Shackle with Loose Pin



Twisted Shackle with Screw Pin

GALVANIZED ALLOY STEEL—Great for marine and heavy-lift construction operations. Bodies and pins are forged, high-strength alloy steel with a galvanized finish. Shackles meet physical requirements of MIL-S-24214 (SHIPS), Type 1, Class 2 or Class 3, Grade A or B.

GALVANIZED STEEL—Heat-treated, tempered, forged steel shackles have a galvanized finish and alloy steel pins. They meet the requirements of federal specifications RR-C-271b, MIL-S-24214 Grade A, and ASTM A153.

STAINLESS STEEL—Excellent for chemical, marine, and other industries where corrosive conditions exist. Anchor shackles are forged of Type 316 or Type 305 Cu stainless steel. Twisted shackles are forged of Type 304 stainless steel.

					SCREW PINS				BOLT PINS				LOOSE PINS			
Stock Dia.	A	B	C	Std. Pkg. Qty.	Work Load Limit, Lbs.★	No.	NET EACH Brkn Pkg	NET EACH Full Pkg.	Work Load Limit, Lbs.★	No.	NET EACH Brkn Pkg	NET EACH Full Pkg.	Work Load Limit, Lbs.★	No.	NET EACH Brkn Pkg	NET EACH Full Pkg.
GALVANIZED ALLOY STEEL ANCHOR SHACKLE																
3/8"	21/32"	7/16"	1 7/16"	10	4 000	3663T51•■	$3.53	$3.11	—	—	—	—	—	—	—	—
1/2"	13/16"	5/8"	1 15/16"	10	6 500	3663T42■	5.33	4.70	6 500	8966T51◆	$12.28	$10.78	—	—	—	—
5/8"	1 1/16"	3/4"	2 1/2"	10	10,000	3663T43■	7.56	6.70	10 000	8966T52◆	17.28	15.33	—	—	—	—
3/4"	1 1/4"	7/8"	3"	5	14 000	3663T44■	10.38	9.22	14 000	8966T53◆	25.90	22.72	—	—	—	—
7/8"	1 7/16"	1"	3 1/4"	5	19 000	3663T45■	11.06	12.45	19 000	8966T54◆	27.28	24.71	—	—	—	—
1"	1 11/16"	1 1/8"	3 3/4"	5	25 000	3663T46■	19.37	17.33	[illegible]	8966T55◆	36.37	33.01	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	5	[illegible]	[illegible]	[illegible]	[illegible]	42 000	8966T56◆	55.12	50.39	—	—	—	—
1 1/4"	2 1/8"	1 3/8"	5 1/4"	5	50 000	3663T48■	75.39	66.52	60 000	8966T57◆	95.51	87.33	—	—	—	—
1 1/2"	2 5/8"	2"	7"	5	—	—	—	—	80 000	8966T12◆	161.78	144.62	—	—	—	—
2"	3 1/4"	2 1/4"	7 3/4"	5	86 000	3663T49■	178.31	157.33	100 000	8966T14◆	224.10	200.69	—	—	—	—
• Grade A only ■ Class 2 ◆ Class 3																
GALVANIZED STEEL ANCHOR SHACKLE																
3/16"	3/8"	1/4"	7/8"	25	666	3558T44	$2.22	$2.00	—	—	—	—	—	—	—	—
1/4"	15/32"	5/16"	1 1/8"	25	1 000	3558T45	2.34	1.97	—	—	—	—	1 000	3559T44	$2.22	$1.89
5/16"	17/32"	3/8"	1 7/32"	25	1 500	3558T46	3.03	2.57	—	—	—	—	1 500	3559T45	2.94	2.52
3/8"	21/32"	7/16"	1 7/16"	25	2 000	3558T47	3.28	2.77	—	—	—	—	2 000	3559T46	3.17	2.65
7/16"	23/32"	1/2"	1 11/16"	25	3 000	3558T48	3.67	3.11	—	—	—	—	3 000	3559T47	3.36	3.03
1/2"	13/16"	5/8"	1 7/8"	25	4 000	3558T49	4.40	3.76	4 000	3555T51	$8.04	$6.89	4 000	3559T48	4.38	3.72
5/8"	1 1/16"	3/4"	2 3/8"	25	6 500	3558T51	7.62	6.43	6 500	3555T52	11.57	9.84	6 500	3559T49	7.78	6.51
3/4"	1 1/4"	7/8"	2 13/16"	10	9 500	3558T52	11.00	9.36	9 500	3555T53	16.66	13.97	9 500	3559T51	10.76	9.16
7/8"	1 7/16"	1"	3 5/16"	10	13 000	3558T53	15.42	13.13	13 000	3555T54	23.09	19.50	13 000	3559T52	16.68	13.65
1"	1 11/16"	1 1/8"	3 3/4"	10	17 000	3558T54	20.26	17.36	17 000	3555T55	29.01	25.48	17 000	3559T53	19.09	18.23
1 1/8"	1 13/16"	1 1/4"	4 1/4"	10	19,000	3558T55	28.95	24.54	19 000	3555T56	41.07	34.22	19 000	3559T54	24.67	20.71
1 1/4"	2 1/32"	1 3/8"	4 11/16"	10	24 000	3558T56	38.43	32.94	24 000	3555T57	60.33	51.30	24 000	3559T55	38.43	36.85
1 3/8"	2 1/4"	1 1/2"	5 1/4"	10	27 000	3558T57	57.11	50.47	28 000	3555T58	81.02	69.45	28,000	3559T56	55.27	47.23
1 1/2"	2 3/8"	1 5/8"	5 3/4"	5	34 000	3558T58	76.95	65.40	34 000	3555T59	92.17	82.57	34 000	3559T57	68.17	58.25
1 3/4"	2 7/8"	2"	7"	5	50.000	3558T59	125.15	106.26	50 000	3555T61	149.59	134.01	50 000	3559T58	96.47	85.21
2"	3 1/4"	2 1/4"	7 3/4"	5	70 000	3558T61	153.00	137.70	70 000	3555T62	194.95	174.65	70,000	3559T59	140.27	120.92
TYPE 316 STAINLESS STEEL ANCHOR SHACKLE																
1/4"	1/2"	5/16"	1 1/8"	10	450	3583T34	$15.73	$13.78	450	3860T51	$27.91	$24.63	450	3859T34	$19.19	$16.68
5/16"	9/16"	3/8"	1 1/4"	10	650	3583T36	17.45	15.62	650	3860T52	30.15	26.61	650	3859T35	21.13	18.33
3/8"	11/16"	7/16"	1 7/16"	10	1 000	3583T38	18.82	16.85	1 000	3860T53	34.20	30.14	1 000	3859T36	23.97	20.75
7/16"	3/4"	1/2"	1 5/8"	10	1 375	3583T53	26.73	23.64	1 375	3860T64	36.87	34.13	1,375	3859T57	27.36	25.33
1/2"	13/16"	5/8"	1 15/16"	10	1,990	3583T39	27.94	24.83	1,990	3860T55	43.25	38.23	1,990	3859T38	33.15	28.23
5/8"	1 1/16"	3/4"	2 7/16"	5	3,050	3583T41	48.36	43.71	3 050	3860T56	74.36	64.63	3,050	3859T39	50.65	43.94
3/4"	1 1/4"	7/8"	3"	5	4 475	3583T43	66.64	60.10	4,475	3860T57	96.73	84.02	4,475	3859T41	78.16	67.59
7/8"	1 7/16"	1"	3 1/4"	5	6,000	3583T45	82.25	75.92	6 000	3860T58	125.27	108.84	6 000	3859T42	101.69	88.32
1"	1 11/16"	1 1/8"	3 3/4"	5	7 950	3583T47	95.36	86.37	7,950	3860T59	165.72	144.07	7,950	3859T43	111.77	97.04
TYPE 305 STAINLESS STEEL ANCHOR SHACKLE																
3/32"	3/16"	3/16"	11/16"	10	397	3797T41	$8.01	$6.41	—	—	—	—	353	3797T31•	$5.58	$4.46
1/8"	13/32"	1/4"	29/32"	10	662	3797T42	9.47	7.58	—	—	—	—	529	3797T32•	6.28	5.02
1/4"	15/32"	5/32"	1 1/16"	10	926	3797T43	12.56	10.04	—	—	—	—	706	3797T33•	8.06	6.44
5/16"	5/8"	11/32"	1 15/32"	10	1 532	3797T44	18.54	14.83	—	—	—	—	1 323	3797T34•	12.71	10.17
13/32"	25/32"	7/16"	1 13/16"	10	2 293	3797T45	29.68	23.74	—	—	—	—	2 294	3797T35•	21.02	15.31
• Loose screw on pin type without cotter pin																
TYPE 304 STAINLESS STEEL TWISTED SHACKLE																
5/32"	3/8"	5/32"	1 1/8"	10	660	33845T91	$4.60	$4.09	—	—	—	—	—	—	—	—
3/16"	3/8"	3/16"	1 7/16"	10	880	33845T92	3.83	3.40	—	—	—	—	—	—	—	—
1/4"	9/16"	1/4"	1 17/32"	10	1 540	33845T93	5.59	4.97	—	—	—	—	—	—	—	—
5/16"	5/8"	5/16"	2"	10	2 970	33845T94	10.16	9.03	—	—	—	—	—	—	—	—
3/8"	21/32"	3/8"	2 3/32"	10	4 350	33845T95	19.22	17.08	—	—	—	—	—	—	—	—
1/2"	3/4"	1/2"	2 17/32"	10	9 250	33845T96	22.07	19.61	—	—	—	—	—	—	—	—

★ WARNING: DO NOT EXCEED WORK LOAD LIMITS

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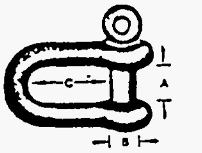
Ste



Chain Shackle with Screw Pin

GALVANIZED STEEL CHAIN SHACK
that has a galvanized finish, with alloy st
and tempered. Shackles meet requirer
tions RR-C-271b, MIL-S-24214 Grade A

