1 of 4

# DISTRIBUTION SHEET

| To | From | Page 1 of 1 |
|---|---|---|
| Distribution | Packaging Safety Engineering | Date 08/25/94 |
| Project Title/Work Order | | EDT No. 603612 |
| SAFETY EVALUATION FOR PACKAGING TRANSPORTATION OF EQUIPMENT FOR TANK 241-C-106 WASTE SLUICING SYSTEM (WHC-SD-TP-SEP-024) | | ECN No. NA |

| Name | MSIN | Text With All Attach. | Text Only | Attach./ Appendix Only | EDT/ECN Only |
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AUG 25 1994
Station 21

# ENGINEERING DATA TRANSMITTAL



1. EDT 603612

| | | |
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| 5. Proj./Prog./Dept./Div.: 84100 | 6. Cog. Engr.: D. B. Calmus | 7. Purchase Order No.: NA |
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| 1 | WHC-SD-TP-SEP-024 | | 0 | Safety Evaluation for Packaging Transportation of Equipment for Tank 241-C-106 Waste Sluicing System | SQ | 1 | 1 | |

16. KEY

| Impact Level (F) | Reason for Transmittal (G) | Disposition (H) & (I) |
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| 1 | 1 | Cog.Eng.: DB Calmus | [signature] | 8/24/94 | G2-02 | JW Thornton | [signature] | 8/24/94 | G2-03 | 1 | 1 |
| 1 | 1 | Cog. Mgr.: JG Field | [signature] | 8/24/94 | G2-02 | JL Rathbun | [signature] | 8/25/94 | R3-09 | 1 | 1 |
| 1 | 1 | QA: SB Dutta | [signature] | 8/24 | L6-35 | | | | | | |
| 1 | 1 | Safety: GW Mettler | [signature] | 8/24/94 | R3-20 | | | | | | |
| 1 | 1 | HL Boynton | [signature] | 8/24/94 | T3-04 | | | | | | |
| 1 | 1 | JP Harris | [signature] | 8/24/94 | S6-12 | | | | | | |
| 1 | 1 for | R Ni | [signature] | 8/24/94 | S5-07 | | | | | | |

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| D. B. Calmus [signature] 8/24/94 Signature of EDT Originator Date | Authorized Representative for Receiving Organization Date | J. G. Field [signature] 8/24/94 Cognizant/Project Engineer's Manager Date | Ltr. No. [] Approved [] Approved w/comments [] Disapproved w/comments |

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**This document was reviewed following the procedures described in WHC-CM-3-4 and is:**

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**WHC Information Release Administration Specialist:**

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7. Abstract


This Safety Evaluation for Packaging (SEP) provides analysis and evaluations considered necessary to approve a short-term transfer campaign of two pumps removed from Tank 241-C-106. The SEP will demonstrate that the transfer of the pumps in new packaging containers will provide an equivalent degree of safety as would be provided by pacakges meeting DOT/NRC requirements. This fulfills onsite transportation requirements implemented by WHC-CM-2-14.




9. Impact Level SQ

10. RELEASE STAMP

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### PART A - PACKAGE DESCRIPTION AND OPERATIONS

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## LIST OF TERMS

| | |
|---|---|
| ASME | American Society of Mechanical Engineers |
| ASTM | American Society for Testing and Materials |
| CWC | Central Waste Complex |
| DOT | U.S. Department of Transportation |
| ECN | Engineering Change Notice |
| HEPA | high efficiency particulate air (filter) |
| LST | lowest service temperature |
| NBS | nominal breaking strength |
| NDT | nil ductility testing |
| NRC | U.S. Nuclear Regulatory Commission |
| QA | Quality Assurance |
| SARP | Safety Analysis Report for Packaging |
| SEP | Safety Evaluation for Packaging |
| TRU | transuranic |
| WHC | Westinghouse Hanford Company |
| WSS | Waste Sluicing System |

# PART A - PACKAGE DESCRIPTION AND OPERATIONS

## 1.0 INTRODUCTION

### 1.1 BACKGROUND INFORMATION

A Waste Sluicing System (WSS) is scheduled for installation in underground waste storage tank 241-C-106 (106-C). The WSS will transfer high heat generating sludge from single shell tank 106-C to double shell waste storage tank 241-AY-102 (102-AY). Prior to installation of the WSS, a heel pump and a transfer pump will be removed from tank 106-C and an agitator pump will be removed from tank 102-AY.

Special flexible receivers will be used to contain the pumps during removal from the tanks. After equipment removal, the flexible receivers will be placed in separate containers (packagings). The packaging and contents (packages) 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.

Two sizes of packagings will be provided for transferring the equipment from the Tank Farms to the interim storage facility. The packagings will be designated as the WSSP-1 and WSSP-2 packagings throughout the remainder of this Safety Evaluation for Packaging (SEP). The WSSP-1 packagings will transport the heel and transfer pumps from 106-C and the WSSP-2 packaging will transport the agitator pump from 102-AY. The WSSP-1 and WSSP-2 packagings are similar except for the length.

The SEP, at this time, will only approve use of the WSSP-1 packaging to transfer the heel pump and transfer pump from waste storage tank 106-C to the designated storage facility. Design drawings of the WSSP-2 packaging are presently being completed and will not be available for evaluation in this SEP. This SEP will be revised at a later date by an Engineering Change Notice (ECN) to approve transfer of equipment (agitator pump) in the WSSP-2 packaging. In general, support studies and other information in this SEP will include data for both the WSSP-1 and WSSP-2 packagings. In cases where information for the WSSP-2 packaging is not available, the missing information will be designated by use of "TO BE DETERMINED" (TBD).

A Packaging Design Criteria (PDC) (WHC 1993) was developed to provide packaging design criteria for both the onsite transfer and storage of the removed equipment. Data presented in the PDC indicates that the equipment (pumps) are a Type B quantity of waste and should be classified as mixed transuranic (TRU) waste for purposes of packaging design and transportation evaluations.

Classification as both mixed and TRU waste 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 SEP provides safety analyses and evaluations considered necessary to support a safe one-time onsite waste transfer campaign. The campaign evaluated in this SEP consists of transferring two identical WSSP-1 packages containing a heel pump and a transfer pump removed from tank 241-C-106. The scope will include the transfer of the packages from the Tank Farms to the CWC for interim storage and then to T Plant for processing and disposition.

This SEP has been prepared in lieu of a formal Safety Analysis Report for Packaging (SARP) and demonstrates that the short-term onsite transfer campaign for the heel and transfer pumps will provide an equivalent degree of safety as would be provided by packages meeting the U.S. Department of Transportation (DOT) safety requirements. 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 pumps 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 packagings consists of two lengths of containers (Part A, Section 9.2) that are of identical design and construction. The packagings are 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 packagings will only be transferred in the horizontal position and include adequate lifting attachments and tiedown devices. Shielding, if required, will be installed on the outside of the packagings to limit radiation dose rates at the surface of the packages to acceptable values during transfer and interim storage.

This SEP will approve transfer of packages one year from date of issue unless otherwise designated by issue of an 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 52 in. outside diameter x 0.375 in. wall thickness. The closure on one end of the packaging is a solid 2 in. thick plate welded to the end of the 52 in. diameter pipe. The closure on the opposite end of the assembly is a solid $\frac{3}{4}$ in. thick plate bolted to a $1\frac{3}{4}$ in. thick ring flange attached to the end of the 52 in. diameter pipe. The removable closure plate is attached to the ring flange with sixteen 1 in. diameter bolts, nuts, and lock washers. A $\frac{1}{8}$ in. thick gasket seals the bolted plate to the ring flange. Double containment of the end closures required for storage of the package is provided by a $1\frac{1}{4}$ in. thick plate welded inside the of 52 in. pipe at the welded closure end of the packaging and by a plate assembly installed around the outside of the bolted closure end.

Stiffening rings are installed at intervals along the length of the packaging to support/protect the package during lifting and normal and/or potential accident conditions. A layer of 3/16 in. thick plate is installed between the stiffening rings to form a $1\frac{1}{2}$ in. wide annulus for installation of shielding material along the full length of the packaging. The shielding annulus also provides double containment of the waste contents along the sidewalls of the packaging for storage of the package.

The overall length of the WSSP-1 packaging container is nominally 49 ft, and the overall length of the WSSP-2 packaging container is nominally 62 ft.

## 2.3 MATERIALS OF CONSTRUCTION

Material requirements for the WSSP-1 packagings are described in the parts list on Westinghouse Hanford Company (WHC) design drawings H-2-83722, H-2-83723, H-2-83724, H-2-83726, and H-2-83727 (Part A, Section 9.2). In general, all structural components are carbon steel. Specifically, the standard wall 52 in. diameter piping material and closure end plates are American Society for Testing and Materials (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 WSSP-1 packagings are described on packaging design drawings H-2-83722, H-2-83723, H-2-83724, H-2-83726, and H-2-83727 (Part A, Section 9.2).

## 2.5 WEIGHTS

The calculated maximum gross weight of the WSSP-1 package with external shielding (lead shot) and contents (heel pump) is approximately 65,900 lb. The weight of the WSSP-1 package without shielding and with contents (heel pump) is 28,300 lb. The calculated maximum gross weight of the WSSP-2 package with external shielding (steel shot) and with contents (agitator pump) is approximately 62,290 lb. The weight of the WSSP-2 package without shielding and with contents is 32,280 lb. The maximum weight of the packages 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 packages. The primary containment boundary is sealed on one end with a welded plate and is sealed on the opposite end with a bolted plate and gasket. A secondary containment boundary is provided on the packaging by installing additional plates on each end of the main enclosure and by installing the shielding annulus the full length of the packaging. Two pipe fittings are 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 WSSP-1 packaging is 51¼ in. diameter by 49 ft long and the WSSP-2 packaging cavity is 51¼ in. diameter by 62 ft long.

## 2.8 HEAT DISSIPATION

Maximum heat dissipation from waste contents for the WSSP-1 and WSSP-2 packages is 4.2 Btu/h and 6.2 Btu/h, respectively (Part B, Section 7.0). The heat is considered to be transferred passively to the environment.

## 2.9 SHIELDING

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

## 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 yoke assembly provided for this project.

## 2.11 TIEDOWN DEVICES

Two special attachments are installed on each end of the packaging to secure (tiedown) the package to a strongback/transport unit provided for this project. In the event the strongback assembly is not used to transport the package, stiffening rings installed at intervals along the length of the packaging are provided with holes that can be used to attach tiedowns to a flatbed trailer.

# 3.0 PACKAGE CONTENTS

## 3.1 GENERAL DESCRIPTION

Contents of the WSSP-1 and WSSP-2 packages are considered to be three pumps placed in three flexible receiver assemblies. Specific details of the flexible receiver assembly system is shown on design drawing H-2-79341. The following data relates to the three pumps scheduled for removal from the tanks and placed in specific packages for transfer:

*WSSP-1 Packages*:

1. One heel pump located in tank 241-C-106. The physical description and reference drawings are as follows:

| | |
|---|---|
| Maximum length: | 37 ft - 8 5/64 in. |
| Maximum diameter: | 36 in. |
| Estimated weight: | 1730 lb |
| Reference drawings: | H-2-41294 |
| | H-2-41297 |
| | H-2-41295 |

2. One transfer pump located in tank 241-C-106. The physical description and reference drawings are as follows:

| | |
|---|---|
| Maximum length: | 38 ft - 2¼ in. |
| Maximum diameter: | 32½ in. |
| Estimated weight: | 1000 lb |
| Reference drawings: | H-9-1105 |
| | H-2-38610 |
| | H-2-33461 |
| | H-2-69897 |
| | H-2-69898 |

*WSSP-2 Package*:

3. One agitator pump located in tank 241-AY-101. The physical description and reference drawings are as follows:

| | |
|---|---|
| Maximum length: | 53 ft - 5⅞ in. |
| Maximum diameter: | 42.43 in. |
| Estimated weight: | 2000 lb |
| Reference drawings: | H-2-95343 |
| | H-2-64449 |

### 3.2 RADIONUCLIDE ACTIVITY

Radionuclide activity in terms of curie content is evaluated in Part B, Section 2.1 and indicates that the WSSP-1 and WSSP-2 packages must be transported as a Type B quantity of waste. Specifically the total estimated curies of waste material attached to the heel pump is 673.09 Ci and is 1080 times the effective $A_2$ value of the mixture of radionuclides, the total curies for the transfer pump is 96.86 Ci and is 254 times the effective $A_2$ value. The total activity for the agitator pump is 926.8 Ci and is 2450 times the effective $A_2$ value for the mixture.

### 3.3 FISSILE CONTENT

Fissile content (in grams) of the estimated amount of waste material attached to each of the three pumps is evaluated in Part B, Section 2.2. The evaluation indicated that the quantity of fissile material attached to the heel pump is 11.6 g, the transfer pump is 1.7 g, and the agitator pump is 1.8 g. Each package is considered as "fissile exempt" since the total fissile content in each package is less than 15 g.

# 4.0 TRANSPORTATION SYSTEM

## 4.1 TRANSPORTER

The transporter system consists of a special truck/trailer/tilt assembly suitable for transfer of one WSSP-1 (maximum 34.0 tons) or WSSP-2 package (maximum 32.0 tons). Suitable attachments are provided on the vehicle for securing the package to the trailer bed. In addition, a modified flatbed trailer will also be available if the truck/trailer/tilt unit cannot be used.

## 4.2 TIEDOWN SYSTEM

Design of a tiedown system is provided to safely secure the packages 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 transfers 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 as "Exclusive Use Only" for the 106-C and 102-AY transfer operations. Transporting any other material not associated with the transfer of a WSSP-1 or WSSP-2 package on the same vehicle is prohibited for use with this SEP. The transport of any materials other than those listed above will require a revision to this SEP or a totally new SEP.

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

4. Only one pump package shall be transferred during each operation. Removal of the package from the special strongback/transporter or loading/unloading the package onto/from a flatbed trailer shall only be performed with the package in the horizontal position.

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

6. The waste package shall be secured to the transport vehicle using the tiedown system described in Part B, Section 6.5.

7. The packages 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.

8. Radiation levels at the package and driver location shall not exceed values indicated in Part B, Section 5.2 of this SEP.

## 5.0 ACCEPTANCE OF PACKAGING FOR USE

The following requirements shall be verified and/or inspections shall be performed prior to use of the packaging:

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

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

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

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

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

6. Verify that there are no detrimental gouges, dents, or scratches on flange sealing surfaces.

# 6.0 OPERATING REQUIREMENTS

## 6.1 GENERAL

Operating requirements provided in this section of the SEP are recommended guidelines for using the packaging. Specific operating procedures shall be developed by operations personnel and shall be approved by designated Transportation and Packaging personnel prior to transfer of the package.

All applicable instructions and procedures for onsite transfer of the packages shall be in compliance with WHC-CM-2-14. The approved SEP shall be considered the controlling document for transfer of the WSSP-1 and WSSP-2 packages except where other applicable WHC requirements are more restrictive. Operating procedures shall include instructions to assure that the packaging is being used in accordance with the SEP.

Operating procedures, in general, shall cover the loading of the contents into the packaging, loading of the packaging on the transport vehicle, 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 waste contents (see Part A, Section 2.2.2) will be placed in the packaging containers at the 106-C and 102-AY Tank Farm locations prior to transfer to the CWC. Installation of the flexible receivers in the packaging containers should include the following steps:

1. Place the packaging in the special strongback assembly provided for this project, and raise the packaging to the vertical position in accordance with DOE-RL-92-36, *Hanford Site Hoisting and Rigging Manual* (RL 1993).

2. Place the flexible receiver in the packaging in accordance with DOE-RL-92-36, *Hanford Site Hoisting and Rigging Manual* (RL 1993). Assure that approved absorbent material has been placed in the flexible receiver and/or the packaging to absorb at least twice the amount of expected free liquids that may be present in the waste contents.

3. Lower the package (packaging and contents) to the horizontal position in accordance with DOE-RL-92-36, *Hanford Site Hoisting and Rigging Manual* (RL 1993) and place a spacer in the package as required to prevent movement of the contents during transfer.