Stock Dia.	A	B	C	Pkg Qty
GALVANIZED STEEL				
1/4"	15/32"	5/16"	7/8"	25
5/16"	17/32"	3/8"	1"	25
3/8"	21/32"	7/16"	1 1/4"	25
7/16"	23/32"	1/2"	1 1/2"	25
1/2"	13/16"	5/8"	1 5/8"	2
5/8"	1 1/16"	3/4"	2"	2
3/4"	1 1/4"	7/8"	2 3/8"	1
7/8"	1 7/16"	1"	2 13/16"	1
1"	1 11/16"	1 1/8"	3 1/4"	1
1 1/8"	1 13/16"	1 1/4"	3 1/2"	1
1 1/4"	2"	1 3/8"	3 11/16"	1
1 3/8"	2 1/4"	1 1/2"	4 1/2"	1
1 1/2"	2 3/8"	1 5/8"	5"	
1 3/4"	2 7/8"	2"	5 7/8"	
2"	[illegible]	[illegible]	[illegible]	

— WIT

Stock Dia.	A	B	C
TYPE 305 STAINLESS ST			
3/32"	3/16"	3/32"	1/2"
3/16"	13/32"	3/16"	5/8"
1/4"	15/32"	1/4"	29/32"
5/16"	5/8"	5/16"	1 1/32"
13/32"	25/32"	13/32"	1 5/16"
15/32"	7/16"	15/32"	1 17/32"
TYPE 305 STAINLESS ST			
3/32"	3/16"	3/32"	1 7/32"
3/16"	13/32"	3/16"	1 17/32"
1/4"	15/32"	1/4"	1 13/16"
5/16"	5/8"	5/16"	2 7/16"

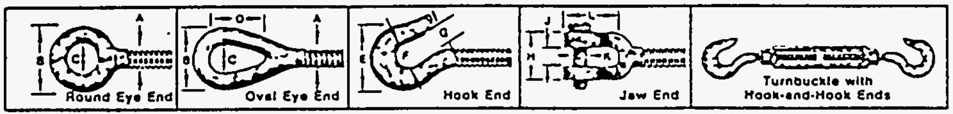
Stock Dia.	A
TYPE 305 STAINLESS ST	
3/16"	1/2"
1/4"	5/8"
5/16"	27/32"

Forged S

Easy-to-grip, tee-handle pins are
held fast by hairpin locks. Perfec
for hitching and towing that require
rapid hookup and release. Forged
from high-strength carbon steel
Pins are heat treated and zin
plated. Color is orange

The extra width you need for w
Clevis features a bolt-style pin that
alloy steel with a zinc chromate fin
Units meet military specificatio
load limit is the load the clevis ca
nent deformation. Do not exceed

Turnbuckles



Drop-Forged Galvanized-Steel Turnbuckles

Made of hot-dipped galvanized steel with strong, seamless construction. Jaw-style end fittings are pin-and-cotter-key style. On hook-and-eye style, do not exceed work load limit shown for hook end. Take-up is the total amount of adjustment. Meet federal specification FF-T-791b, Type I, Form I with Unified National Coarse threads.

End fittings are available separately. Please order No. 3004ST333 and specify end fitting style (eye, hook, or jaw), bolt diameter, take-up length, and right- or left-hand thread direction.

Jam nuts are available too; order No. 3004ST555 and please specify thread size and right- or left-hand thread direction.

TURNBUCKLE END SPECIFICATIONS

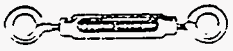
Bolt Dia.	EYE END				HOOK END				JAW END				
A	B	C	D	WLL•	E	F	G	WLL•	H	J	K	L	WLL•
¼"	1	½"	—	500	1⅛"	5/16"	9/32"	400	13/16"	3/8"	¼"	1 5/32"	500
5/16"	1¼"	5/8"	—	800	1 7/16"	½"	½"	700	29/32"	13/32"	¼"	1 7/16"	800
3/8"	1½"	¾"	—	1 200	1⅝"	½"	½"	900	1 1/16"	½"	5/16"	1 13/32"	1 200
½"	2"	1"	—	2 200	2⅛"	5/8"	11/16"	1300	1¼"	5/8"	7/16"	1 23/32"	2,200
5/8"	2 5/16"	1¼"	—	3 500	2½"	25/32"	27/32"	2200	1⅝"	¾"	½"	2 3/16"	3,500
¾"	2¾"	1½"	—	5 200	2⅞"	1⅛"	29/32"	2700	1 13/16"	15/16"	5/8"	2 11/32"	5 200
7/8"	3¼"	1¾"	—	7 000	2 29/32"	1 3/16"	1 1/16"	3200	2⅛"	1 3/32"	¾"	2⅞"	7 000
1"	3½"	2"	—	10 000	3½"	1⅜"	1¼"	4200	2 5/16"	1 1/16"	7/8"	3 15/32"	10 000
1⅛"	3 11/16"	1 7/16"	3"	10 000	4¼"	1⅜"	1¼"	5000	2⅝"	1 3/16"	7/8"	3¾"	10 000
1¼"	4 1/16"	1 11/16"	3 9/16"	15 200	5⅛"	1¾"	1½"	5000	[illegible]	[illegible]	[illegible]	[illegible]	15 200
1½"	4⅝"	2⅛"	4 5/16"	21 400	5¾"	2⅛"	1⅞"	7500	3 11/32"	2¼"	1⅜"	5 3/16"	21 400
1¾"	5⅝"	2⅜"	4⅝"	28 000	—	—	—	—	4 11/32"	2½"	1⅞"	5 21/32"	28 000
2"	6 5/16"	2 11/16"	5¼"	37 000	—	—	—	—	5⅜"	2⅝"	2"	7 9/32"	37 000

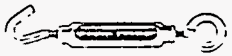
• Work load limit lbs ◦24" take-up size only

Thread Size	Take-Up	Approx. Closed Length	EYE & EYE, HOOK & EYE, HOOK & HOOK—SPECIFY STYLE No.	NET EACH 1-5	NET EACH 6-Up	JAW & EYE No.	NET EACH 1-5	NET EACH 6-Up	JAW & JAW No.	NET EACH 1-5	NET EACH 6-Up	BODY ONLY Lg.	No.	NET EACH 1-5	NET EACH 6-Up
¼"-20	4"	8¼"	2999T11	$7.57	$6.71	3000T51	$9.25	$8.21	3001T51	$10.83	$9.51	4 7/16"	3004ST41	$4.05	$3.55
5/16"-18	4½"	9½"	2999T12	9.25	8.22	3000T52	10.79	9.53	3001T52	12.38	10.99	5⅝"	3004ST42	5.21	4.55
3/8"-16	6"	12"	2999T13	10.28	9.14	3000T53	12.16	10.81	3001T53	13.84	12.30	7⅛"	3004ST43	5.42	4.73
½"-13	6"	14¼"	2999T14	11.71	10.40	3000T54	13.13	11.65	3001T54	14.79	13.12	7½"	3004ST44	5.83	5.09
½"-13	9"	17¼"	2999T15	15.34	13.63	3000T55	17.25	15.28	3001T55	19.29	17.15	10½"	3004ST45	8.75	7.64
½"-13	12"	20¼"	2999T16	17.46	15.56	3000T56	19.65	17.51	3001T56	21.73	19.32	13½"	3004ST46	10.10	8.82
5/8"-11	6"	15¾"	2999T17	$14.60	$13.18	3000T57	$17.50	$15.59	3001T57	$20.71	$18.41	7⅛"	3004ST47	$7.29	$6.36
5/8"-11	9"	18¾"	2999T18	20.95	18.59	3000T58	23.21	20.59	3001T58	26.68	23.72	10⅝"	3004ST48	10.40	9.07
5/8"-11	12"	21¾"	2999T19	22.75	20.18	3000T59	25.23	23.31	3001T59	30.16	26.81	13⅝"	3004ST49	11.94	10.42
¾"-10	6"	16⅝"	2999T21	25.87	23.04	3000T61	26.79	23.81	3001T61	28.28	25.14	8⅛"	3004ST51	9.69	8.45
¾"-10	9"	19⅝"	2999T22	29.84	26.52	3000T62	30.95	27.39	3001T62	31.82	28.22	11⅝"	3004ST52	11.67	10.18
¾"-10	12"	22⅝"	2999T23	30.45	25.17	3000T63	35.97	32.03	3001T63	39.38	35.08	14⅝"	3004ST53	16.92	14.75
¾"-10	18"	28⅝"	2999T24	39.76	36.70	3000T64	44.08	39.26	3001T64	47.98	42.64	20⅝"	3004ST54	25.31	22.09
7/8"-9	6"	19½"	2999T48	$38.70	$34.47	3000T32	$43.75	$38.99	3001T32	$48.40	$43.02	8⅝"	3004ST28	$12.33	$10.76
7/8"-9	12"	24½"	2999T25	42.23	37.61	3000T65	46.38	41.31	3001T65	51.79	46.02	14⅝"	3004ST55	18.85	16.45
7/8"-9	18"	30½"	2999T26	54.35	48.49	3000T66	61.43	54.71	3001T66	62.90	55.93	20⅝"	3004ST56	36.88	32.18
1"-8	6"	21 9/16"	2999T27	51.14	45.17	3000T67	51.80	45.95	3001T67	52.48	46.74	9"	3004ST57	15.21	13.27
1"-8	12"	25½"	2999T28	52.72	46.76	3000T68	54.45	48.49	3001T68	58.67	52.25	15"	3004ST58	22.71	19.82
1"-8	18"	31½"	2999T29	67.94	60.62	3000T69	76.37	68.01	3001T69	83.83	74.66	21"	3004ST59	36.88	32.18
1"-8	24"	39 11/16"	2999T31	96.83	87.75	3000T71	103.29	91.63	3001T71	107.07	95.54	27"	3004ST61	52.04	45.42
1¼"-7	12"	30 11/16"	2999T32	$85.38	$77.37	3000T72	$108.00	$97.55	3001T72	$115.36	$102.93	15⅝"	3004ST62	$37.02	$32.31
1¼"-7	18"	36 11/16"	2999T33	106.79	96.78	3000T73	131.63	118.89	3001T73	142.91	127.52	21⅝"	3004ST63	58.27	50.85
1¼"-7	24"	42 11/16"	2999T34	132.21	119.81	3000T74	166.05	149.98	3001T74	191.79	171.14	27⅝"	3004ST64	81.33	70.98
1½"-6	18"	39"	2999T35	155.86	141.25	3000T75	187.07	168.97	3001T75	192.72	171.97	21¾"	3004ST65	79.65	69.51
1½"-6	24"	45"	2999T36	194.59	176.34	3000T76	231.43	209.03	3001T76	259.76	231.79	27¾"	3004ST66	106.54	92.98
1¾"-5	18"	42⅛"	2999T77 ♦	$264.41	$239.63	3000T77	$335.57	$303.10	3001T77	$388.24	$346.43	22⅝"	3004ST67	$102.33	$89.75
1¾"-5	24"	48⅛"	2999T78 ♦	353.79	320.63	3000T78	371.37	330.75	3001T78	446.90	398.77	28⅝"	3004ST68	205.21	179.09
2"-4½	24"	55 1/16"	2999T79 ♦	516.72	468.25	3000T79	557.05	496.13	3001T79	603.31	538.34	29"	3004ST69	209.25	192.52

♦ Eye & Eye style available only

Compact Turnbuckles


Eye and Eye


Hook and Eye

Zinc and Steel

The open body is cast-zinc alloy with zinc-plated steel end fittings. The end fittings are available in eye-and-eye, hook-and-eye, and hook-and-hook styles. Please specify end style when ordering. Package quantity is 10.

Thread Dia.	Thread Size	Take-Up	Closed Length	End Fitting Hook/Eye ID	No.	NET EACH Bkn Pkg	NET EACH Full Pkg
5/32"	8-32	1¼"	3½"	5/16"	3010T2	$0.69	$0.62
3/16"	10-24	1⅝"	4½"	3/8"	3010T3	.78	.70
¼"	¼"-20	2⅛"	5⅞"	7/16"	3010T4	1.29	1.13
5/16"	5/16"-18	2¾"	6⅜"	9/16"	3010T5	1.88	1.63
3/8"	3/8"-16	3⅛"	7⅛"	5/8"	3010T6	2.12	1.86

Aluminum and Stainless Steel

The open body is cast aluminum, with Type 305 stainless steel fittings for extra corrosion resistance. End fittings are available in eye-and-eye and hook-and-eye styles; please specify end style when ordering. Package quantity is 10.

Thread Dia.	Thread Size	Take-Up	Closed Length	End Fitting Hook/Eye ID	No.	NET EACH Bkn. Pkg	NET EACH Full Pkg
3/16"	10-24	1"	4¼"	½"	3009ST1	$2.02	$1.35
¼"	¼"-20	1¼"	5¼"	9/16"	3009ST2	3.18	2.98
3/8"	3/8"-16	2½"	8½"	1"	3009ST3	5.94	5.43

NEVER EXCEED WORK LOAD LIMITS

McMASTER-CARR

7.0 THERMAL EVALUATION

7.1 INTRODUCTION

Internal heat generation of the contents shall not prevent the package from maintaining its integrity during the specified lifetime of the waste package. Evaluation of heat transfer data will include information or assumptions as required to determine if the package is capable of passively transferring the heat load to the environment or if specific cooling devices are necessary.

7.2 THERMAL SOURCE SPECIFICATION

From a waste generation study (WHC 1994a), Table B2-1 in Part B, Section 2.1, provides the activity of radionuclides estimated to be attached to the mixer pump based on an estimated 3 mm thick film of tank waste material attached to specific areas of the pump and liquid holdup of 68 gallons inside the pump. This is considered the "worst case" waste that will be attached to and contained inside the pump and will be used for calculation of the internal thermal heat load (decay heat) for the shipping container.

7.3 SUMMARY OF THERMAL PROPERTIES OF MATERIALS

The absorption factors for yellow and white paint which may be used to coat the shipping container are 0.8 and 0.15, respectively.

7.4 THERMAL EVALUATION FOR NORMAL TRANSFER CONDITIONS

7.4.1 Conditions to be Evaluated

The thermal evaluation for the HMMP Package is provided in Part B, Section 7.6. The evaluation examined the thermal characteristics of loading and storing of the HMMP in the shipping container. Steady state and transient temperatures were calculated for combined heat sources from internal decay heat and external solar heating using the TAP-A computer code (WHC-SD-FF-ER-050). Thermal predictions were obtained for a relatively high absorption factor that is typical for standard yellow paint used for shipping containers. Additional predictions were obtained using a relatively low absorption factor that is available in a white paint. Figure 1 in Part B, Section 7.6, describes the pump and container arrangement.

Three conditions were examined for a yellow painted container with decay heat and solar insolation, a yellow painted container with no decay heat and only solar insolation, and a white painted container with both solar insolation and decay heat.

7.4.2 Acceptance Criteria

The maximum allowable temperature for the shipping container surface is 180 °F.

7.4.3 Thermal Model

The thermal model of the pump and shipping container is a one dimensional cylindrical radial section using dimensions taken at the maximum pump diameter at the volute region. Figure 2 in Part B, Section 7.6, illustrates the model. Combined decay heat from 68 gallons of retained tank waste and surface film was assumed as uniformly distributed length wise and amounted to 6.4×10^{-4} W/in (0.88 W). This was converted to a volumetric value in the model. Solar heat is applied to the external surface of the model in the form of tabulated surface heat fluxes for specific times in a 24 hour period. Values of hourly solar insolation were obtained from WHC-SD-TP-RPT-005 as recommended for the Hanford Site (Table 1 in Part B, Section 7.6). Thermal radiation and convection heat losses are calculated relative to the standard Hanford ambient temperature 24 hour variation.

7.4.4 Thermal Analysis

Transient temperatures were calculated for the pump and shipping container which has two heat sources:

1. Daily variations of ambient temperature and solar insolation.

2. Constant decay heat from 68 gallons of tank waste that is retained inside the pump and a film on the external surfaces of the pump.

The distribution of decay heat from 68 gallons of retained tank waste and film was coordinated with the shielding evaluation and is the same basis used in this thermal evaluation, namely, the combined decay heat source is uniformly distributed along the length which amounts to a relatively small value of 6.4×10^{-4} W/in (0.88 W). Table 2 in Part B, Section 7.6, shows these calculations.

Three conditions were examined as follows:

1. A yellow painted container (0.8 absorption factor) with decay heat and solar insolation.

2. A yellow painted container with no decay heat and only solar insolation.

3. A white painted container (0.15 absorption factor) with solar insolation and decay heat.

7.5 THERMAL EVALUATIONS AND CONCLUSIONS

The maximum allowable temperature for the container external surface is 180 °F. Peak temperatures for a yellow painted container with solar insolation and decay heating are predicted to exceed the allowable limit of 180 °F as shown in Figure 3 (Part B, Section 7.6). Removal of the uniformly distributed decay heat has no discernable influence on reducing the peak temperature for the yellow painted container as shown in Figure 4 (Part B, Section 7.6). Solar heating is the dominant heat source. Reducing solar absorption can significantly reduce peak temperatures. Figure 5 (Part B, Section 7.6) shows results of transient predictions for a white painted container having an absorption factor of 0.15 with peak temperatures under 125 °F. The internal temperature of the pump is seen to rise slowly, but is not expected to exceed approximately 105 °F.

Per Drawing H-2-83734, the shipping container external surface is painted with a top coat of Ameron 450 HS White. The peak temperature of this external surface related to solar heating will not exceed 125 °F, hence the temperature limit of 180 °F is satisfied. Pressure increase inside the shipping container will be insignificant with the internal temperature not exceeding 105 °F.

7.6 THERMAL ANALYSIS

Westinghouse Hanford Company

Internal Memo

From: TWRS Thermal Hydraulics 7E870-JCG-94-057
Phone: 376-6588 HO-33
Date: July 12, 1994
Subject: THERMAL EVALUATION SY101 HYDROGEN MITIGATION MIXER PUMP (HMMP) CONTAINER

To: R. F. Carlstrom G2-02

cc: J. G. Fadeff HO-33*
J. J. Irwin HO-33*
T. B. McCall HO-33
JCG File/LB
*w/o attachment

Attached is a description of the thermal evaluation of a proposed shipping container for the SY101 Hydrogen Mitigation Mixer Pump (HMMP). The pump is 60 feet long, has a maximum diameter of 53 inches, and weighs about 20,000 pounds. The container design is 65 feet long and uses concentric cylinders to form an annulus for shielding material (lead balls). The outer diameter of the carbon steel container is 6 feet. When the pump is removed from SY101 it retains about 68 gallons of radioactive liquid in addition to an external covering of film. These relate to a linear decay heat value of 3.3×10^{-3} watts/in for a total of 0.88 watts.

The container will have two sources of heat, namely, decay heat and solar heat. For this container solar heating dominates temperatures. The evaluation includes temperature predictions for high solar absorption that is common with standard yellow paint and significantly lower absorptions by using a white painted exterior.

All results and related information have been stored in the Task Record THA-94-012.

J.C. Guzek

J. C. Guzek, Fellow Engineer
TWRS Thermal Hydraulics

skw

Attachment

T.B. McCall

CONCURRENCE: ____________________
T. B. McCall, Manager
TWRS Thermal Hydraulics

THERMAL EVALUATION SY101 HYDROGEN MITIGATION MIXER PUMP (HMMP) SHIPPING CONTAINER

J C Guzek

Prepared by: ________________________________
J. C. Guzek, Fellow Engineer
TWRS Thermal Hydraulics

J. J. Irwin

Reviewed by: ________________________________
J. J. Irwin, Principal Engineer
TWRS Thermal Hydraulics

FIGURES

Figure 1. SY101 Mixer Pump (HMMP) Storage Container.
Figure 2. TAP-A Thermal Model.
Figure 3. HMMP Container Solar and Internal Decay Heat.
Figure 4. HMMP Container Solar and No Internal Heat.
Figure 5. HMMP Container Decay and Solar Heat - White Paint.