4. Install the two top closure plates on the package being careful not to damage the gasket material. Tighten bolts on the closure plates using the tightening sequence and torquing requirements provided in the field procedures.

5. Verify that the radiation dose rate at any contact surfaces of the package does not exceed 100 mrem/h. If this dose rate is exceeded, additional lead shielding must be installed to reduce the dose rate to acceptable limits prior to transfer of the package. Verify that the surface contamination does not exceed limits listed in 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.

6. If the package will be transported in the special tilt/trailer assembly, install the package tiedowns on the special tilt/trailer per instructions in Part B, Section 6.5. Fully inspect and release the package for transport.

7. If the package will be transported in a separate trailer, follow steps listed in Part A, Section 6.3.

## 6.3 LOADING THE PACKAGE ONTO SEPARATE VEHICLE

1. Prepare an analysis to indicate the actual center of gravity of the package and total gross weight based on the packaging, waste contents and shielding (if required) installed on the outside of the package. Prepare and approve a plan to safely lift the package in the horizontal position. The WSSP-1 package containing the transfer pump weighs approximately 27,000 lb without shielding. The WSSP-1 package containing the heel pump weighs approximately 28,300 lb without shielding. The WSSP-2 package containing the agitator pump weighs approximately 32,300 lb without shielding.

2. Lift the package in the horizontal position and place the packaging on the approved transport vehicle in accordance with DOE-RL-92-36, *Hanford Site Hoisting and Rigging Manual* (RL 1993).

3. Install the package tiedowns on the separate trailer per instructions in Part B, Section 6.5.

4. Verify that the radiation dose rate at any contact surfaces of the package does not exceed 100 mrem/h. If this dose rate is exceeded, additional lead shielding must be installed to reduce the dose rate to acceptable limits prior to transfer of the package. Verify that the surface contamination does not exceed limits listed in the table in Part A, Section 6.2, number 5.

5. Fully inspect and release the package for transport.

## 6.4 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 limits shown in the table included in Part A, Section 6.2, step 5. Inspect the package and determine that it is acceptable for storage and/or processing of the contents at the designated facility.

2. Prepare an analysis to indicate the actual center of gravity of the package and total gross weight based on the packaging, waste contents and shielding (if required) installed on the outside of the package (see Part A, Section 6.3, step 1 for details).

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

4. Verify that surface contamination of the package does not exceed limits listed in Part A, Section 6.2, Item 5.

5. Provide a suitable crane and rigging to safely lift the specified loads 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).

# 7.0 QUALITY ASSURANCE

## 7.1 INTRODUCTION

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 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, verification, and other activities for the packaging container were in accordance with, or equivalent to, WHC-CM-4-2, *Quality Assurance Manual*.

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

3. The assigned safety class 3 of the packaging and safety class 3 of the packaging components (Part A, Section 9.3) were in accordance with requirements of *Management Requirements and Procedures* (MRP) 5.46, WHC-CM-1-3.

4. All required inspections and testing of the packagings were 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-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.

WHC, 1993, *Packaging Design Criteria for Transfer and Disposal of Equipment, Tank 241-C-106 Waste Sluicing System*, WHC-SD-TP-PDC-015, Westinghouse Hanford Company, Richland, Washington.

## 9.2 DRAWINGS

### 9.2.1 WSSP-1 PACKAGING

| Drawing Number | Revision | Sheet | Title |
|---|---|---|---|
| H-2-83722 | 0 | 1 | 52 in. Diameter Transport Assembly Top Cap |
| H-2-83723 | 0 | 1 | 52 in. Diameter Transport Assembly Top Funnel |
| H-2-83724 | 0 | 1 | 49 ft x 52 in. Diameter Transport Assembly - Main Assembly |
| | 0 | 2 | 49 ft x 52 in. Diameter Transport Assembly - Pipe Assembly |
| | 0 | 3 | 49 ft x 52 in. Diameter Transport Assembly - Details and Sections |
| | 0 | 4 | 49 ft x 52 in. Diameter Transport Assembly - Annulus Detail |
| | 0 | 5 | 49 ft x 52 in. Diameter Transport Assembly - Flange Details |
| | 0 | 6 | 49 ft x 52 in. Diameter Transport Assembly - Details |
| | 0 | 7 | 49 ft x 52 in. Diameter Transport Assembly - Internal Stop |
| | 0 | 8 | 49 ft x 52 in. Diameter Transport Assembly - Internal Stop |
| | 0 | 9 | 49 ft x 52 in. Diameter Transport Assembly - Internal Stop |
| H-2-83726 | 0 | 1 | 49 ft x 62 ft x 52 in. Diameter Transport Assembly - Arrangement |
| | 0 | 2 | 49 ft x 62 ft x 52 in. Diameter Transport Assembly - Arrangement |
| | 0 | 3 | 49 ft x 62 ft x 52 in. Diameter Transport Assembly - Arrangement |
| H-2-83727 | 0 | 1 | 52 in. Diameter Transport Assembly Blind Flange |

# ENGINEERING CHANGE NOTICE

Page 1 of 2

1. ECN ~~60823C~~

Proj. ECN W-320-23

| | | | |
|---|---|---|---|
| 2. ECN Category (mark one)<br>Supplemental [X]<br>Direct Revision [ ]<br>Change ECN [ ]<br>Temporary [ ]<br>Standby [ ]<br>Supersedure [ ]<br>Cancel/Void [ ] | 3. Originator's Name, Organization, MSIN, and Telephone No.<br>S. R. Crow, 84200, G2-03, 376-5388 | | 4. Date<br>6/6/94 |
| | 5. Project Title/No./Work Order No.<br>Project W-320/D2M9B | 6. Bldg./Sys./Fac. No. | 7. Impact Level<br>SQ |
| | 8. Document Numbers Changed by this ECN (includes sheet no. and rev.)<br>H-2-83724, Sht. 1, Rev. 0<br>H-2-83724, Sht. 5, Rev. 0 | 9. Related ECN No(s).<br>N/A | 10. Related PO No.<br>N/A |

| 11a. Modification Work | 11b. Work Package No. | 11c. Modification Work Complete | 11d. Restored to Original Condition (Temp. or Standby ECN only) |
|---|---|---|---|
| [] Yes (fill out Blk. 11b)<br>[X] No (NA Blks. 11b, 11c, 11d) | N/A | N/A<br>Cog. Engineer Signature & Date | N/A<br>Cog. Engineer Signature & Date |

12. Description of Change

1. Add the following Note #16 to the General Notes on Dwg. H-2-83724, Sht. 1:

   16. ROUND BAR USED FOR FLANGE DOWEL PINS SHALL CONFORM TO ASTM A322, GRADE 4130. THE PINS SHALL BE HEAT TREATED TO A MINIMUM YIELD STRENGTH OF 120 KSI AND HARDNESS OF HB 270.

2. Change the callout for the dowel pins in Section P and Section R (4 Places) on Dwg. H-2-83724, Sht. 5.

   CHANGE TO: PROVIDE LN3 FIT FOR LOCATING 1/2 ∅ DOWEL, DOWEL MATERIAL PER NOTE 16. DOWEL MAY BE THREADED INTO FLG, USE 1/2"-13 UNC.

   WAS: PROVIDE LN3 FIT FOR LOCATING 1/2 ∅ DOWEL, DOWEL MATERIAL ASTM A36, DOWEL MAY BE THREADED INTO FLG, USE 1/2"-13 UNC.

| 13a. Justification (mark one) | | | |
|---|---|---|---|
| | Criteria Change [] | Design Improvement [X] | Environmental [] |
| As-Found [] | Facilitate Const. [] | Const. Error/Omission [] | Design Error/Omission [] |

13b. Justification Details

The material for the flange guide pins is being changed to a stronger material.

14. Distribution (include name, MSIN, and no. of copies)

| | | | | | |
|---|---|---|---|---|---|
| Bellomy, J. R. (III) | S6-12 | 1 | * Station #4 | R1-29 | 1 |
| Calmus, D. B. | G2-03 | 1 | Station #10 | A3-87 | 1 |
| Crow, S. R. | G2-03 | 1 | Station #16 | S5-00 | 1 |
| Mackey, T. C. | S2-03 | 1 | Station #20 | T4-00 | 1 |
| Peterson, T. K. | S2-03 | 1 | Station #24 | S5-00 | 1 |
| Shiraga, S. S. | N1-40 | 1 | | | |
| Station #1 | S5-59 | 1 | | | |
| Station #2 | S6-81 | 1 | | | |

RELEASE STAMP

OFFICIAL RELEASE BY WHC (11)
DATE JUN 08 1994
Station #12

A-7900-013-2 (06/92) GEF095

* advance copy

A-7900-013-1 (06/9

## ENGINEERING CHANGE NOTICE

Page 2 of 2

1. ECN (use no. from pg. 1): W-320-23

**15. Design Verification Required**
[] Yes
[X] No

**16. Cost Impact**

| | ENGINEERING | | CONSTRUCTION | |
|---|---|---|---|---|
| Additional | [] | $ | [] | $ |
| Savings | [] | $N/A | [] | $N/A |

**17. Schedule Impact (days)**
Improvement []
Delay [] N/A

**18. Change Impact Review:** Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 12. Enter the affected document number in Block 19.

| | | | | | |
|---|---|---|---|---|---|
| SDD/DD | [] | Seismic/Stress Analysis | [] | Tank Calibration Manual | [] |
| Functional Design Criteria | [] | Stress/Design Report | [] | Health Physics Procedure | [] |
| Operating Specification | [] | Interface Control Drawing | [] | Spares Multiple Unit Listing | [] |
| Criticality Specification | [] | Calibration Procedure | [] | Test Procedures/Specification | [] |
| Conceptual Design Report | [] | Installation Procedure | [] | Component Index | [] |
| Equipment Spec. | [] | Maintenance Procedure | [] | ASME Coded Item | [] |
| Const. Spec. | [] | Engineering Procedure | [] | Human Factor Consideration | [] |
| Procurement Spec. | [] | Operating Instruction | [] | Computer Software | [] |
| Vendor Information | [] | Operating Procedure | [] | Electric Circuit Schedule | [] |
| OM Manual | [] | Operational Safety Requirement | [] | ICRS Procedure | [] |
| FSAR/SAR | [] | IEFD Drawing | [] | Process Control Manual/Plan | [] |
| Safety Equipment List | [] | Cell Arrangement Drawing | [] | Process Flow Chart | [] |
| Radiation Work Permit | [] | Essential Material Specification | [] | Purchase Requisition | [] |
| Environmental Impact Statement | [] | Fac. Proc. Samp. Schedule | [] | | [] |
| Environmental Report | [] | Inspection Plan | [] | | [] |
| Environmental Permit | [] | Inventory Adjustment Request | [] | | [] |

**19. Other Affected Documents:** (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

| Document Number/Revision | Document Number/Revision | Document Number Revision |
|---|---|---|
| N/A | | |

**20. Approvals**

| | Signature | Date |
|---|---|---|
| OPERATIONS AND ENGINEERING | | |
| Cog Engineer | J R Crow | 6/6/94 |
| Cog. Mgr. | J J Hunter | 6/6/94 |
| QA | J R Crow for J.J. Huston per telecon | 6/6/94 |
| Safety | J.R. Crow for G.E. McPherson | 6/8/94 |
| Security | | |
| Environ. | | |
| Projects/Programs | J R Crow for J.R. Bellomy (III) per telecon | 6/6/94 |
| Tank Waste Remediation System | | |
| Facilities Operations | | |
| Restoration & Remediation | | |
| Operations & Support Services | | |
| IRM | | |
| Other | DB Calmus | 6/6/94 |

| | Signature | Date |
|---|---|---|
| ARCHITECT-ENGINEER | | |
| PE | | |
| QA | | |
| Safety | | |
| Design | | |
| Environ. | | |
| Other | | |
| DEPARTMENT OF ENERGY | | |
| Signature or Letter No. | | |
| ADDITIONAL | | |

## ENGINEERING CHANGE NOTICE

Page 1 of 3

1. ECN ~~608243~~
Proj. ECN W-320-29

| | | | |
|---|---|---|---|
| 2. ECN Category (mark one)<br>Supplemental [X]<br>Direct Revision [ ]<br>Change ECN [ ]<br>Temporary [ ]<br>Standby [ ]<br>Supersedure [ ]<br>Cancel/Void [ ] | 3. Originator's Name, Organization, MSIN, and Telephone No.<br>S. R. Crow, 84200, G2-03, 376-5388 | | 4. Date<br>6/6/94 |
| | 5. Project Title/No./Work Order No.<br>Project W-320/D2M9B | 6. Bldg./Sys./Fac. No. | 7. Impact Level<br>Q |
| | 8. Document Numbers Changed by this ECN (includes sheet no. and rev.)<br>H-2-83724, Sht. 3, Rev. 0<br>H-2-83724, Sht. 5, Rev. 0<br>H-2-83722, Sht. 1, Rev. 0<br>H-2-83727, Sht. 1, Rev. 0 | 9. Related ECN No(s).<br>N/A | 10. Related PO No.<br>N/A |

| | | | |
|---|---|---|---|
| 11a. Modification Work<br>[ ] Yes (fill out Blk. 11b)<br>[X] No (NA Blks. 11b, 11c, 11d) | 11b. Work Package No.<br>N/A | 11c. Modification Work Complete<br>N/A<br>Cog. Engineer Signature & Date | 11d. Restored to Original Condition (Temp. or Standby ECN only)<br>N/A<br>Cog. Engineer Signature & Date |

12. Description of Change

See attached page.

13a. Justification (mark one)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Criteria Change | [ ] | Design Improvement | [ ] | Environmental | [ ] |
| As-Found | [ ] | Facilitate Const. | [ ] | Const. Error/Omission | [ ] | Design Error/Omission | [X] |

13b. Justification Details

The changes are to correct errors on the drawings which were identified during the validation of the redline drawings to the released H-2 drawings.