TABLES

Table 1. Solar Insolation for An Average July Day at Hanford Site.
Table 2. HMMP Container Decay Heat Calculation

THERMAL EVALUATION SY101 HYDROGEN MITIGATION MIXER PUMP (HMMP) SHIPPING CONTAINER

SCOPE This evaluation examined the thermal characteristics of loading and storage of the SY101 HMMP in a container. Steady state and transient temperatures were calculated for combined heat sources from internal decay heat and external solar heating using the TAP-A computer code (Reference 1). Thermal predictions were obtained for a relatively high absorption factor of 0.8 that is typical of the standard yellow paint generally used for shipping containers. Additional predictions were obtained using a relatively low absorption factor of 0.15 that is available in a white paint. Figure 1 describes the HMMP and container arrangement.

MODEL The thermal model of the Pump/Container is a one dimensional cylindrical radial section using dimensions taken at the maximum pump diameter location at the volute region. Figure 2 illustrates the model. Combined decay heat from 68 gal of retained tank liquid and surface film was assumed as uniformly distributed length wise and amounted to 3.3×10^{-3} W/in. This was converted to a volumetric value in the model. Solar heat is applied to the external surface of the model in the form of tabulated surface heat fluxes for specific times in a 24 hour period. Values of hourly solar insolation were obtained from Reference 2 as recommended for the Hanford site (Table 1). Thermal radiation and convection heat losses are calculated relative to the standard Hanford ambient temperature 24-hour variation (See Table 1).

METHOD Transient temperatures were calculated for the pump-container configuration which has two heat sources: a) daily variations of ambient temperature and solar insolation; b) constant decay heat from 68 gal of tank fluid that is retained in the pump a film on the external surfaces of the pump.

The distribution of decay heat from 68 gal of retained tank fluid and film was coordinated with the shielding evaluation and is the same basis used in this thermal evaluation, namely, the combined decay heat source is uniformly distributed along the length which amounts to a relatively small value of 3.3×10^{-3} watts/inch. Table 2 shows these calculations.

Three conditions were examined as follows: 1) a yellow painted container (0.8 absorption factor) with decay heat and solar heat, 2) a yellow painted container with no decay heat and only insolation, and 3) a white painted container (0.15 absorption factor) with both solar and decay heat.

RESULTS The maximum allowable temperature for the container external surface is 180 °F. Peak temperatures for a yellow painted container with solar and decay heating are predicted to exceed the allowable of 180 °F as shown in Figure 3. Removal of the uniformly distributed decay heat has no discernable influence on reducing peak temperature for the yellow painted container as shown in Figure 4. Solar heating is the dominant heat source. Therefore, reducing solar absorption can significantly reduce peak temperatures. Figure 5 shows results of transient predictions for a white painted container having an absorption factor of 0.15 with peak temperatures under 125 °F. The internal temperature of the pump is seen to rise slowly, but is not expected to exceed approximately 105 ° F.

REFERENCES

1. WHC-SD-FF-ER-050, *TAP-A Code Notebook*, 1990.

2. WHC-SD-50-RPT-005, *Thermal Analysis Methods for Safety Analysis Reports for Packaging*, 1993, Westinghouse Hanford Company, Richland, Washington.

Figure 1. SY101 Mixer Pump (HMMP) Storage Container.

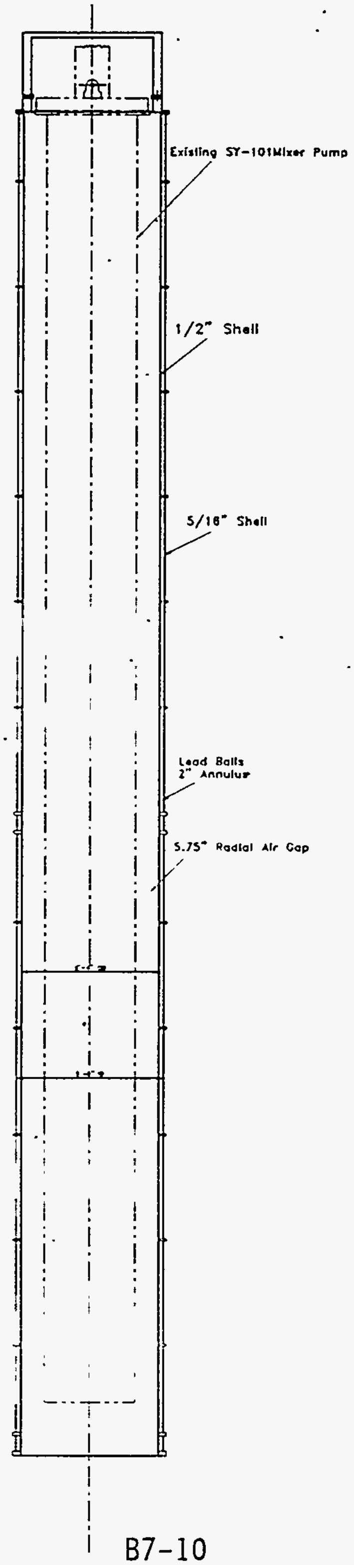


Figure 2. TAP-A Thermal Model.

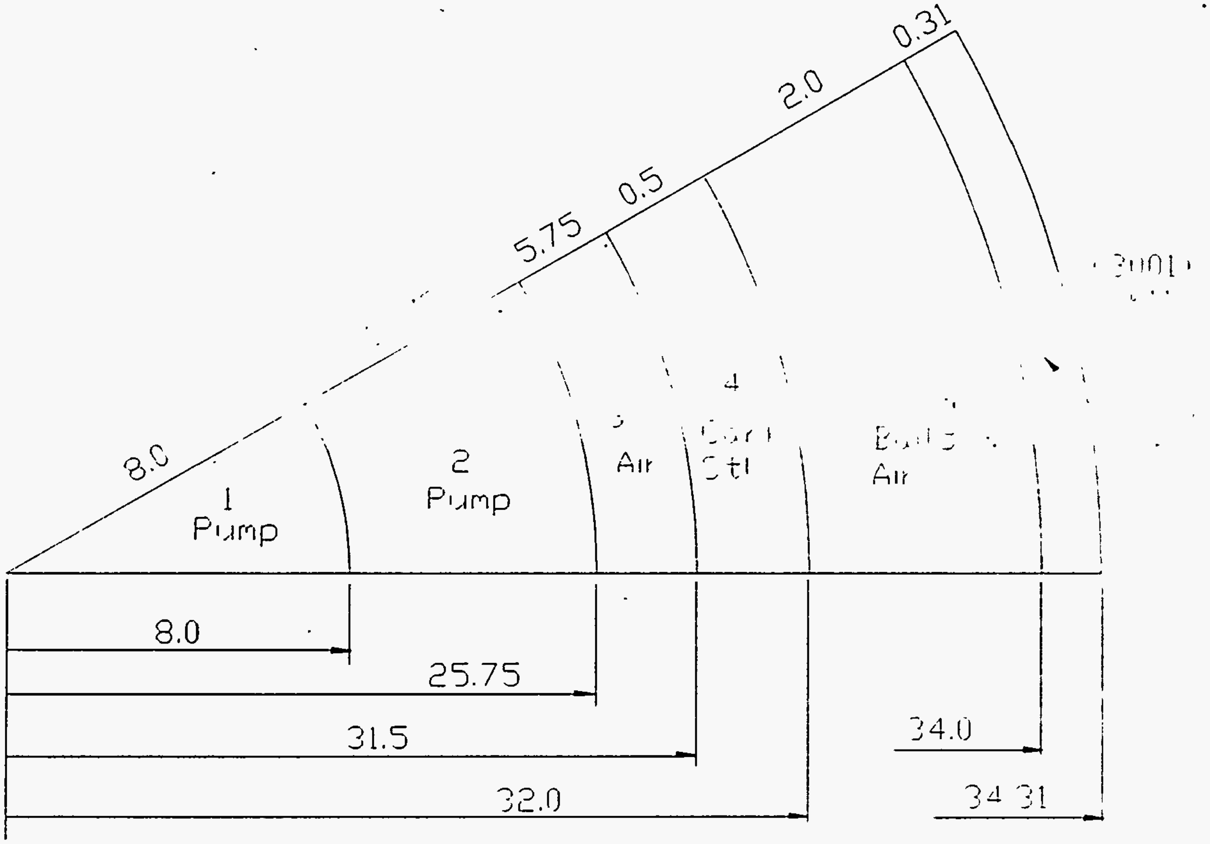


Figure 3. HMMP Container Solar and Internal Decay Heat.

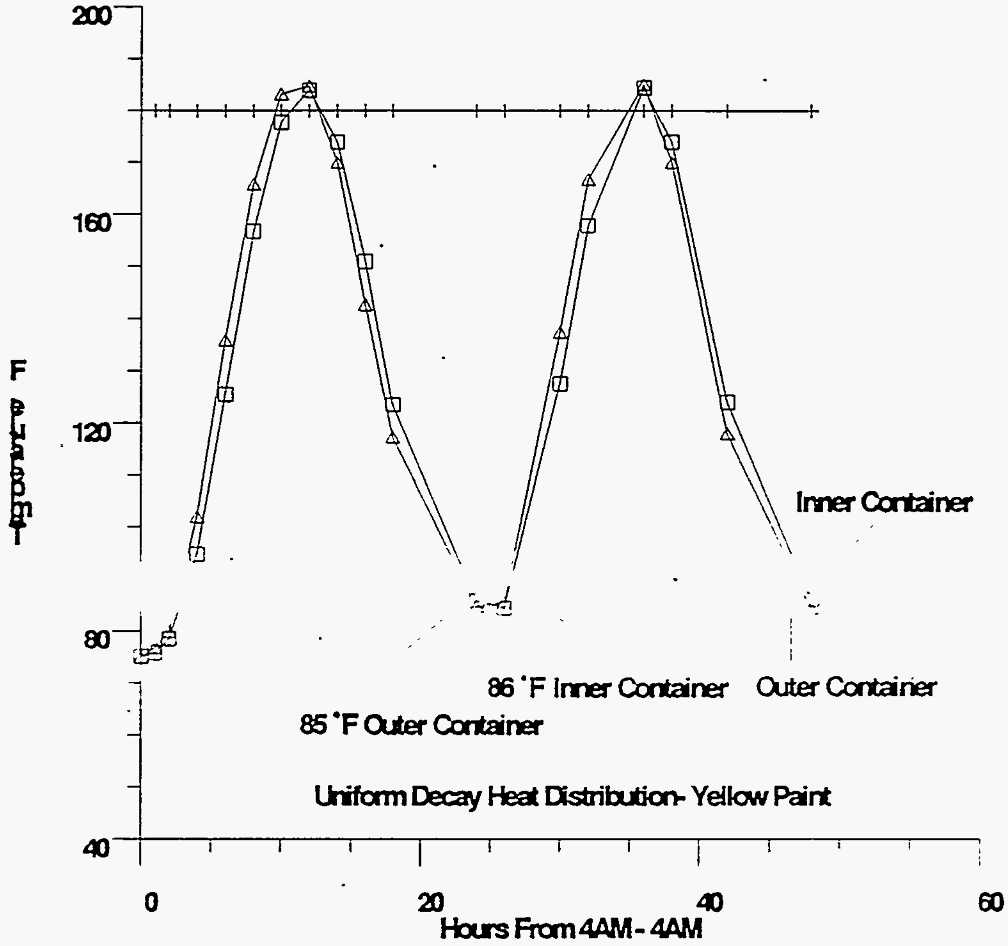


Figure 4. HMMP Container Solar No Internal Heat.

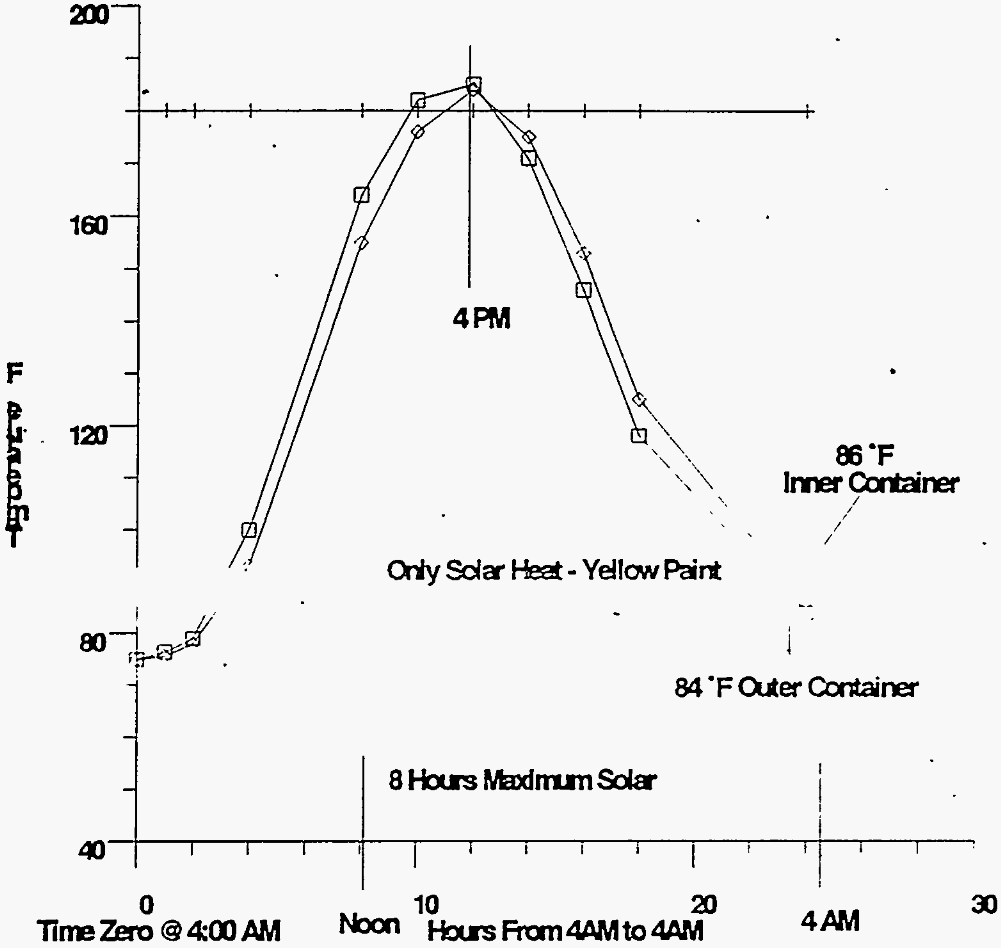


Figure 5. HMMP Container Decay Heat - White Paint.

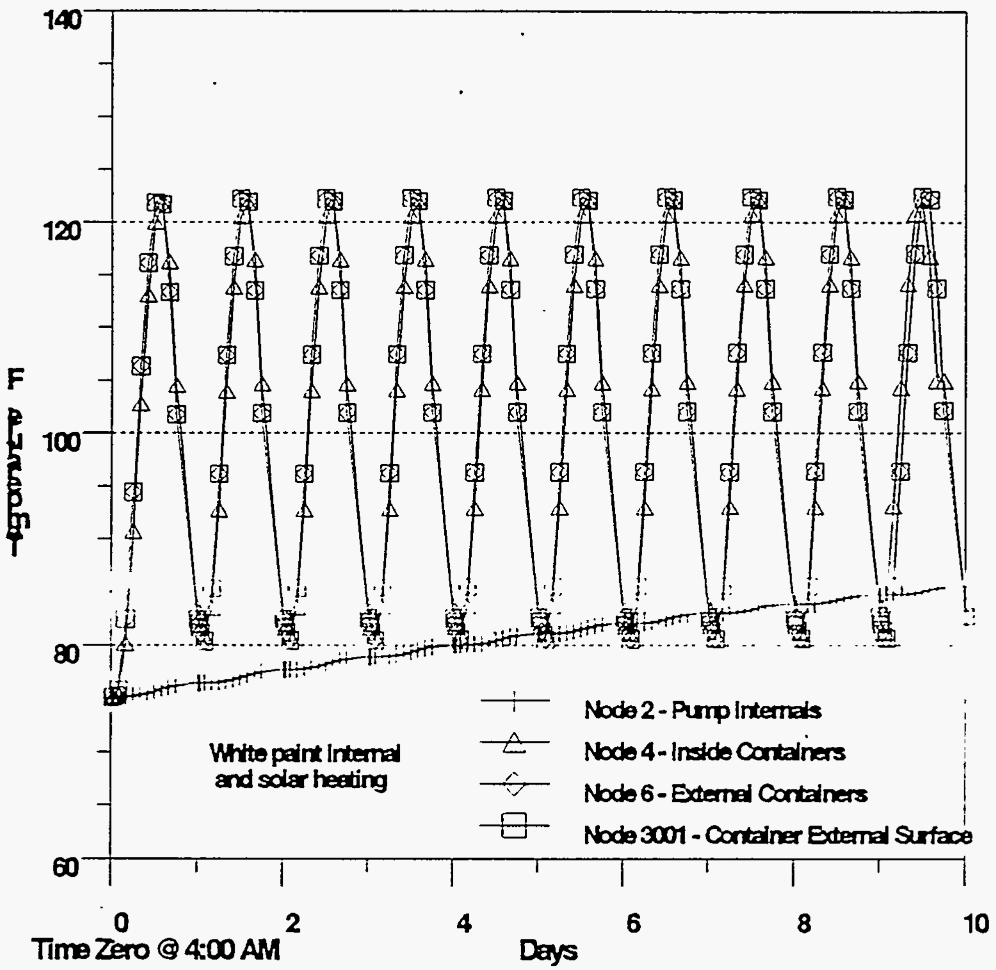


Table 1. Solar Insolation for an Average July Day at Hanford Site.

	WHC-1992b[a]		10CFR71[b]		COSINE		ASHRAE OFF-SITE[c]	
Hour-PST	Langleys[d]	Btu/ft^2	Langleys	Btu/ft^2	Langleys	Btu/ft^2	Langleys	Btu/ft^2
12-01 am	0	0	0	0	0	0	0	0
01-02 am	0	0	0	0	0	0	0	0
02-03 am	0	0	0	0	0	0	0	0
03-04 am	0	0	0	0	0	0	0	0
04-05 am	2.5	9.2	3.1	11.4	13.6	50.1	0	0
05-06 am	9.8	36.1	12.1	44.7	26.8	98.8	0	0
06-07 am	22.1	81.5	27.3	100.7	39.0	143.8	18.3	67.3
07-08 am	36.6	134.9	45.2	166.8	49.9	184.0	42.3	156.0
08-09 am	49.9	184.0	61.7	227.5	59.2	218.3	63.9	235.5
09-10 am	60.7	223.8	75.0	276.7	66.4	244.8	81.5	300.4
10-11 am	68.3	251.8	84.4	311.3	71.3	262.9	93.9	346.0
11-12 am	72.1	265.8	89.1	328.6	73.8	272.1	100.4	370.0
12-01 pm	71.9	265.1	88.9	327.7	73.8	272.1	100.4	370.0
01-02 pm	67.8	250.0	83.8	309.0	71.3	262.9	93.9	346.0
02-03 pm	60.5	223.1	74.8	275.8	66.4	244.8	81.5	300.4
03-04 pm	49.9	184.0	61.7	227.5	59.2	218.3	63.9	235.5
04-05 pm	37.2	137.2	46.0	169.6	49.9	184.0	42.3	156.0
05-06 pm	23.6	87.0	29.2	107.6	39.0	143.8	18.3	67.3
06-07 pm	11.3	41.7	14.0	51.5	26.8	98.8	0	0
07-08 pm	2.9	10.7	3.6	13.2	13.6	50.1	0	0
08-09 pm	0	0	0	0	0	0	0	0
09-10 pm	0	0	0	0	0	0	0	0
10-11 pm	0	0	0	0	0	0	0	0
11-12 pm	0	0	0	0	0	0	0	0
SUM	647.1	2386.	800.0	2950.	800.	2950.	800.	2950.

a) Recommended for Hanford Site.
b) Hanford Site Insolation Normalized to 10CFR71 Requirements.
c) Recommended off-site case, meets 10CFR71 Requirements.
d) A Langley is defined as 1 gram calorie per square centimeter.