14. Distribution (include name, MSIN, and no. of copies)

| | | | | | |
|---|---|---|---|---|---|
| Bellomy, J. R. (III) | S6-12 | 1 | Sta.#1 | S5-59 | 1 |
| Calmus, D. B. | G2-03 | 1 | Sta.#2 | S6-81 | 1 |
| Crow, S. R. | G2-03 | 1 | Sta.#3 | S2-05 | 1 |
| Lesser, K. R. | G7-50 | 1 | Sta.#4 | R1-29 | 1 |
| Mackey, T. C. | S2-03 | 1 | Sta.#5 | T4-30 | 1 |
| Peterson, T. K. | S2-03 | 1 | Sta.#6 | T2-03 | 1 |
| Shiraga, S. S. | N1-40 | 1 | Sta.#16 | S5-00 | 1 |
| | | | Sta.#20 | T4-00 | 1 |

RELEASE STAMP

OFFICIAL RELEASE (11)
BY WHC
DATE JUL 22 1994
Station #12

A-7900-013-2 (06/92) GEF095

A-7900-013-1 (06/92)

| ENGINEERING CHANGE NOTICE | Page 2 of 3 | 1. ECN (use no. from pg. 1) W-320-29 |
|---|---|---|

**15. Design Verification Required**
[] Yes
[X] No

**16. Cost Impact**

| | ENGINEERING | | CONSTRUCTION | |
|---|---|---|---|---|
| Additional | [] $ | Additional | [] $ |
| Savings | [] $N/A | Savings | [] $N/A |

**17. Schedule Impact (days)**
Improvement []
Delay [] N/A

**18. Change Impact Review:** Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 12. Enter the affected document number in Block 19.

| | | | | | |
|---|---|---|---|---|---|
| SDD/DD | [] | Seismic/Stress Analysis | [] | Tank Calibration Manual | [] |
| Functional Design Criteria | [] | Stress/Design Report | [] | Health Physics Procedure | [] |
| Operating Specification | [] | Interface Control Drawing | [] | Spares Multiple Unit Listing | [] |
| Criticality Specification | [] | Calibration Procedure | [] | Test Procedures/Specification | [] |
| Conceptual Design Report | [] | Installation Procedure | [] | Component Index | [] |
| Equipment Spec. | [] | Maintenance Procedure | [] | ASME Coded Item | [] |
| Const. Spec. | [] | Engineering Procedure | [] | Human Factor Consideration | [] |
| Procurement Spec. | [] | Operating Instruction | [] | Computer Software | [] |
| Vendor Information | [] | Operating Procedure | [] | Electric Circuit Schedule | [] |
| OM Manual | [] | Operational Safety Requirement | [] | ICRS Procedure | [] |
| FSAR/SAR | [] | IEFD Drawing | [] | Process Control Manual/Plan | [] |
| Safety Equipment List | [] | Cell Arrangement Drawing | [] | Process Flow Chart | [] |
| Radiation Work Permit | [] | Essential Material Specification | [] | Purchase Requisition | [] |
| Environmental Impact Statement | [] | Fac. Proc. Samp. Schedule | [] | | [] |
| Environmental Report | [] | Inspection Plan | [] | | [] |
| Environmental Permit | [] | Inventory Adjustment Request | [] | | [] |

**19. Other Affected Documents:** (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

| Document Number/Revision | Document Number/Revision | Document Number Revision |
|---|---|---|
| N/A | | |

**20. Approvals**

| Signature | Date | Signature | Date |
|---|---|---|---|
| OPERATIONS AND ENGINEERING | | ARCHITECT-ENGINEER | |
| Cog Engineer R Crow | 6/23/94 | PE | |
| Cog. Mgr. [signature] | 6/23/94 | QA | |
| QA R Crow for J J Huston per telecon | 6/24/94 | Safety | |
| Safety G W Miller | 7/21/94 | Design | |
| Security | | Environ. | |
| Environ. | | Other | |
| Projects/Programs Dick Crow for J R. Bellamy per telecon | 6/28/94 | | |
| Tank Waste Remediation System | | | |
| Facilities Operations | | DEPARTMENT OF ENERGY | |
| Restoration & Remediation | | Signature or Letter No. | |
| Operations & Support Services | | | |
| IRM | | ADDITIONAL | |
| Other DB Calmus | 6/23/94 | | |

| ENGINEERING CHANGE NOTICE CONTINUATION SHEET | Page 3 of 3 | 1. ECN W-320-29 |
|---|---|---|

1. Change the chamfer callout in Detail 5 on Dwg. H-2-83724, Sht. 3:

   CHANGE TO: 45°x2", 4 PL WAS: 45°x2", 2 PL

2. Change two of the radius callouts in Section D on Dwg. H-2-83724, Sht. 3.

   CHANGE TO: R 2 1/2", 4 PL WAS: R 1/2", 2 PL

   CHANGE TO: R 3", 4 PL WAS: R 3", 2 PL

3. Change the pipe callout in Detail 2 on Dwg. H-2-83724, Sht. 5.

   CHANGE TO: PIPE, 2 1/2" Ø x 3 1/4 LONG ASTM, A53 SCH 40

   WAS: PIPE, 2 1/2" Ø x 3 1/4 LONG ASTM, A36 SCH 40

4. Change the material callout in Assembly 3 on Dwg. H-2-83722, Sht. 1.

   CHANGE TO: PLATE 1" THICK ASTM A516, GR 70 OR ASTM A36

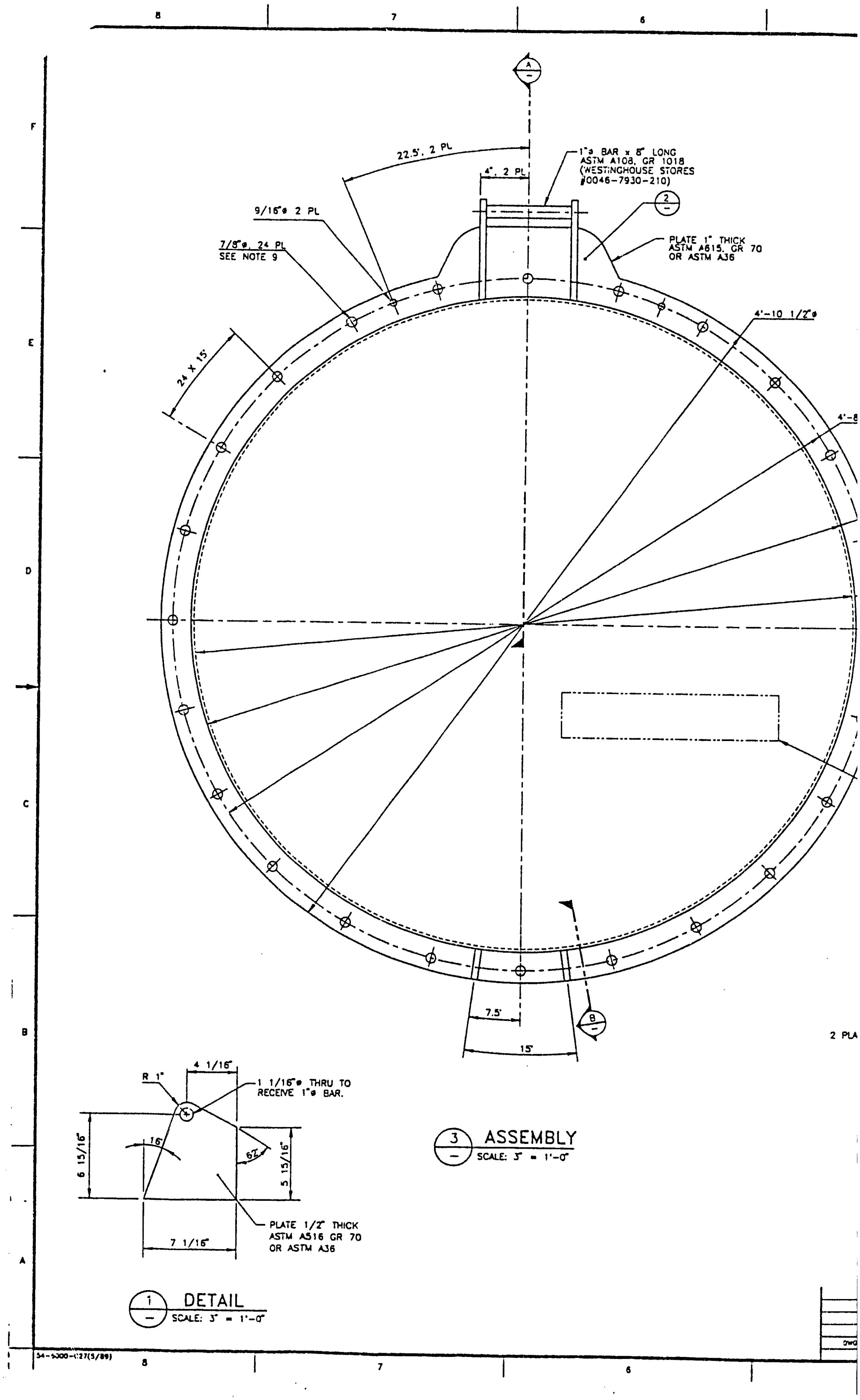
   WAS: PLATE 1" THICK ASTM A615, GR 70 OR ASTM A36

5. Change the material callout in Detail A on Dwg. H-2-83727, Sht. 1.

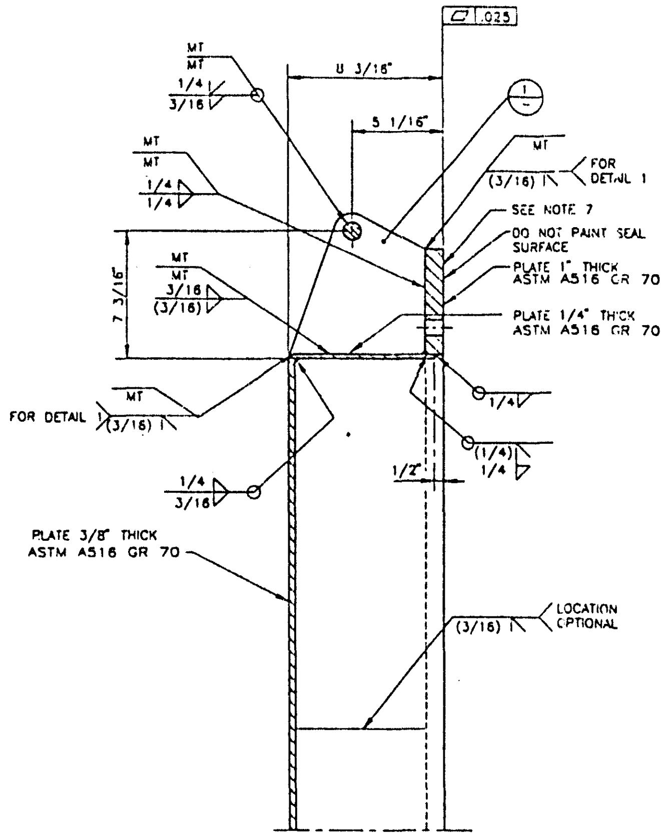
   CHANGE TO: PL 3/4" THICK ASTM A516, GR 70 OR ASTM A36

   WAS: PL 3/4" THICK ASTM A615, GR 70 OR ASTM A36

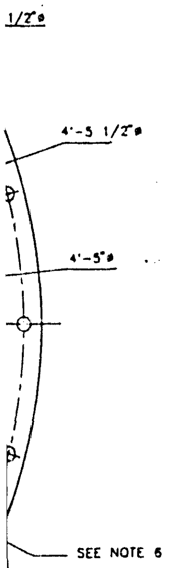
A-7320-036.2 (11/88) (EF) GEF094
Engineering Change Notice Continuation Sheet



22.5°, 2 PL
4", 2 PL
1"φ BAR x 8" LONG
ASTM A108, GR 1018
(WESTINGHOUSE STORES
#0046-7930-210)
9/16"φ 2 PL
7/8"φ, 24 PL
SEE NOTE 9
PLATE 1" THICK
ASTM A515, GR 70
OR ASTM A36
4'-10 1/2"φ
24 X 15°
7.5°
15°
2 PLA
R 1"
4 1/16"
1 1/16"φ THRU TO
RECEIVE 1"φ BAR.
6 15/16"
16°
62°
5 15/16"
7 1/16"
PLATE 1/2" THICK
ASTM A516 GR 70
OR ASTM A36
3 ASSEMBLY
SCALE: 3" = 1'-0"
1 DETAIL
SCALE: 3" = 1'-0"
54-5300-027(5/89)

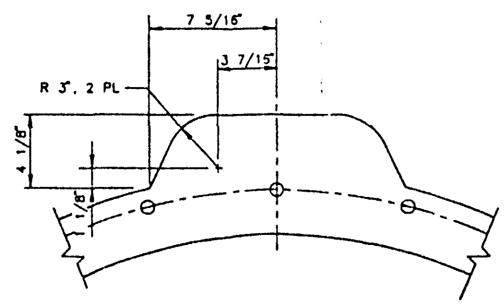



A SECTION
SCALE: 3" = 1'-0"

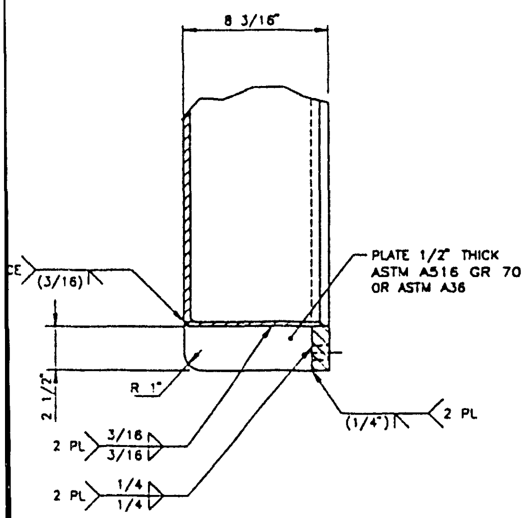



## GENERAL NOTES (UNLESS OTHERWISE SPECIFIED)

1. TOLERANCING IN FRACTIONS ARE: FRAC ±1/16. TOLERANCING IN DECIMAL ARE PER ANSI Y14.5M-82 DEC XX ±.01, XXX ±.005, ANLR ± 1°.
2. ALL MACHINED SURFACES 125√ IN ACCORDANCE WITH ANSI B46.1. (LATEST REV).
3. REMOVE ALL BURRS AND SHARP EDGES.
4. ALL MACHINED TOOL R .03 MAX.
5. WELD AND INSPECT PER AWS D1.1. VT ALL WELDS FINAL PASS. WELDER QUALIFICATION AND WELDING PROCEDURES PER ASME SECTION IX ARE AN APPROVED SUBSTITUTION.
6. MARK PER HS-9S-0015 TYPE 8, IN LOCATION INDICATED USING 1" HIGH BLACK CHARACTERS.
   DWG NO & REV NO ______________
7. SURFACE PREPARATION SHALL BE IN ACCORDANCE WITH SSPC-SP-6, BY GRIT BLAST. PROTECT FLANGE SEAL SURFACES.
8. PAINT ALL EXTERIOR SURFACES PER FEDERAL SPEC BELOW, WITH ONE ZINC-RICH CHROMATE FREE PRIMER COAT TT-P-664D, FOLLOWED WITH TWO TOP COATS TT-E-489H, COLOR SHALL BE YELLOW. MIN DRY FILM THICKNES SHALL BE 4.5 MIL. PAINT BOLT HOLES AS WELL AS POSSIBLE.
9. TEMPLATE HOLES FROM FLANGE RING DETAIL 14, SHEET 5 OF H-2-83724.
10. ALL SPECIFICATIONS SHALL MEET THE FOLLOWING REVISIONS:
    ASTM A36/A36M-92
    ASTM A516/A516M-90
    ASTM A108/108M-90
11. MATERIAL SHALL BE MARKED SUCH THAT IT IS TRACEABLE TO THE CHEMICAL ANALYSIS AND MECHANICAL TEST REPARTS.
12. HEAT NUMBER TRACEABILITY OF THE MATERIAL SHALL BE MAINTAINED.
13. DOCUMENT ALL WELDING ON KEH 0433 FORM.