Table 2. HMMP Container Decay Heat.

Tank Fluid Retained in Pump @ 68 gal x 3785 = 2.57 x 10^5 cm^3
Tank Fluid Film Pump Surfaces (0-1016 cm) = 4.8 x 10^4 cm^3
Tank Fluid Density = 1.74 gm/cm^3
Volume of Fluid per unit length (2.57 x 10^5 cm^3/652 cm) = 395 cm^3/cm
Fluid Mass per unit length = [(395 cm^3/cm)x((1.74 gm/cm^3)]
= 687 gm/cm-length
Surface Film mass per unit length = [(4.8 x 10^4/1016)] = 47. 2 cm^3/cm
Film Mass per unit length = [(47.2 cm^3/cm)x(1.74 gm/cm^3)]
= 82.2 gm/cm-length
Fluid and Film Mass = [82.2 + 687] = 769 gm/cm-length
Tank Fluid Activitiy @ 360 x 10^{-6} Ci/gm
Decay Heat @ 4.72 x 10^{-3} watts/Ci
Decay Heat per Unit Length:
(769 gm/cm-length) x (360 x $^{-6}$ Ci/gm) x (4.7 x 10^{-3} watts/Ci)
= 1.3 x 10^{-3} watts/cm-length x 2.54 cm/in
= 3.3 x 10^{-3} watts/in-length
Total Decay Heat = 0.88 watts

8.0 GAS GENERATION EVALUATION

8.1 GENERAL INFORMATION

Packages of radioactive waste with the potential for gas generation or with the potential to reach explosive concentrations of hydrogen and oxygen or other explosive gases may require vents or catalyst packs to deplete free oxygen and prevent explosive concentrations. A gas generation study (Part B, Section 8.3) was completed to determine the estimated extent of hydrogen gas or other explosive gas build-up in the HMMP Package. Based on results of the study, vents or other methods were evaluated to ensure that estimated gas build-up will not result in unsafe conditions. The study also identified the estimated pressure build-up and thermal loading of the HMMP Package due to waste contents.

8.2 GAS GENERATION EVALUATION AND CONCLUSIONS

Results of a gas generation study indicated that hydrogen gas buildup will exceed the U.S. Nuclear Regulatory Commission (NRC) limit of 2½% (NRC 1992) for transportation within 13.2 years and the Westinghouse Hanford Company (WHC) limit of 5% within 26.3 years (WHC 1993). To assure that hydrogen build-up will not exceed the acceptable limits during the 20 year service life of the package, the primary containment barrier of the package is vented. The study also indicated that the estimated maximum internal pressure build-up in the package at the 5% hydrogen level would be 0.77 psi. Considering this low rate (0.77 psi) of pressure build-up combined with the requirement that the package be vented and the high packaging design pressure ratings, extensive pressure leak testing analysis is not required for the package described in this SEP.

Relating to a postulated accident scenario during the pump lifting operation (Benegas 1994), release of liquid from the pump legs could interact with impact blocks inside the pump which contain a crushed material (aluminum compounds). Contact of liquid with the crushed material may cause hydrogen generation within the flexible bag. Due to the physical location and makeup of the pump and shipping container, the designed and planned use of the shipping container, and the worst case projected waste filled pump scenario, the potential of waste contacting the aluminum crushed material was deemed extremely unlikely. This scenario was not considered in the gas generation analysis.

8.3 HYDROGEN GAS GENERATION ANALYSIS

ENGINEERING ANALYSIS

Building: 1100/MO-404 Rev.: ______ Page: 1 of 2
Subject: Gas Generation for HMMP
Originator: J. R. Green JR Green Date: 6/3/94
Checker: J.E. Mercado J.E. Mercado Date: 6/6/94

Subject: Determination of hydrogen gas generation and pressure buildup in packaging containing a pump removed from Tank 101-SY. In addition estimate the thermal output of the defined source terms.

References:
(1) GEND-041, "A Calculation Technique to Predict Combustible Gas Generation in Sealed Radioactive Waste Containers," May 1986

(2) WHC-SD-TP-PDC-019, "Packaging Design Criteria Transfer and Disposal of Hydrogen Mitigation Mixer Pump," Rev. 0, January 1994.

Determination:

The methodolgy described in Reference 1 was used to perform the analysis for packaging containing pumps removed from Tank 101-SY. The Lotus 1-2-3® spreadsheed provided with Reference 1 was used for the analysis. This spreadsheet has been approved by the U.S. Nuclear Regulatory Commission (NRC) for use in the determination of hydrogen generation in low-level waste.

The following table contains data used for input to the spreadsheet.

Input:

Pump Assembly Dimensions	47 ft long
	53 in. diameter
Package Dimensions (Interior)	62 ft long
	63.25 in. diameter
Est. Package Volume	647.2 ft^3
Est. Container Void Volume	632.75 ft^3
Waste Weight	1569 lb
Waste Volume	14.45
Waste Density	108.6 lb/ft^3

The following table contains the results obtained from spreadsheet calculations.

ENGINEERING ANALYSIS

Building: 1100/MO-404 Rev.: Page: 2 of 2
Subject: Gas Generation for HMMP
Originator: J. R. Green JR Green Date: 6/5/94
Checker: J. C. Mercado J. C. Mercado Date: 6/6/94

Results:

Initial Gas Generation Rate	5.503 cc/h
Gas Generation Rate at 5% Hydrogen Concentration	4.095 cc/h
Days (yrs) to 5% Concentration	9587 (26.27)
Pressure at 5% Concentration	0.77 psi
Max Decay Heat Watts (BTU/h)	1.441 (4.92)

See spreadsheets and data library attached.

PROGRAM to CLASSIFY RADIOACTIVE WASTE				
CONTAINERS for TRANSPORTATION and DISPOSAL		FILE REF:		
CP Deltete ..Analytical Resources, Inc., 2/85 & 6/90				
(Modified for DOE Radionuclides and Thermal Wattage..		DATE:	5/23/94	
RP Genoa/KJ Field..Westinghouse-Hanford Co....6/88)				
		BY:	JRG	6/3/94
Originally Published by the Electric Power Research				
Institute in NP-4938 and NP-4757		CHECKED:		6/6/94
*** WASTE GENERAL INFORMATION ***				
Enter waste description	>			
	>			
	>			
Enter waste form ("Special" or "Normal")	>	normal	>> Reqd input for DOT calculations	
Enter physical form ("Solid", "Liquid" or "Gas")	>	liquid	>> Reqd input for DOT calculations	
Is waste Activated Metal ? ("Yes", or "No")	>	no	>> Reqd input for 10CFR61 calculations	
Enter container type (1=55 gal. drum, 2=4x4 liner	>	4	>> Reqd input for H2 calculations	
3=5x5 liner, 4=6x6 liner)				
Is container a vented HIC ? ("Yes", or "No")	>	no	*Note: For a vented HIC, assume	
			"Date sealed" is date shipped in Cask	
Enter date of curie calculations	>	05/23/94		
Enter date last sealed*	>	05/23/94	>>	
Enter date to be shipped	>	05/24/94	>> Must be later than Ci calcs	
Enter date of shipment receipt	>	05/24/94		
CALCULATED Decay before sealing (years)	=	0.00	Days=	0
CALCULATED Decay before shipment (years)	=	0.00	Days=	1
CALCULATED Duration package is sealed (years)	=	0.00	Days=	1
Enter package interior volume	>	647.2	Ft3	
Enter waste volume	>	14.5	Ft3	
CALCULATED Container void volume		632.8	Ft3	
Enter estimated waste void volume	>		Ft3	
** OR **				
Enter waste true density (vendor data)	>	108.6	Lbs/Ft3	
CALCULATED Waste void fraction	=	0.000		
CALCULATED Waste void volume	=	0.00	Ft3	
CALCULATED Package interior volume	=	1.833E+07	cc	
CALCULATED Waste volume	=	4.092E+05	cc	
CALCULATED Total void volume	=	1.792E+07	cc	
Enter waste weight	>	1569	Lbs	
CALCULATED Weight	=	7.123E+05	gms	
CALCULATED Waste bulk density	=	1.7409	gms/cc	
Enter G-H2 (molecules/100 ev)	>	0.50		
OR				
Enter volume cation resin (cu ft)	>			
Enter volume anion resin (cu ft)	>			
Enter volume mix bed resin (cu ft)	>			
Enter volume other resin (cu ft)	>			
Enter G-H2 of other resin	>			
CALCULATED G-H2 for waste	=	0.00		
*** CALCULATED RESULTS ***				
H2 Generation Summary				
Total Integrated Dose	=	1.591E+04	Rads	
H2 Volume	=	1.321E+02	cm3	
H2 Concentration	=	0.00	%	
H2 Generation Rate	=	5.503E+00	cc/hr	
Pressure Buildup Rate	=	1.084E-04	psi/day	
Pressure (seal to ship)	=	0.00	psi	