2 DETAIL
SCALE: 3" = 1'-0"




B SECTION
SCALE: 3" = 1'-0"

MAY 23 1994

| | |
|---|---|
| WHC-SD-W320-DA-001 | SUPPORT DOCUMENT |
| H-2-83726 | ARRANGEMENT DRAWING |
| REF NUMBER | TITLE |
| REFERENCES | |

NEXT USED ON H-2-83726

DRAWING TRACEABILITY LIST

CADFILE BC83722A | CADCODE COS:5:ACD2:12:SS

REVISIONS

| | | |
|---|---|---|
| DRAWN | SW WILLIS | 12/93 |
| CHECKED | D. HAVENS | 5-94 |
| | [signature] | 5-94 |
| | R BELLOMY | 12/93 |

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

52" DIAMETER TRANSPORT ASSEMBLY TOP CAP

| SIZE | BLDG NO | INDEX NO | DWG NO | REV |
|---|---|---|---|---|
| F | 200G | 2302 | H-2-83722 | 0 |

SCALE SHOWN | 700023 | SHEET 1 OF 1

8 | 7 | 6

F

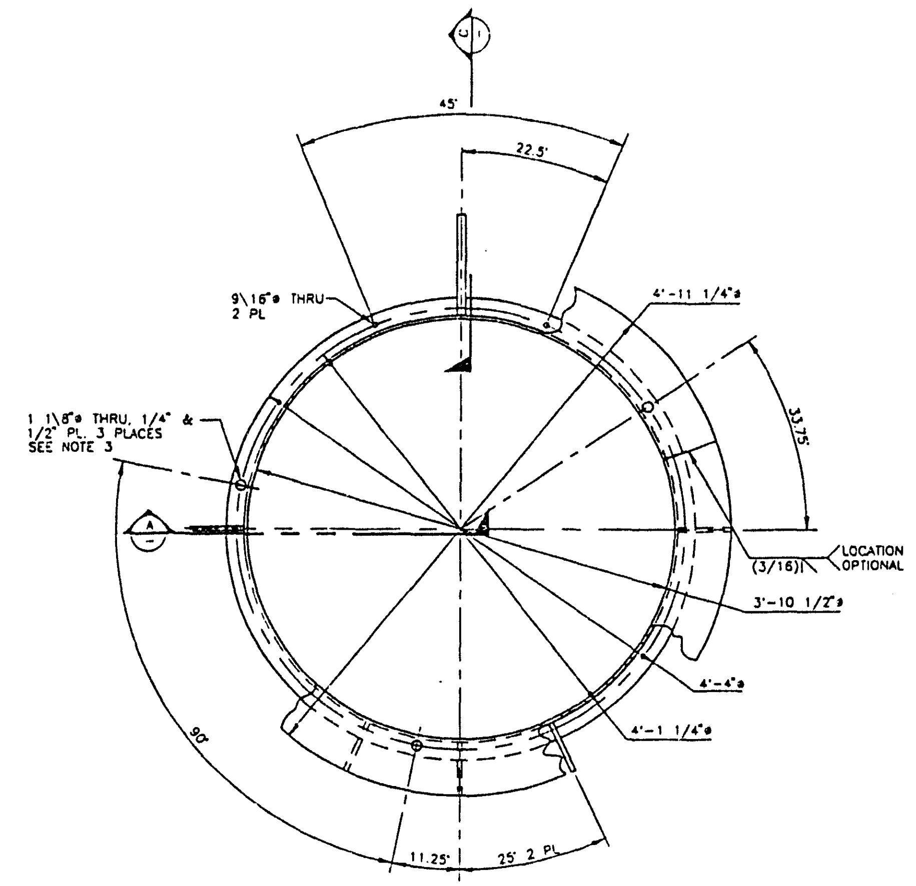
E

D

C

B

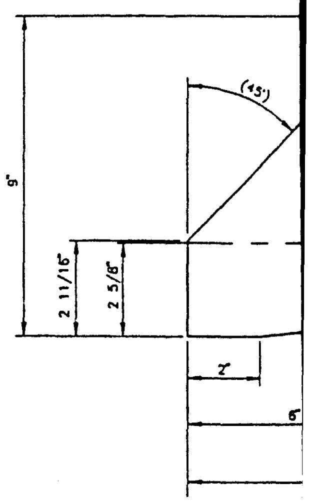
A

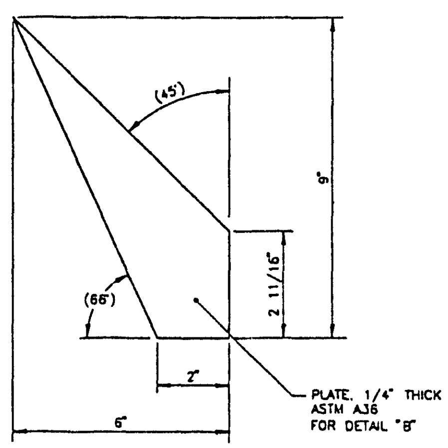



1 ASSEMBLY
SCALE: 1 1/2"=1'-0"

5 F

PLA
AST



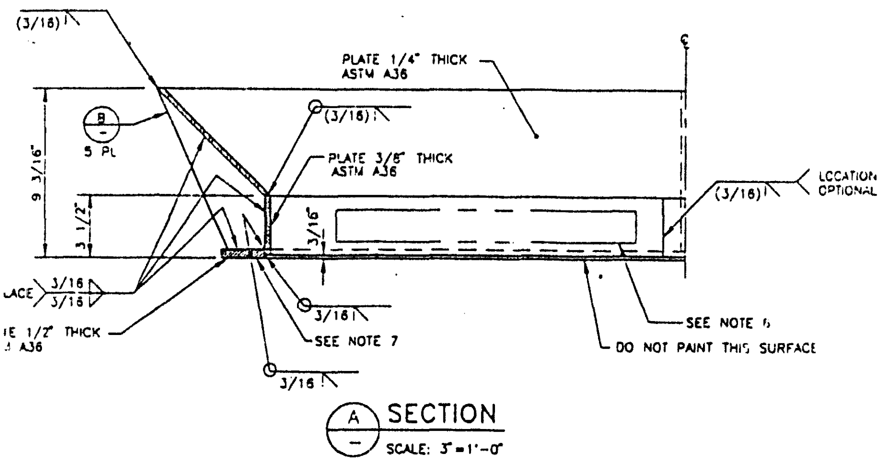

D DETAIL
SCALE: 6"=1

B DETAIL (5 REQD)
SCALE: 6"=1'-0"

DWG

34-6000-C27(5/39)

8 | 7 | 6



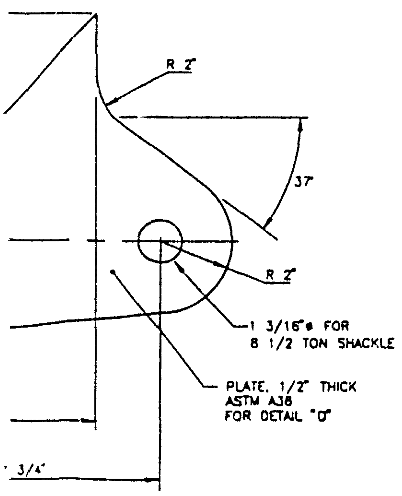

A SECTION
SCALE: 3" = 1'-0"

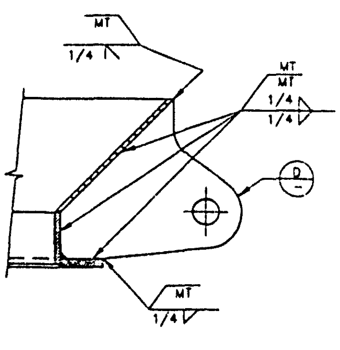
## GENERAL NOTES (UNLESS OTHERWISE SPECIFIED)

1. TOLERANCING IN FRACTIONS ARE: FRAC ±1/16

   TOLERANCING IN DECIMAL ARE PER ANSI Y14.5M-82 DEC XX ±.01, XXX ±.005, ANLR ± 1°.
2. REMOVE ALL BURRS AND SHARP EDGES.
3. TEMPLATE HOLES FROM FLANGE RING DETAIL 11, SHEET 5 OF H-2-83724.
4. PAINT ALL EXPOSED CARBON STEEL SURFACES WITH 2 COATS OF AMERLOCK 400, HIGH SOLIDS EPOXY COATING (5-8 MIL THICK), FOLLOWED WITH 1 COAT OF AMERCOAT 450HS, ALIPHATIC POLYURETHANE (2 MIL THICK). PAINT BOLT HOLES AS WELL AS POSSIBLE. FINAL COLOR SHALL BE BEIGE.
5. WELD AND INSPECT PER AWS D1.1. VT ALL WELDS FINAL PASS. WELDER QUALIFICATION AND WELDING PROCEDURES PER ASME SECTION IX ARE AN APPROVED SUBSTITUTION.
6. MARK PER HS-BS-0015 TYPE 8, IN LOCATION INDICATED USING 1" HIGH BLACK CHARACTERS.

   DWG NO & REV NO ____________
7. SURFACE PREPARATION SHALL BE IN ACCORDANCE WITH SSPC-SP-6, BY GRIT BLAST. PROTECT FLANGE SEAL SURFACES.
8. ALL SPECIFICATIONS SHALL MEET THE FOLLOWING REVISIONS: ASTM A36/A36M-92
9. MATERIAL SHALL BE MARKED SUCH THAT IT IS TRACEABLE TO THE CHEMICAL ANALYSIS & MECHANICAL TEST REPORTS.
10. HEAT NUMBER TRACEABILITY OF MATERIAL SHALL BE MAINTAINED.
11. DOCUMENT ALL WELDING ON KEH 0433 FORM.




C SECTION
SCALE: 3" = 1'-0"

(1 REQD)

MAY 23 1994

| | |
|---|---|
| REF NUMBER | TITLE |
| WHC-SD-W320-CA-001 | SUPPORT DOCUMENT |
| H-2-83726 | ARRANGEMENT DRAWING |

DRAWING TRACEABILITY LIST — NEXT USED ON H-2-83725

CADFILE E083723A — CADCODE DOS 5 ACD2 12.5S

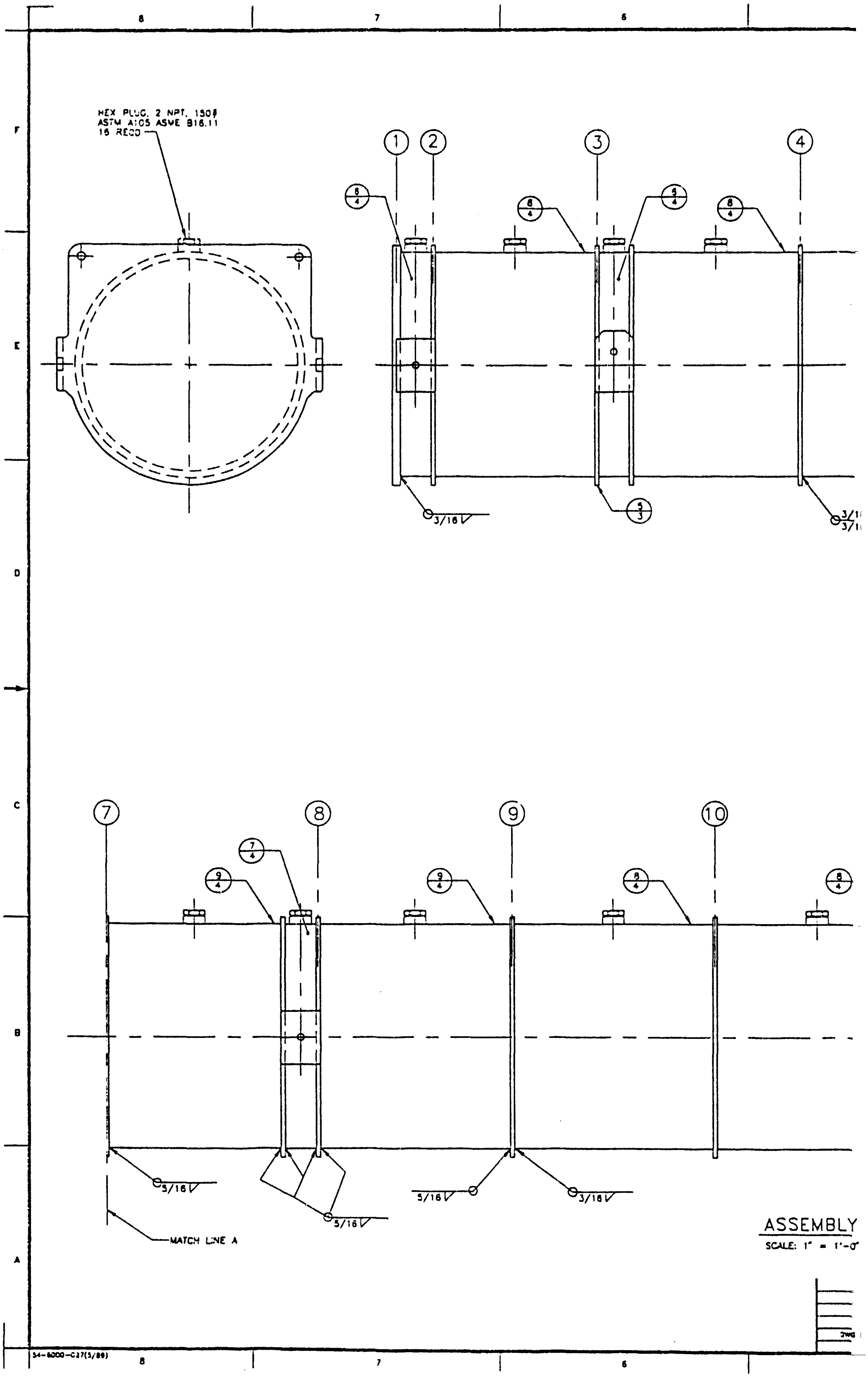
DRAWN SW WILLIS 12/93
CHECKED D. HAVENS 5-94
[signature] 5-94
JR BELLOMY 12/93

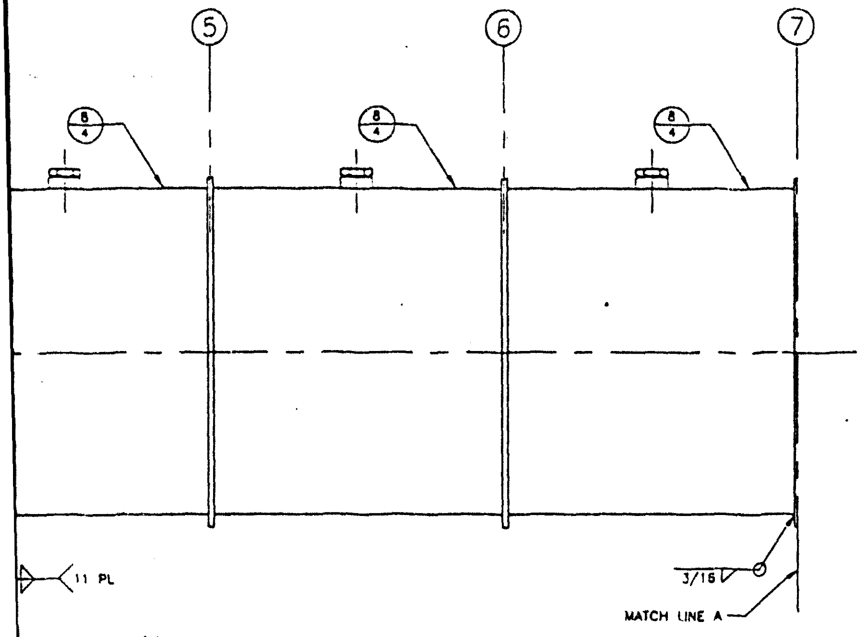
U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

52" DIAMETER TRANSPORT ASSEMBLY TOP FUNNEL

| SIZE | BLDG NO | INDEX NO | DWG NO | REV |
|---|---|---|---|---|
| F | 200G | 2302 | H-2-83723 | 0 |

SCALE SHOWN — 700023 — SHEET 1 OF 1


HEX PLUG, 2 NPT, 150#
ASTM A105 ASME B16.11
16 REQD
3/16
5/16
MATCH LINE A
ASSEMBLY
SCALE: 1" = 1'-0"
54-6000-C27(5/89)




## GENERAL NOTES (UNLESS OTHERWISE SPECIFIED)

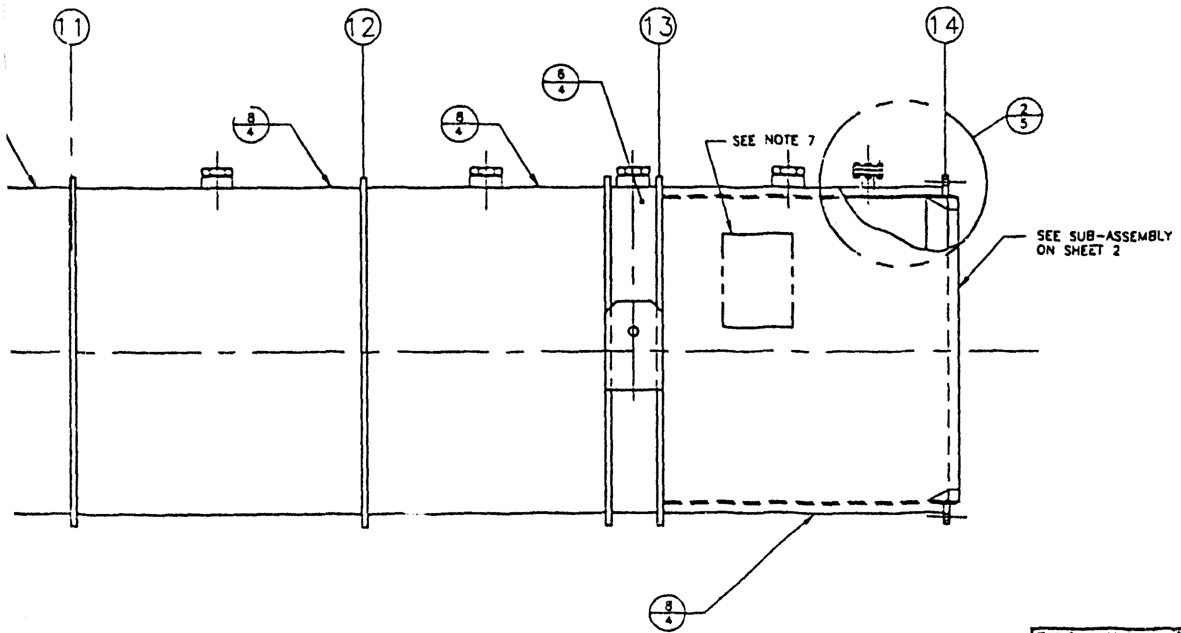
1. TOLERANCING IN FRACTIONS ARE: ±1/16.