Enter Measured H2 Concentration (if known)----------	>	0.00	%	
Ratio Measured to Calculated H2 Concentrations	=	0.00		
Activity Summary @ Shipment:				
Total Activity*	=	2.891E+02	Ci (*Excludes Daughters	
Specific Activity, Total*	=	0.706	mCi/cc with T 1/2 < 10 days)	
Specific Activity*, T 1/2 < 5 Years	—	6.649E+02	µCi/cc	
T 1/2 > 5 Years	—	7.065E+02	µCi/cc >> Verify Disposal License	
Decay Heat @ Shipment:				
Decay Heat @ Shipment	=	1.441	Watts	
or		4.920	BTU/hr	
Fissile Material:				
Fissile Material (49 CFR 173 & 10 CFR 71)	—	1.926	gms	
Other DOE Fissile Material (DOE 5480.1A)		38.551	gms >> Isotope list is incomplete	
Special Nuclear Material:				
Special Nuclear Material (SNM)	—	1.935	gms	
Other DOE Accountable Material (DOE 5633.3)	—	38.602	gms >> Isotope list is incomplete	
Transuranic:				
Specific Activity, Transuranic	—	312.256	nCi/gms >>Potential GTCC	
10 CFR 61.55 Classification:		Unity Fraction		Classification
Table 1 Isotopes	—	33.622	A	Class > C
(Long Lived)		N/A	B	
		3.362	C	Limiting Isotope
				Am-241
Table 2 Isotopes	—	2431.262	A	
(Short Lived)		14.706	B	Miscellaneous
		0.146	C	
Transportation Classification:		Unity Fraction		
LSA Determination	—	1.248E+01	> LSA	
Type Determination	—	1.328E+02	Type 'B'	
Highway Route Control (HRC) Determination	—	4.426E-02	Non HRC	
Limited Quantity (LQ) Determination	—	1.328E+06	> LQ	
Advance Notification Quantity ?	—	Yes		
EPA Reportable Quantity (RQ) Determination	—	3.852E+02	Reportable Quantity	

	INPUT: LISTED ISOTOPES					
	(**** = Daughter Product)				Curies when	Curies when
		Curies	or	%	Sealed	Shipped
	Total Curies					
		(ONLY if entering %) =			xxxxx	xxxxx
	H-3——>	0.000E+00			0.000E+00	0.000E+00
	C-14——>	6.170E-04			6.170E-04	6.170E-04
	Na-22——>				0.000E+00	0.000E+00
	Cr-51——>	0.000E+00			0.000E+00	0.000E+00
	Mn-54——>	0.000E+00			0.000E+00	0.000E+00
	Fe-55——>	0.000E+00			0.000E+00	0.000E+00
	Co-57——>				0.000E+00	0.000E+00
	Co-58——>				0.000E+00	0.000E+00
	Fe-59——>				0.000E+00	0.000E+00
	Ni-59——>	8.580E-05			8.580E-05	8.580E-05
	Co-60——>	3.330E-01			3.330E-01	3.329E-01
	Ni-63——>	1.370E-02			1.370E-02	1.370E-02
	Zn-65——>				0.000E+00	0.000E+00
	Se-79——>	2.140E-04			2.140E-04	2.140E-04
	Kr-85——>				0.000E+00	0.000E+00
	Sr-89——>				0.000E+00	0.000E+00
	Sr-90——>	2.990E+01			2.990E+01	2.990E+01
	Y-90——>	****		****	2.990E+01	2.990E+01
	Y-91——>				0.000E+00	0.000E+00
	Zr-93——>				0.000E+00	0.000E+00
	Nb-93m——>	2.500E-03			2.500E-03	2.500E-03
	Nb-94——>	2.990E-05			2.990E-05	2.990E-05
	Zr-95——>				0.000E+00	0.000E+00
	Nb-95——>				0.000E+00	0.000E+00
	Nb-95m——>				0.000E+00	0.000E+00
	Tc-99——>	2.400E-01			2.400E-01	2.400E-01
	Ru-103——>				0.000E+00	0.000E+00
	Rh-103m——>	****		****	0.000E+00	0.000E+00
	Ru-106——>				0.000E+00	0.000E+00
	Rh-106——>	****		****	0.000E+00	0.000E+00
	Pd-107——>				0.000E+00	0.000E+00
	Cd-109——>				0.000E+00	0.000E+00
	Ag-110m——>				0.000E+00	0.000E+00
	Ag-110——>	****		****	0.000E+00	0.000E+00
	Sn-113——>				0.000E+00	0.000E+00
	In-113m——>	****		****	0.000E+00	0.000E+00
	Cd-113m——>				0.000E+00	0.000E+00
	Cd-115m——>				0.000E+00	0.000E+00
	Sn-119m——>				0.000E+00	0.000E+00
	Sn-121m——>				0.000E+00	0.000E+00
	Sn-123——>				0.000E+00	0.000E+00
	Te-123m——>				0.000E+00	0.000E+00
	Sb-124——>				0.000E+00	0.000E+00
	Sb-125——>				0.000E+00	0.000E+00
	Te-125m——>				0.000E+00	0.000E+00
	Sn-126——>				0.000E+00	0.000E+00
	Sb-126m——>	****		****	0.000E+00	0.000E+00
	Sb-126——>				0.000E+00	0.000E+00
	Te-127m——>				0.000E+00	0.000E+00
	Te-127——>	****		****	0.000E+00	0.000E+00
	Te-129m——>				0.000E+00	0.000E+00
	Te-129——>	****		****	0.000E+00	0.000E+00
	I-129——>	9.420E-03			9.420E-03	9.420E-03
	I-131——>				0.000E+00	0.000E+00
	Cs-134——>				0.000E+00	0.000E+00
	Cs-135——>				0.000E+00	0.000E+00
	Cs-136——>				0.000E+00	0.000E+00
	Cs-137——>	2.560E+02			2.560E+02	2.560E+02
	Ba-137m——>	****		****	2.422E+02	2.422E+02
	Ba-140——>				0.000E+00	0.000E+00
	La-140——>	****		****	0.000E+00	0.000E+00
	Ce-141——>				0.000E+00	0.000E+00
	Pr-143——>				0.000E+00	0.000E+00
	Ce-144——>				0.000E+00	0.000E+00

	Pr-144———>	****		****	0.000E+00	0.000E+00
	Pr-144m———>				0.000E+00	0.000E+00
	Nd-147———>				0.000E+00	0.000E+00
	Pm-147———>				0.000E+00	0.000E+00
	Pm-148m———>				0.000E+00	0.000E+00
	Pm-148———>	****		****	0.000E+00	0.000E+00
	Sm-151———>				0.000E+00	0.000E+00
	Eu-152———>				0.000E+00	0.000E+00
	Gd-153———>				0.000E+00	0.000E+00
	Eu-154———>	2.380E+00			2.380E+00	2.379E+00
	Eu-155———>				0.000E+00	0.000E+00
	Eu-156———>				0.000E+00	0.000E+00
	Tb-160———>				0.000E+00	0.000E+00
	Ta-182———>				0.000E+00	0.000E+00
	Ra-226———>				0.000E+00	0.000E+00
	U-233———>				0.000E+00	0.000E+00
	U-234———>				0.000E+00	0.000E+00
	U-235———>	3.740E-06			3.740E-06	3.740E-06
	U-236———>	2.530E-06			2.530E-06	2.530E-06
	U-237———>				0.000E+00	0.000E+00
	U-238———>	3.400E-05			3.400E-05	3.400E-05
	Np-237———>	2.660E-02			2.660E-02	2.660E-02
	Pu-238———>	4.480E-04			4.480E-04	4.480E-04
	Pu-239———>	8.970E-03			8.970E-03	8.970E-03
	Pu-240———>	2.120E-03			2.120E-03	2.120E-03
	Pu-241———>	1.780E-02			1.780E-02	1.780E-02
	Pu-242———>	9.920E-08			9.920E-08	9.920E-08
	Am-241———>	1.630E-01			1.630E-01	1.630E-01
	Am-242m———>				0.000E+00	0.000E+00
	Am-242———>	****		****	0.000E+00	0.000E+00
	Am-243———>	0.000E+00			0.000E+00	0.000E+00
	Cm-242———>	8.020E-05			8.019E-05	7.986E-05
	Cm-244———>	3.410E-03			3.410E-03	3.410E-03

· PROGRAM to CLASSIFY RADIOACTIVE WASTE				
CONTAINERS for TRANSPORTATION and DISPOSAL		FILE REF:	HMMP.XLS	
CP Deltete...Analytical Resources, Inc., 2/85 & 6/90				
(Modified for DOE Radionuclides and Thermal Wattage..		DATE:	5/25/94	
RP Gomoni/XJ Field..Westinghouse-Hanford Co....6/88)				
		BY:	JRG	6/3/94
Originally Published by the Electric Power Research				
Institute in NP-4938 and NP-4757		CHECKED:		6/6/94
*** WASTE GENERAL INFORMATION ***				
Enter waste description	>			
	>			
	>			
Enter waste form ("Special" or "Normal")	>	normal	>> Reqd input for DOT calculations	
Enter physical form ("Solid", "Liquid" or "Gas")	>	liquid	>> Reqd input for DOT calculations	
Is waste Activated Metal ? ("Yes", or "No")	>	no	>> Reqd input for 10CFR61 calculations	
Enter container type (1=55 gal. drum, 2=4x4 liner	>	4	>> Reqd input for H2 calculations	
3=5x5 liner, 4=6x6 liner)				
Is container a vented HIC ? ("Yes", or "No")	>	no	*Note: For a vented HIC, assume	
			"Date sealed" is date shipped in Cask	
Enter date of curie calculations	>	05/23/94		
Enter date last sealed*	>	05/23/94	>>	
Enter date to be shipped	>	08/21/20	>> Must be later than Ci calcs	
Enter date of shipment receipt	>	08/21/20		
CALCULATED Decay before sealing (years)	=	0.00	Days=	0
CALCULATED Decay before shipment (years)	=	26.27	Days=	9587
CALCULATED Duration package is sealed (years)	=	26.27	Days=	9587
Enter package exterior volume	>	647.2	Ft3	
Enter waste volume	>	14.5	Ft3	
CALCULATED Container void volume.		632.8	Ft3	
Enter estimated waste void volume	>		Ft3	
** OR **				
Enter waste true density (vendor data)	>	108.6	Lbs/Ft3	
CALCULATED Waste void fraction	=	0.000		
CALCULATED Waste void volume	=	0.00	Ft3	
CALCULATED Package interior volume	=	1.833E+07	cc	
CALCULATED Waste volume	=	4.092E+05	cc	
CALCULATED Total void volume	=	1.792E+07	cc	
Enter waste weight	>	1569	Lbs	
CALCULATED Weight	=	7.123E+05	gms	
CALCULATED Waste bulk density	=	1.7409	gms/cc	
Enter G-H2 (molecules/100 ev)	>	0.50		
OR				
Enter volume cation resin (cu ft)	>			
Enter volume anion resin (cu ft)	>			
Enter volume mix bed resin (cu ft)	>			
Enter volume other resin (cu ft)	>			
Enter G-H2 of other resin	>			
CALCULATED G-H2 for waste	=	0.00		
*** CALCULATED RESULTS ***				
H2 Generation Summary				
Total Integrated Dose	=	1.135E+08	Rads	
H2 Volume	=	9.421E+05	cm3	
H2 Concentration	=	5.00	%	
H2 Generation Rate	=	4.095E+00	cc/hr	
Pressure Buildup Rate	=	8.067E-05	psi/day	
Pressure (seal to ship)	=	0.77	psi	