   TOLERANCING IN DECIMAL ARE:
   XX ±.01, XXX ±.005, ANLR ± 1°.

2. ALL MACHINED SURFACES 125✓ IN ACCORDANCE WITH ANSI B46.1. (LATEST REV).
3. REMOVE ALL BURRS AND SHARP EDGES.
4. ALL MACHINED TOOL R .03 MAX.
5. WELD AND INSPECT PER AWS D1.1 WELDER QUALIFICATIONS AND WELDING PROCEDURES PER ASME B&PV CODE SECTION IX ARE ACCEPTABLE. VT ALL WELDS FINAL PASS.
6. FABRICATE & INSPECT IN ACCORDANCE WITH AWS D1.1-92.
   NO HYDROSTATIC TEST REQUIRED AT ASSY. VT
   FIT-UP, ROOT PASS, & FINAL PASS ON ALL CONTAINMENT WELDS & LIFTING WELDS.
   MT OR PT FINAL PASS ON ALL CONTAINMENT WELDS & LIFTING WELDS. WELDS PREVIOUSLY MADE BY PIPE SUPPLIER ON PROCURED PIPE SHALL BE VT & MT OR PT FINAL PASS BY PIPE SUPPLIER
7. MARK PER HS-BS-0015 TYPE 8, IN LOCATION INDICATED USING 1" HIGH BLACK CHARACTERS.

   DWG NO. PART NO. & REV NO ______
   CONTAINER WT ______

8. SURFACE PREPARATION SHALL BE IN ACCORDANCE WITH SSPC-SP-6, BY GRIT BLAST. PROTECT FLANGE SEAL SURFACES.
9. PAINT ALL EXTERIOR SURFACES PER FEDERAL SPEC BELOW, WITH 1 ZINC-RICH CHROMATE FREE PRIMER COAT TT-P-6640, FOLLOWED WITH TWO TOP COATS TT-E-489H, COLOR SHALL BE YELLOW. MIN DRY FILM THICKNESS SHALL BE 4.5 MILS PAINT BOLT HOLES AS WELL AS POSSIBLE. DO NOT PAINT GASKET SURFACES OF CLOSURE FLANGES.
10. THREADED FASTENERS SHALL BE COATED WITH NICKEL NEVER SEIZE #NS-160 OR LOCTITE C.
11. PIPE WELD BEADS MAY BE DRESSED TO ALLOW FITTING OF RINGS, FLANGES, AND INTERNAL SUPPORTS.
12. ALL SPECIFICATIONS SHALL MEET THE FOLLOWING REVISIONS:
    ASME B16.11.91
    ASTM A36/A36M-92
    ASTM A105/A105M-93
    ASTM A516/A516M-90
    ASTM A671-89a
13. EACH ANNULUS SHALL BE PRESSURE DECAY TESTED TO 11.2 PSI.
14. MATERIAL SHALL BE MARKED SUCH THAT IT IS TRACEABLE TO THE CHEMICAL ANALYSIS AND MECHANICAL TEST REPORTS.
15. HEAT NUMBER TRACEABILITY OF MATERIAL SHALL BE MAINTAINED.




| REF NUMBER | TITLE |
|---|---|
| WHC-SD-W320-DA-001 | SUPPORTING DOC |
| H-2-83726 | ARRANGEMENT DRAWING |
| H-2-83725 | SUPPORT, 52" DIAMETER |
| H-2-83723 | TOP FUNNEL, 52" DIAMETER |
| H-2-83722 | TOP CAP, 52" DIAMETER |

REFERENCES

DRAWING TRACEABILITY LIST — NEXT USED ON H-2-83726

REVISIONS

CADFILE B083724A    CADCODE DOS 5 AC02:12:SS

DRAWN SW WILLIS 12/93
CHECKED D. HAVENS 5-94
5-94
JR BELLOMY 12/93

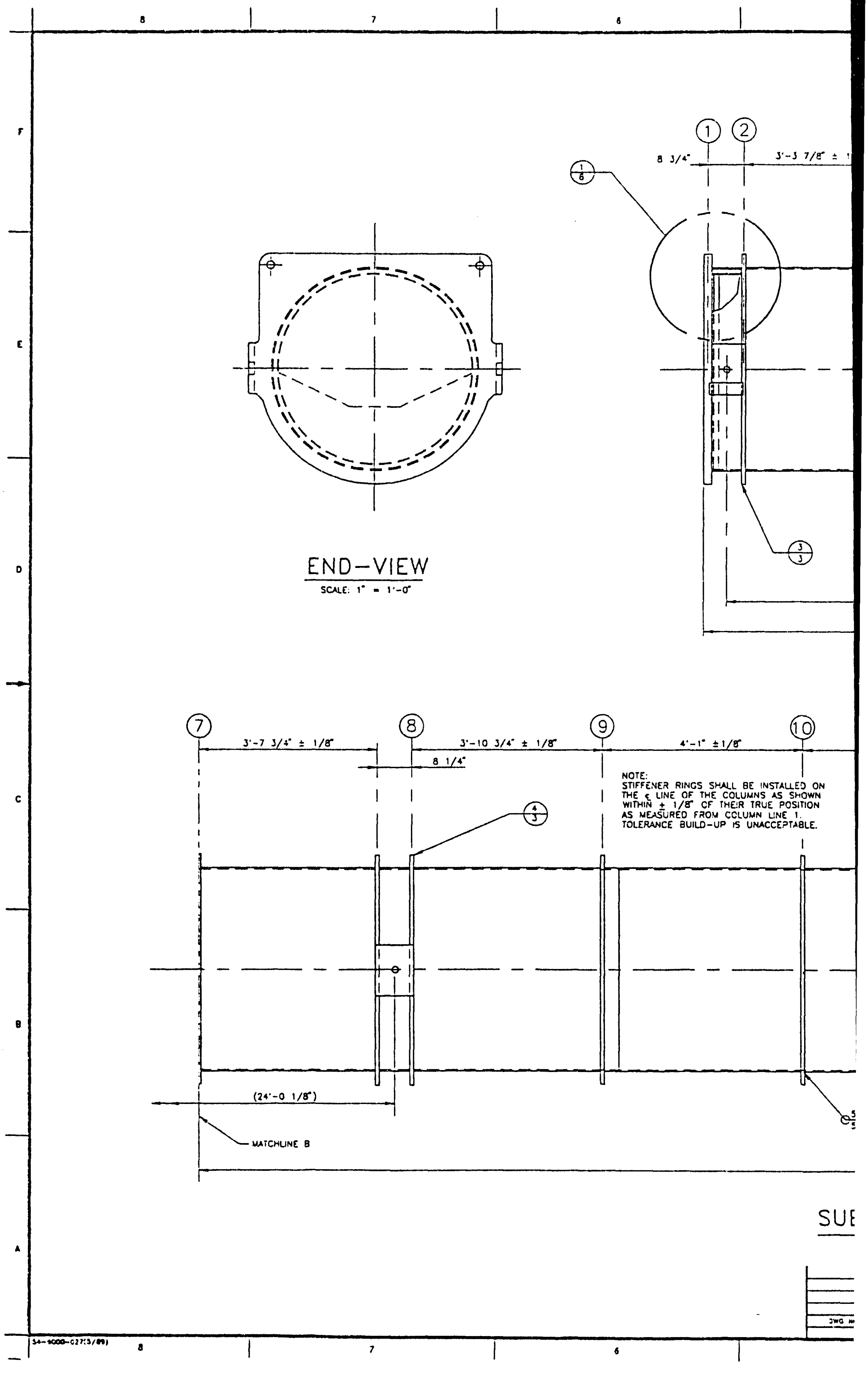
U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

# 49' X 52" DIAMETER TRANSPORT ASSEMBLY MAIN ASSEMBLY

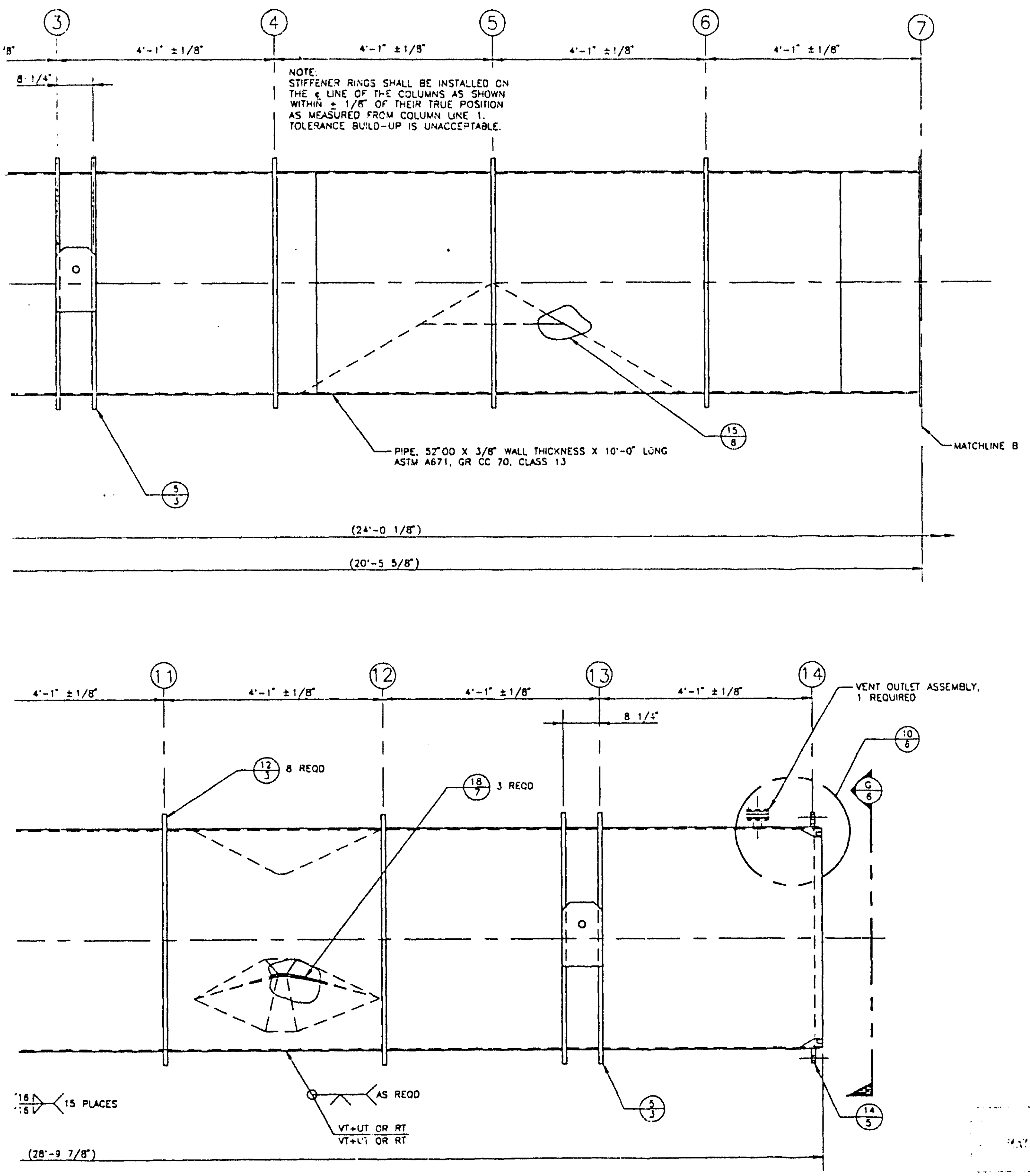
SIZE F | BLDG NO 2000 | INDEX NO 2302 | DWG NO H-2-83724 | REV 0

SCALE SHOWN | 700023 | SHEET 1 OF 9

H-2-83724



8
7
6
F
E
D
C
B
A
1
2
8 3/4"
3'-3 7/8" ±
END-VIEW
SCALE: 1" = 1'-0"
7
8
9
10
3'-7 3/4" ± 1/8"
3'-10 3/4" ± 1/8"
4'-1" ± 1/8"
8 1/4"
NOTE:
STIFFENER RINGS SHALL BE INSTALLED ON THE ℄ LINE OF THE COLUMNS AS SHOWN WITHIN ± 1/8" OF THEIR TRUE POSITION AS MEASURED FROM COLUMN LINE 1.
TOLERANCE BUILD-UP IS UNACCEPTABLE.
(24'-0 1/8")
MATCHLINE B
SUE
54-9000-027(3/89)




FOR GENERAL NOTES SEE SHEET 1

—ASSEMBLY

SCALE: 1" = 1'-0"

| | |
|---|---|
| DRAWN | SW WILLIS 12/93 |
| CHECKED | D HAVENS 5-94 |
| DSTG APPRD | 5-94 |
| COG ENGR | R BELLOMY 12/93 |

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

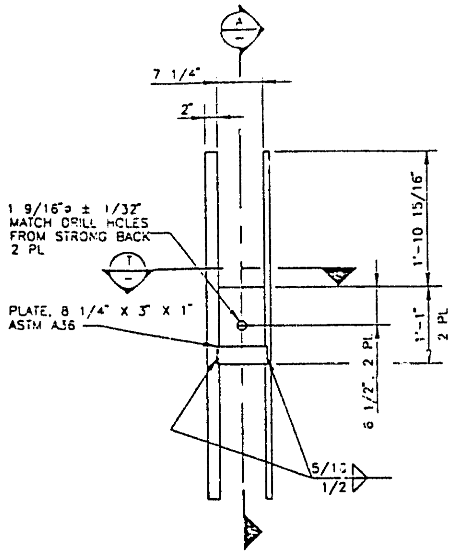
49' X 52" DIAMETER TRANSPORT ASSEMBLY PIPE ASSEMBLY

| SIZE | BLDG NO | INDEX NO | DWG NO | REV |
|---|---|---|---|---|
| F | 200G | 2302 | H-2-83724 | 0 |

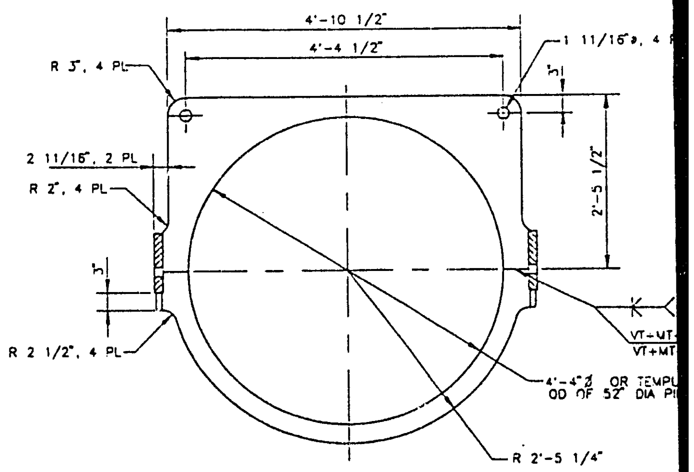
SCALE: SHOWN   700023   SHEET 2

DRAWING TRACEABILITY LIST | REF NUMBER | TITLE | REFERENCES | NEXT USED ON H-2-83724 SH 1

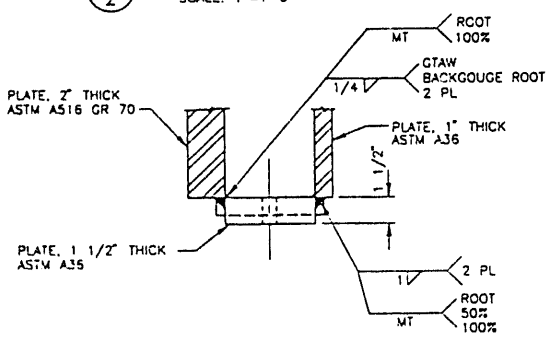
REVISIONS | CADFILE B0837248 | CADCODE DOS 5.0



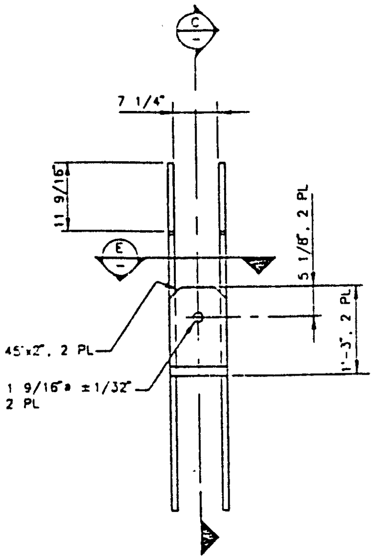

3/2 DOUBLE PLATE
SCALE: 1"=1-0"



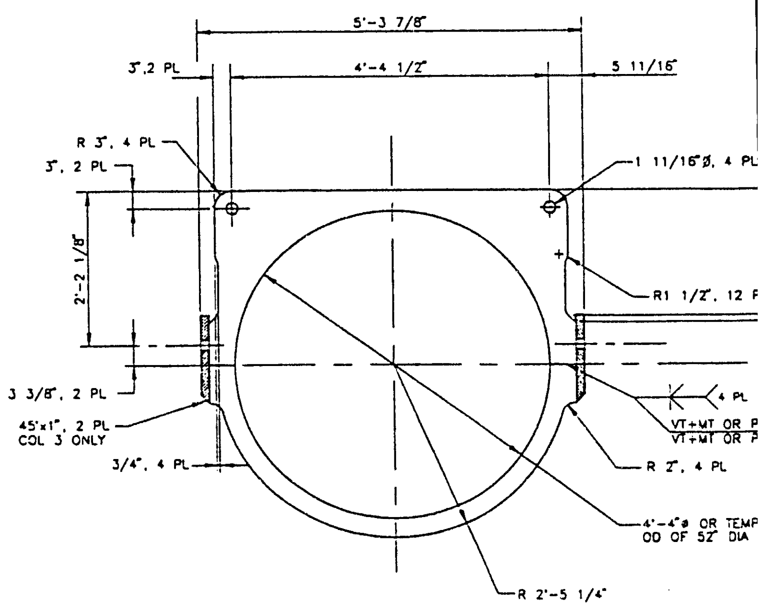

A SECTION
SCALE: 1"-1'-0"




T SECTION
SCALE: 3"=1'-0"

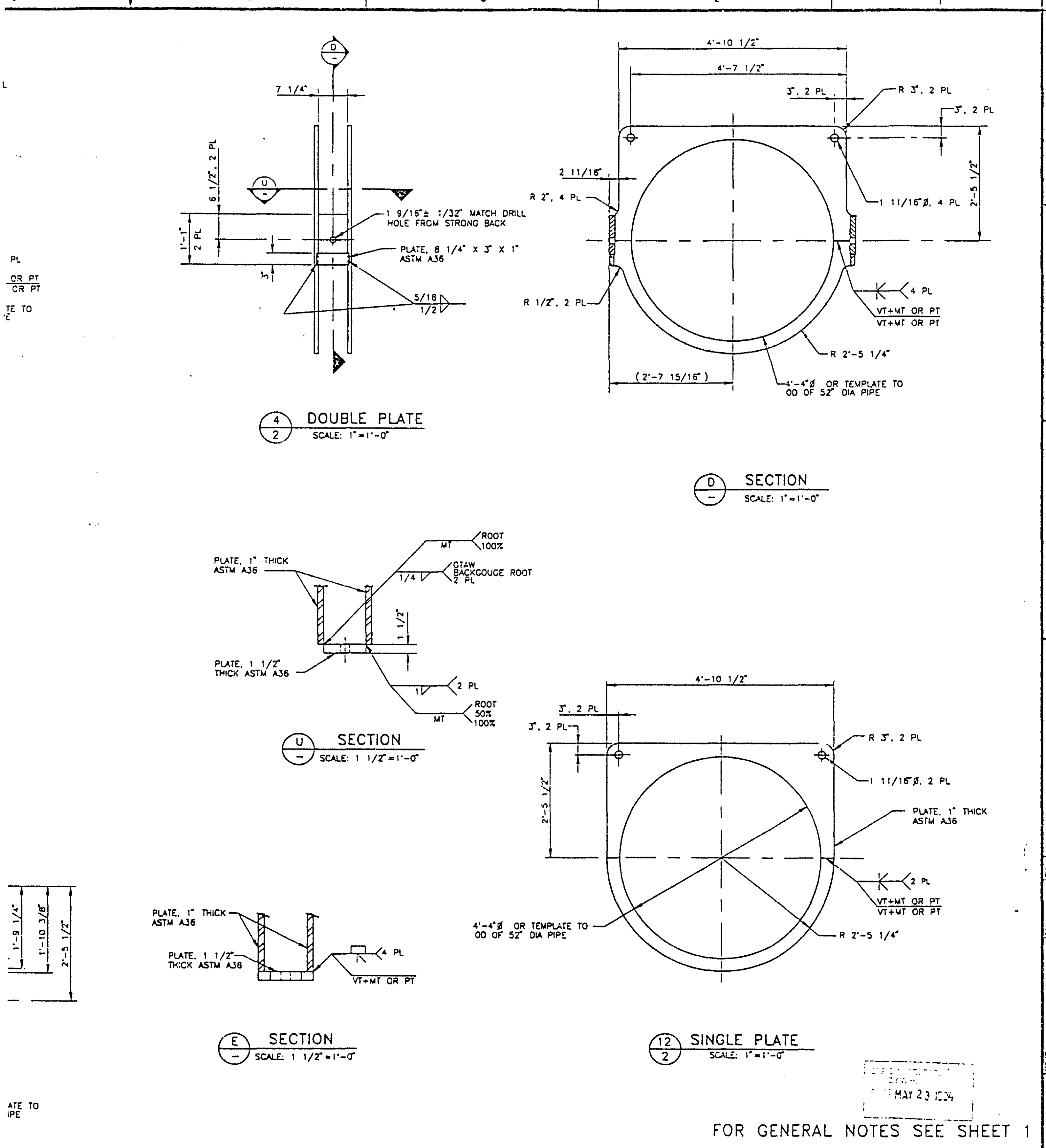



5/2 DOUBLE PLATE
SCALE: 1"= 1'-0"




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

54-6000-027(5/39)




MAY 23 1994

FOR GENERAL NOTES SEE SHEET 1

| | |
|---|---|
| DRAWN | SW WILLIS 12/92 |
| CHECKED | D. HAVENS 5-94 |
| | 5-94 |
| DOE CHCK | JR BELLOMY 12/93 |

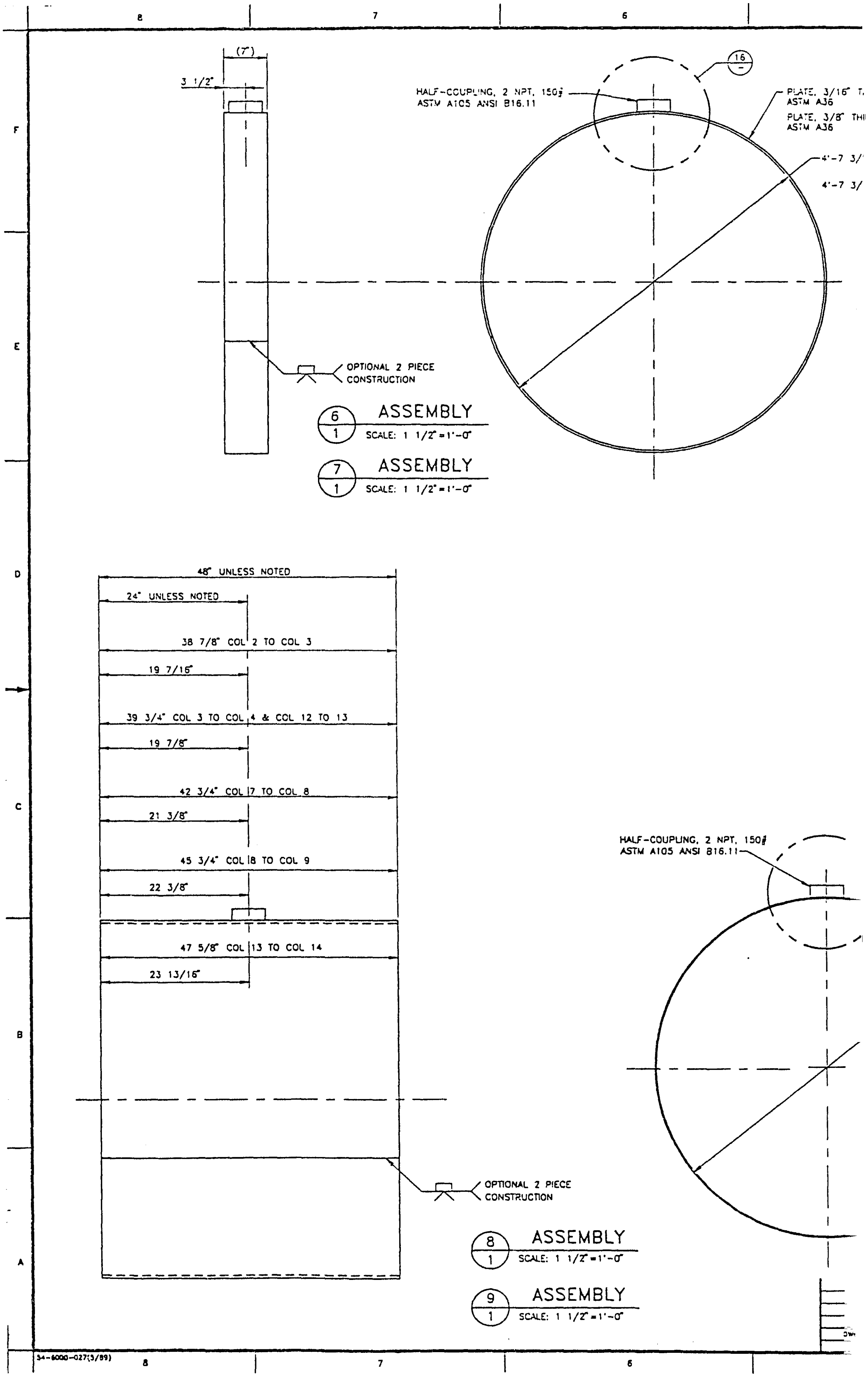
U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

49' X 52" DIAMETER TRANSPORT ASSEMBLY DETAILS AND SECTIONS

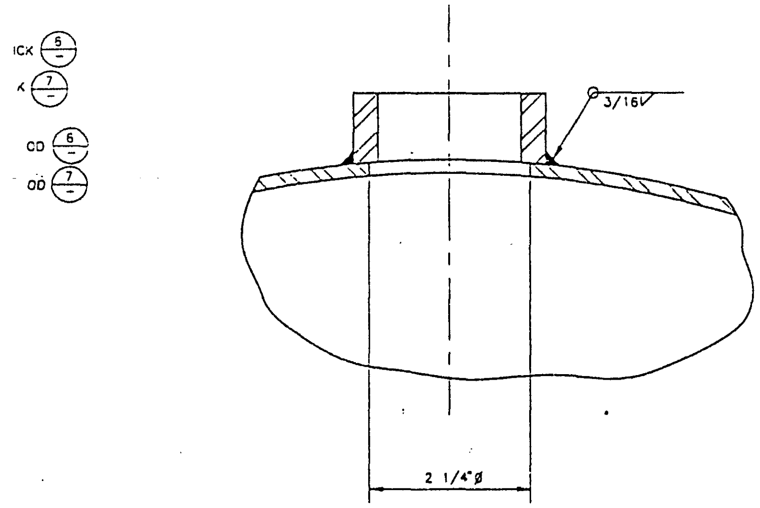
| SIZE | BLDG NO | INDEX NO | DWG NO | REV |
|---|---|---|---|---|
| F | 200C | 2302 | H-2-83724 | 0 |

SCALE: SHOWN | 700023 | SHEET 3

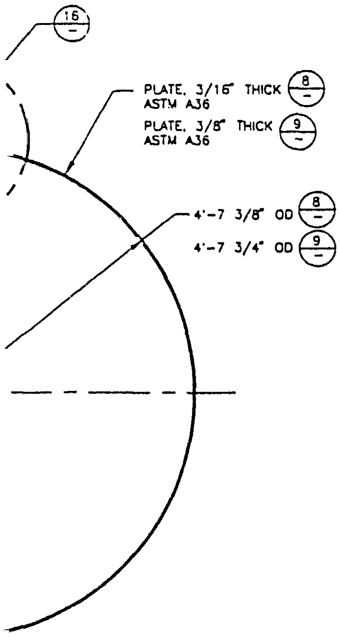
DRAWING TRACEABILITY LIST | REFERENCES | NEXT USED ON H-2-83724 SH 1 | REVISIONS | CADFILE B083724C | CADCODE 20S 5 ACD2 12 SS



8
7
6
F
E
D
C
B
A
(7")
3 1/2"
HALF-COUPLING, 2 NPT, 150#
ASTM A105 ANSI B16.11
16
PLATE, 3/16" T
ASTM A36
PLATE, 3/8" TH
ASTM A36
4'-7 3/
4'-7 3/
OPTIONAL 2 PIECE
CONSTRUCTION
6
1
ASSEMBLY
SCALE: 1 1/2"=1'-0"
7
1
ASSEMBLY
SCALE: 1 1/2"=1'-0"
48" UNLESS NOTED
24" UNLESS NOTED
38 7/8" COL 2 TO COL 3
19 7/16"
39 3/4" COL 3 TO COL 4 & COL 12 TO 13
19 7/8"
42 3/4" COL 7 TO COL 8
21 3/8"
45 3/4" COL 8 TO COL 9
22 3/8"
47 5/8" COL 13 TO COL 14
23 13/16"
HALF-COUPLING, 2 NPT, 150#
ASTM A105 ANSI B16.11
OPTIONAL 2 PIECE
CONSTRUCTION
8
1
ASSEMBLY
SCALE: 1 1/2"=1'-0"
9
1
ASSEMBLY
SCALE: 1 1/2"=1'-0"
54-6000-027(5/89)