Enter Measured H2 Concentration (if known)———	>	0.00	%	
Ratio Measured to Calculated H2 Concentrations	=	0.00		
Activity Summary @ Shipment:				
Total Activity*	=	1.566E+02	Ci	(*Excludes Daughters
Specific Activity, Total*	=	0.383	mCi/cc	with T 1/2 < 10 days)
Specific Activity*, T 1/2 < 5 Years	——	3.624E+02	µCi/cc	
T 1/2 > 5 Years	——	3.828E+02	µCi/cc >> Verify Disposal License	
Decay Heat @ Shipment:				
Decay Heat @ Shipment	=	0.776	Watts	
or		2.649	BTU/hr	
Fissile Material:				
Fissile Material (49 CFR 173 & 10 CFR 71)	——	1.926	gms	
Other DOE Fissile Material (DOE 5480.1A)		38.551	gms >> Isotope list is incomplete	
Special Nuclear Material:				
Special Nuclear Material (SNM)	——	1.935	gms	
Other DOE Accountable Material (DOE 5633.3)	——	38.599	gms >> Isotope list is incomplete	
Transuranics:				
Specific Activity, Transuranics	——	312.256	nCi/gms >>Potential GTCC	
10 CFR 61.55 Classification:		Unity Fraction		Classification
Table 1 Isotopes	——	32.309	A	Class > C
(Long Lived)		N/A	B	
		3.231	C	Limiting Isotope
				Am-241
Table 2 Isotopes	——	[illegible] 451	A	
(Short Lived)		8.936	B	Miscellaneous
		0.090	C	
Transportation Classification:		Unity Fraction		
LSA Determination	——	7.847E+00	> LSA	
Type Determination	——	8.432E+01	Type 'B'	
Highway Route Control (HRC) Determination	——	2.811E-02	Non HRC	
Limited Quantity (LQ) Determination	——	8.432E+05	> LQ	
Advance Notification Quantity ?	——	Yes		
EPA Reportable Quantity (RQ) Determination	——	3.273E+02	Reportable Quantity	

	INPUT: LISTED ISOTOPES					
	(**** = Daughter Product)				Curies when	Curies when
		Curies	or	%	Sealed	Shipped
	Total Curies					
		(ONLY if entering %) =			xxxxx	xxxxx
	H-3——>	0.000E+00			0.000E+00	0.000E+00
	C-14——>	6.170E-04			6.170E-04	6.150E-04
	Na-22——>				0.000E+00	0.000E+00
	Cr-51——>	0.000E+00			0.000E+00	0.000E+00
	Mn-54——>	0.000E+00			0.000E+00	0.000E+00
	Fe-55——>	0.000E+00			0.000E+00	0.000E+00
	Co-57——>				0.000E+00	0.000E+00
	Co-58——>				0.000E+00	0.000E+00
	Fe-59——>				0.000E+00	0.000E+00
	Ni-59——>	8.580E-05			8.580E-05	8.578E-05
	Co-60——>	3.330E-01			3.330E-01	1.054E-02
	Ni-63——>	1.370E-02			1.370E-02	1.142E-02
	Zn-65——>				0.000E+00	0.000E+00
	Se-79——>	2.140E-04			2.140E-04	2.139E-04
	Kr-85——>				0.000E+00	0.000E+00
	Sr-89——>				0.000E+00	0.000E+00
	Sr-90——>	2.990E+01			2.990E+01	1.582E+01
	Y-90——>	****		****	2.990E+01	1.582E+01
	Y-91——>				0.000E+00	0.000E+00
	Zr-93——>				0.000E+00	0.000E+00
	Nb-93m——>	2.500E-03			2.500E-03	7.186E-04
	Nb-94——>	2.990E-05			2.990E-05	2.987E-05
	Zr-95——>				0.000E+00	0.000E+00
	Nb-95——>				0.000E+00	0.000E+00
	Nb-95m——>				0.000E+00	0.000E+00
	Tc-99——>	2.400E-01			2.400E-01	2.400E-01
	Ru-103——>				0.000E+00	0.000E+00
	Rh-103m——>	****		****	0.000E+00	0.000E+00
	Ru-106——>				0.000E+00	0.000E+00
	Rh-106——>	****		****	0.000E+00	0.000E+00
	Pd-107——>				0.000E+00	0.000E+00
	Cd-109——>				0.000E+00	0.000E+00
	Ag-110m——>				0.000E+00	0.000E+00
	Ag-110——>	****		****	0.000E+00	0.000E+00
	Sn-113——>				0.000E+00	0.000E+00
	In-113m——>	****		****	0.000E+00	0.000E+00
	Cd-113m——>				0.000E+00	0.000E+00
	Cd-115m——>				0.000E+00	0.000E+00
	Sn-119m——>				0.000E+00	0.000E+00
	Sn-121m——>				0.000E+00	0.000E+00
	Sn-123——>				0.000E+00	0.000E+00
	Te-123m——>				0.000E+00	0.000E+00
	Sb-124——>				0.000E+00	0.000E+00
	Sb-125——>				0.000E+00	0.000E+00
	Te-125m——>				0.000E+00	0.000E+00
	Sn-126——>				0.000E+00	0.000E+00
	Sb-126m——>	****		****	0.000E+00	0.000E+00
	Sb-126——>				0.000E+00	0.000E+00
	Te-127m——>				0.000E+00	0.000E+00
	Te-127——>	****		****	0.000E+00	0.000E+00
	Te-129m——>				0.000E+00	0.000E+00
	Te-129——>	****		****	0.000E+00	0.000E+00
	I-129——>	9.420E-03			9.420E-03	9.420E-03
	I-131——>				0.000E+00	0.000E+00
	Cs-134——>				0.000E+00	0.000E+00
	Cs-135——>				0.000E+00	0.000E+00
	Cs-136——>				0.000E+00	0.000E+00
	Cs-137——>	2.560E+02			2.560E+02	1.400E+02
	Ba-137m——>	****		****	2.422E+02	1.325E+02
	Ba-140——>				0.000E+00	0.000E+00
	La-140——>	****		****	0.000E+00	0.000E+00
	Ce-141——>				0.000E+00	0.000E+00
	Pr-143——>				0.000E+00	0.000E+00
	Ce-144——>				0.000E+00	0.000E+00

	Pr-144——>	****		****	0.000E+00	0.000E+00
	Pr-144m——>				0.000E+00	0.000E+00
	Nd-147——>				0.000E+00	0.000E+00
	Pm-147——>				0.000E+00	0.000E+00
	Pm-148m——>				0.000E+00	0.000E+00
	Pm-148——>	****		****	0.000E+00	0.000E+00
	Sm-151——>				0.000E+00	0.000E+00
	Eu-152——>				0.000E+00	0.000E+00
	Gd-153——>				0.000E+00	0.000E+00
	Eu-154——>	2.380E+00			2.380E+00	3.008E-01
	Eu-155——>				0.000E+00	0.000E+00
	Eu-156——>				0.000E+00	0.000E+00
	Tb-160——>				0.000E+00	0.000E+00
	Ta-182——>				0.000E+00	0.000E+00
	Ra-226——>				0.000E+00	0.000E+00
	U-233——>				0.000E+00	0.000E+00
	U-234——>				0.000E+00	0.000E+00
	U-235——>	3.740E-06			3.740E-06	3.740E-06
	U-236——>	2.530E-06			2.530E-06	2.530E-06
	U-237——>				0.000E+00	0.000E+00
	U-238——>	3.400E-05			3.400E-05	3.400E-05
	Np-237——>	2.660E-02			2.660E-02	2.660E-02
	Pu-238——>	4.480E-04			4.480E-04	3.641E-04
	Pu-239——>	8.970E-03			8.970E-03	8.963E-03
	Pu-240——>	2.120E-03			2.120E-03	2.114E-03
	Pu-241——>	1.780E-02			1.780E-02	5.029E-03
	Pu-242——>	9.920E-08			9.920E-08	9.920E-08
	Am-241——>	1.630E-01			1.630E-01	1.563E-01
	Am-242m——>				0.000E+00	0.000E+00
	Am-242——>	****		****	0.000E+00	0.000E+00
	Am-243——>	0.000E+00			0.000E+00	0.000E+00
	Cm-242——>	8.020E-05			8.019E-05	1.637E-22
	Cm-244——>	3.410E-03			3.410E-03	1.247E-03

9.0 APPENDIX

9.1 REFERENCES

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