16 DETAIL
SCALE: FULL SIZE




FOR GENERAL NOTES SEE SHEET 1

| | |
|---|---|
| DRAWN | SW WILLIS 12/93 |
| CHECKED | D. HAVENS 5-94 |
| | 5-94 |
| COG ENGR | JR BELLOMY 12/93 |

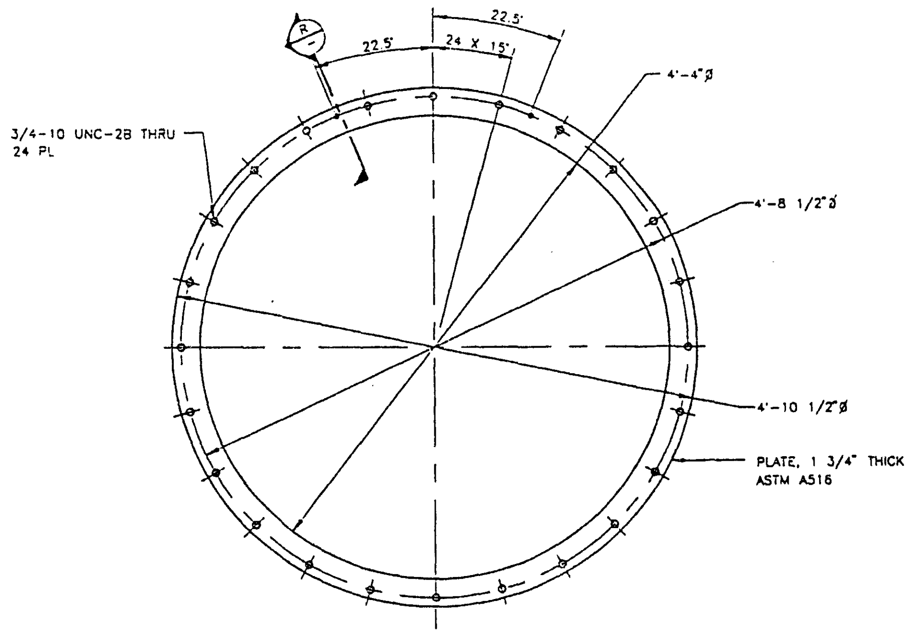
U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

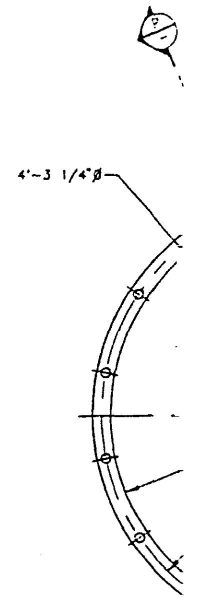
49' X 52" DIAMETER TRANSPORT ASSEMBLY ANNULUS DETAIL

| SIZE | BLDG NO | INDEX NO | DWG NO | REV |
|---|---|---|---|---|
| F | 200G | 2302 | H-2-83724 | 0 |

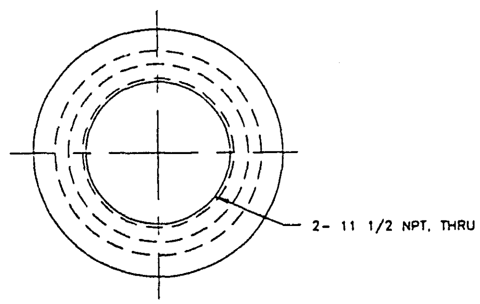
SCALE SHOWN | 700023 | SHEET 4

NO | TITLE | REF NUMBER | TITLE | REFERENCES | REVISIONS
DRAWING TRACEABILITY LIST | NEXT USED ON H-2-83724 SH 1 | CADFILE 90837240 | CADCODE COS:5:ACD2:12:SS

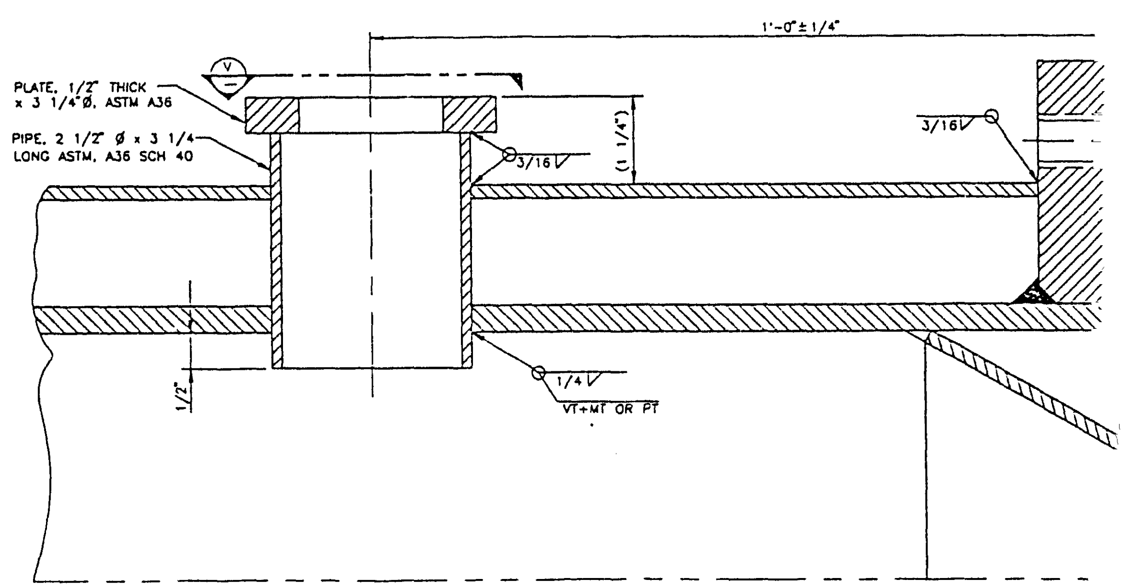


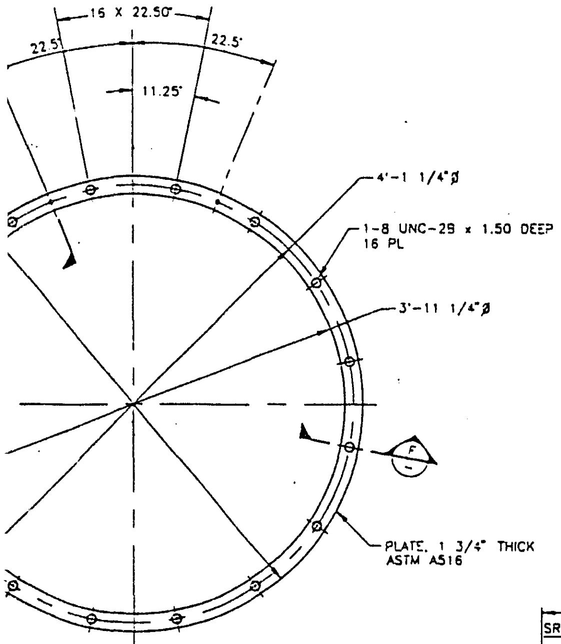

14/6 FLANGE RING DETAIL
SCALE: 1 1/2"=1'-0"




V VIEW
SCALE: FULL SIZE

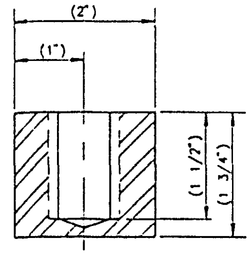



2/1 DETAIL
SCALE: FULL SIZE



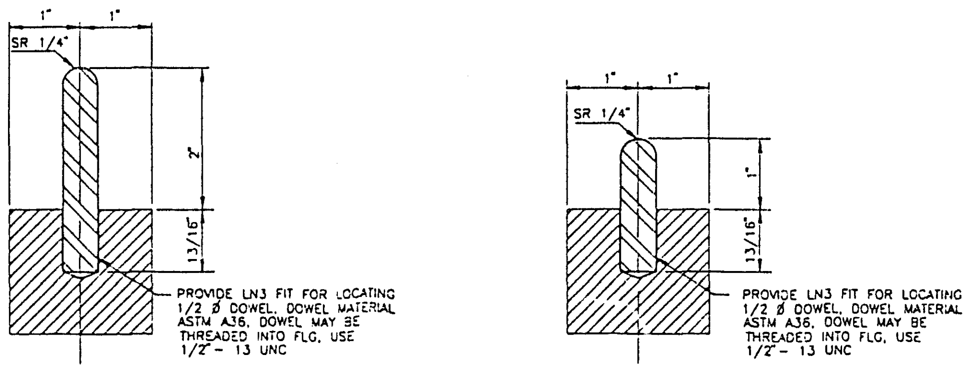

11/6 FLANGE RING DETAIL

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




F SECTION

SCALE: FULL SIZE

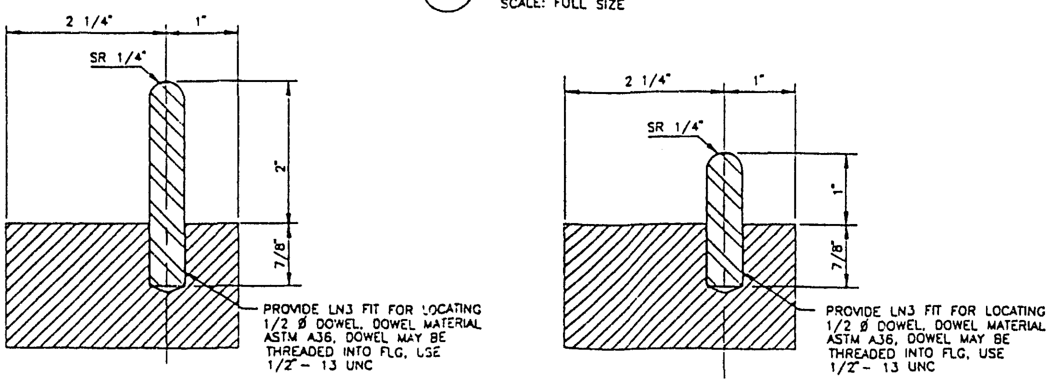



AT (+)22.5° FROM ℄

AT (−)22.5° FROM ℄

P SECTION

SCALE: FULL SIZE

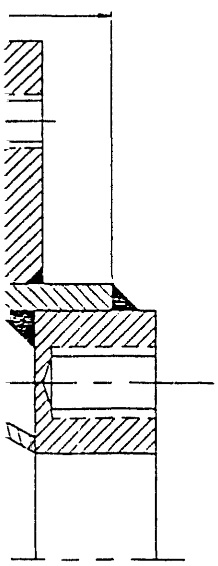



AT (+)22.5° FROM ℄

AT (−)22.5° FROM ℄

R SECTION

SCALE: FULL SIZE



MAY 23 1994

FOR GENERAL NOTES SEE SHEET 1

DRAWN SW WILLIS 12/93
CHECKED D. KAVEAS 5-94
APPROVED 5-94
JR BELLCMY 12/93

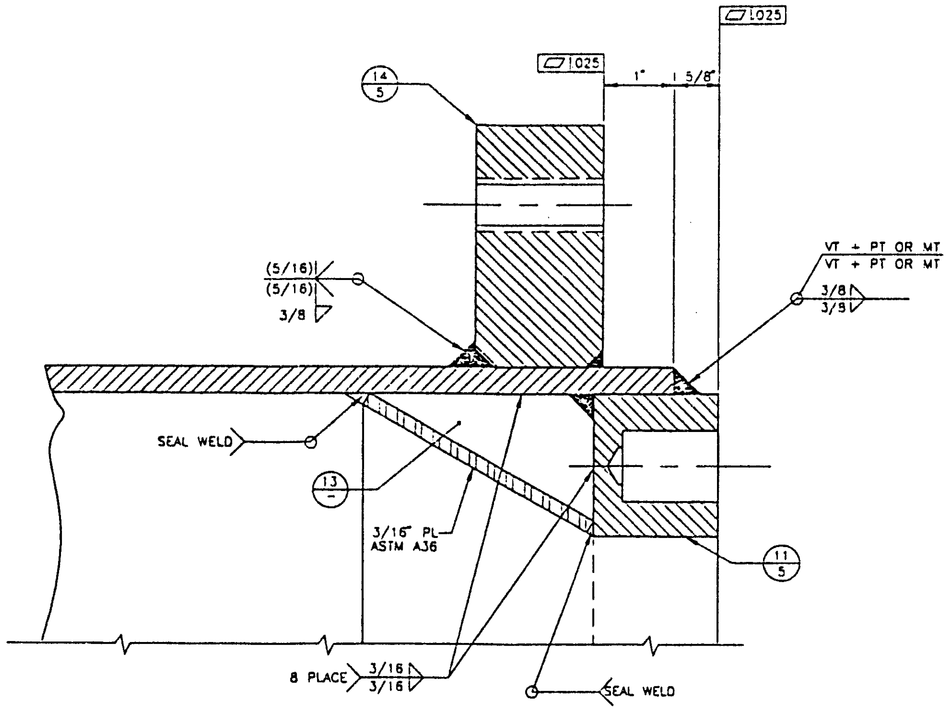
U.S. DEPARTMENT OF ENERGY
DOE Field Office, Richland
Westinghouse Hanford Company

49' X 52" DIAMETER TRANSPORT ASSEMBLY FLANGE DETAILS

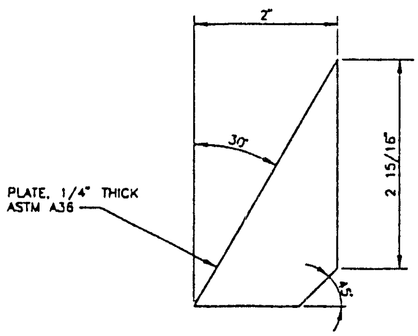
F 200C 2302 H-2-83724 0

SCALE SHOWN 700023 SHEET 5

REF NUMBER | TITLE
REFERENCES
DRAWING TRACEABILITY LIST
NEXT USED ON H-2-83724 SH1
REVISIONS
CADFILE 8083724E
CADCODE 003.5ACD2.12.53

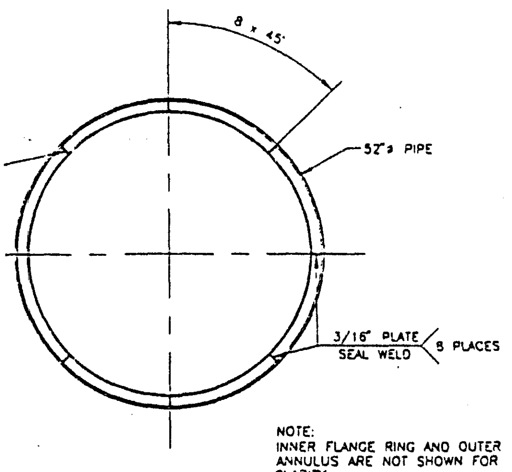



10
2
DETAIL
SCALE: FULL SIZE

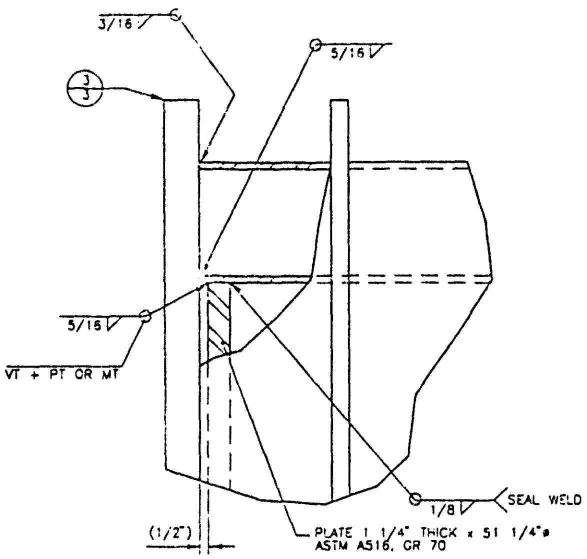



13
—
DETAIL (8 REQD)
SCALE: FULL SIZE

54-6000-027(5/89)




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




DETAIL 1/2
SCALE: 3" = 1'-0"

DATE MAY 23 1994

FOR GENERAL NOTES SEE SHEET 1

| | | |
|---|---|---|
| DRAWN | SW WILLIS | 12/93 |
| CHECKED | D. KANENSI | 5-94 |
| | | 5-94 |
| COG ENGR | R BELLOMY | 12/93 |

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

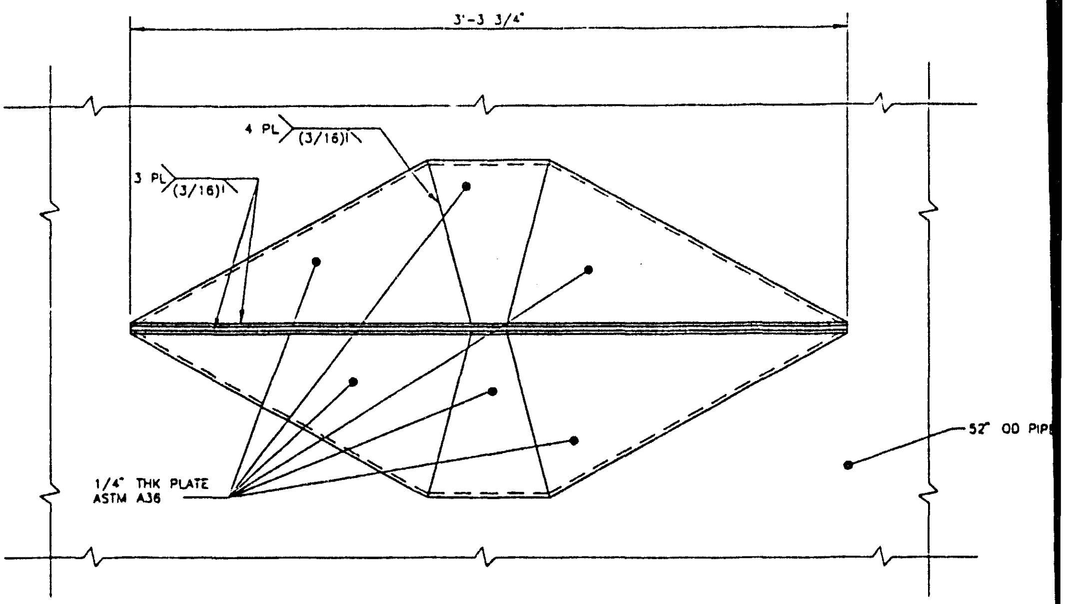
49' X 52" DIAMETER TRANSPORT ASSEMBLY DETAILS

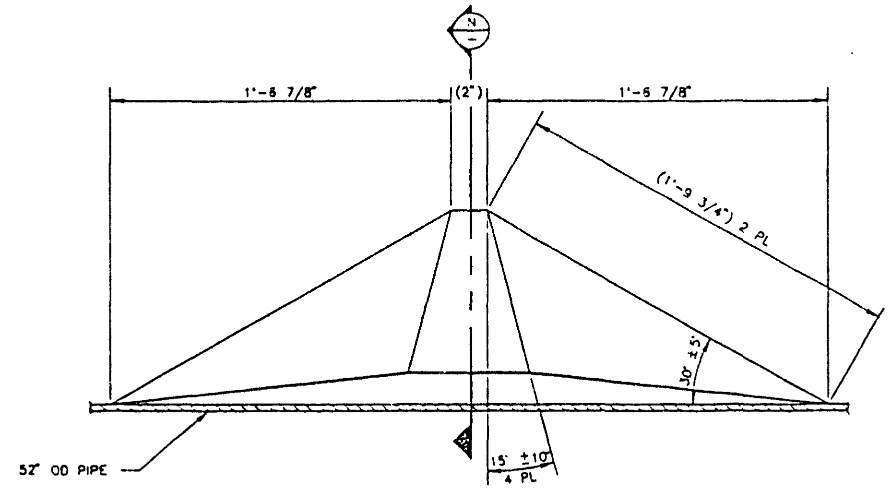
| SIZE | BLDG NO | INDEX NO | DWG NO | REV |
|---|---|---|---|---|
| F | 200G | 2302 | H-2-83724 | 0 |

SCALE SHOWN | 700023 | SHEET 6

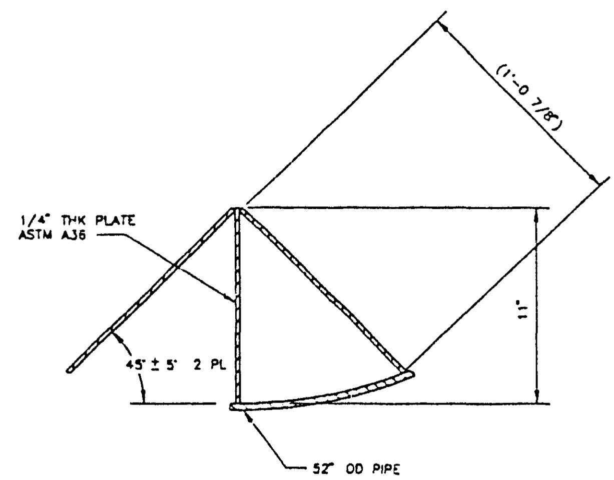
DRAWING TRACEABILITY LIST | NEXT USED ON H-2-83724 SH 1 | REFERENCES | REF NUMBER | TITLE

CADFILE E083724F | CADCODE DOS 5 ACD2:12:SS | REVISIONS



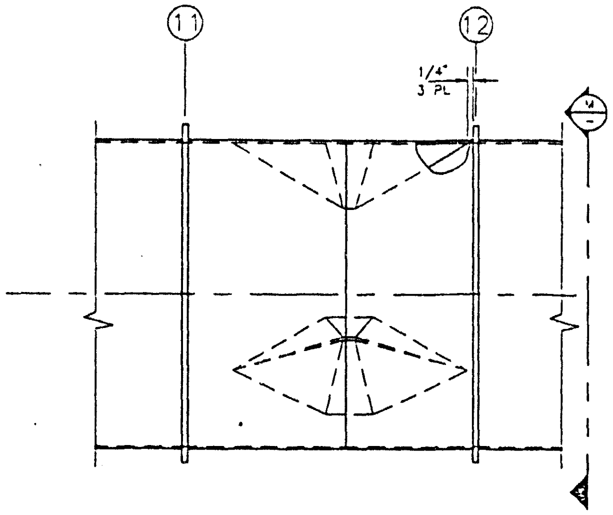




18 DETAIL
SCALE: 3" = 1'-0"

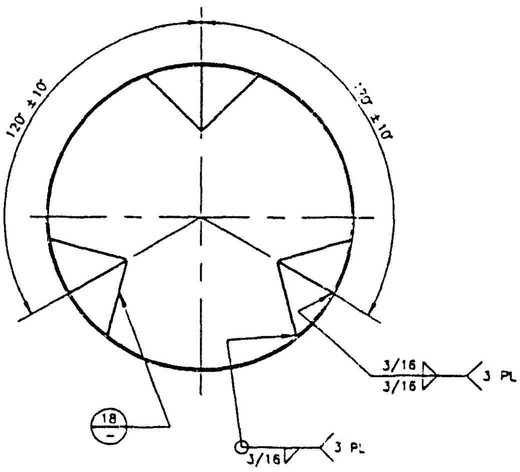



N SECTION
SCALE: 3" = 1'-0"

34-6000-327(5/83)




18/2 DETAIL
SCALE: 1" = 1'-0"




M/- SECTION
SCALE: 1" = 1'-0"

MAY 2 3 1994

FOR GENERAL NOTES SEE SH 1

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

49' X 52" DIAMETER TRANSPORT ASSEMBLY INTERNAL STOP

| | |
|---|---|
| DRAWN | KD JUNT |
| CHECKED | STAVENS 5-94 |
| DOE ENGR | JR BELLOMY 1-94 |

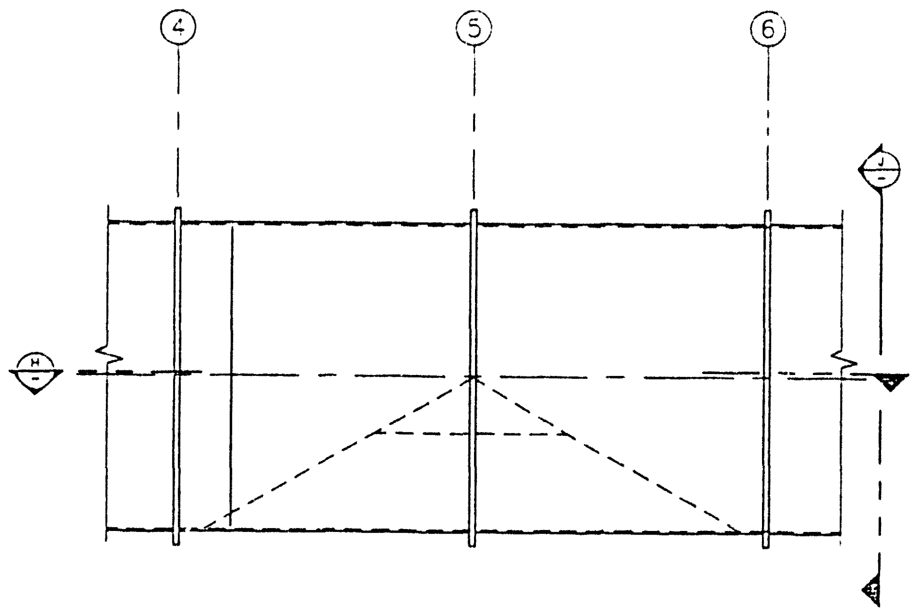
| SIZE | FSCM NO | INDEX NO | DWG NO | REV |
|---|---|---|---|---|
| F | 200G | 2302 | H-2-83724 | 0 |

SCALE SHOWN | 700023 | SHEET 7

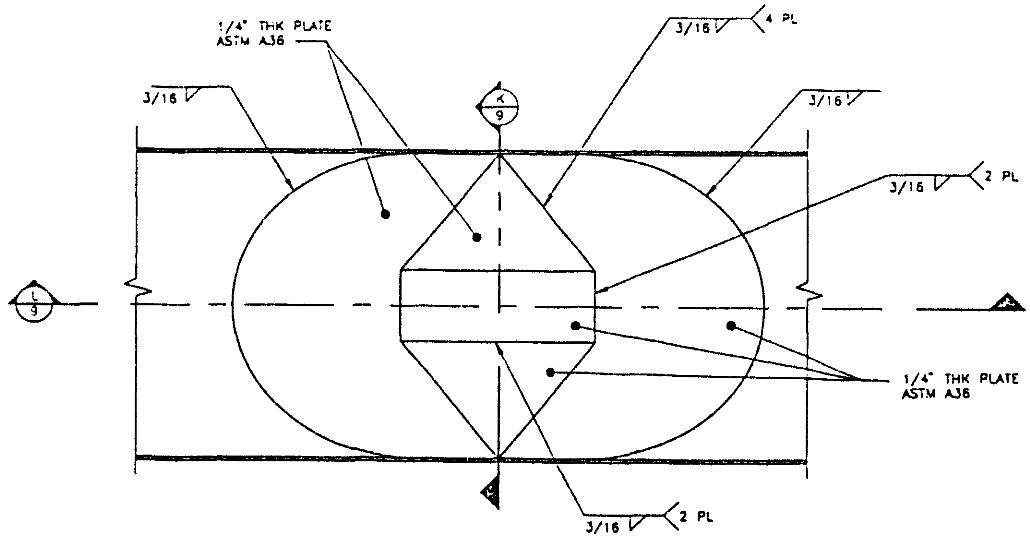
NEXT USED ON H-2-83724 SH 1

CADFILE E083724G | CADCODE DCS 5:AC02:12:00:SS

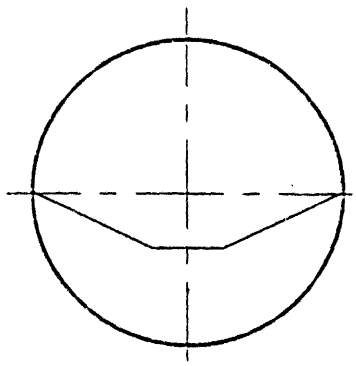
DRAWING TRACEABILITY LIST | REF NUMBER | TITLE | REVISIONS




15/2 DETAIL
SCALE: 1" = 1'-0"




H/— SECTION
SCALE: 1" = 1'-0"



J SECTION

SCALE: 1" = 1'-0"

FOR GENERAL NOTES SEE SH 1

| | |
|---|---|
| DRAWN: KD JUNT | 1-94 |
| CHECKED: D HAVENS | 5-94 |
| APPROVED: [illegible] | 5-94 |
| [illegible]: JR BELLOMY | 1-94 |

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

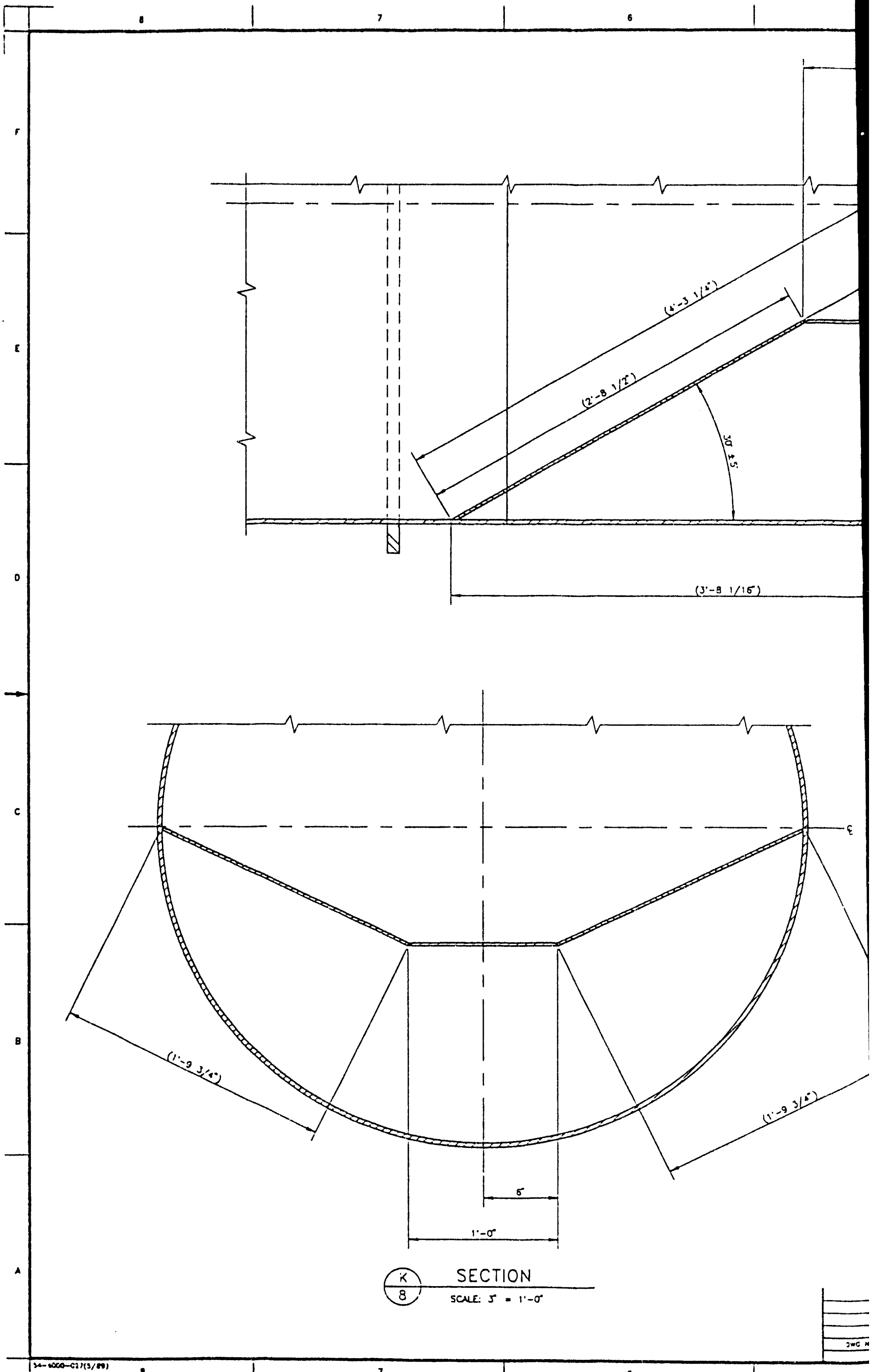
49' X 52" DIAMETER TRANSPORT ASSEMBLY INTERNAL SUPPORT

| SIZE | BLDG NO | INDEX NO | DWG NO | REV |
|---|---|---|---|---|
| F | 200G | 2302 | H-2-83724 | 0 |

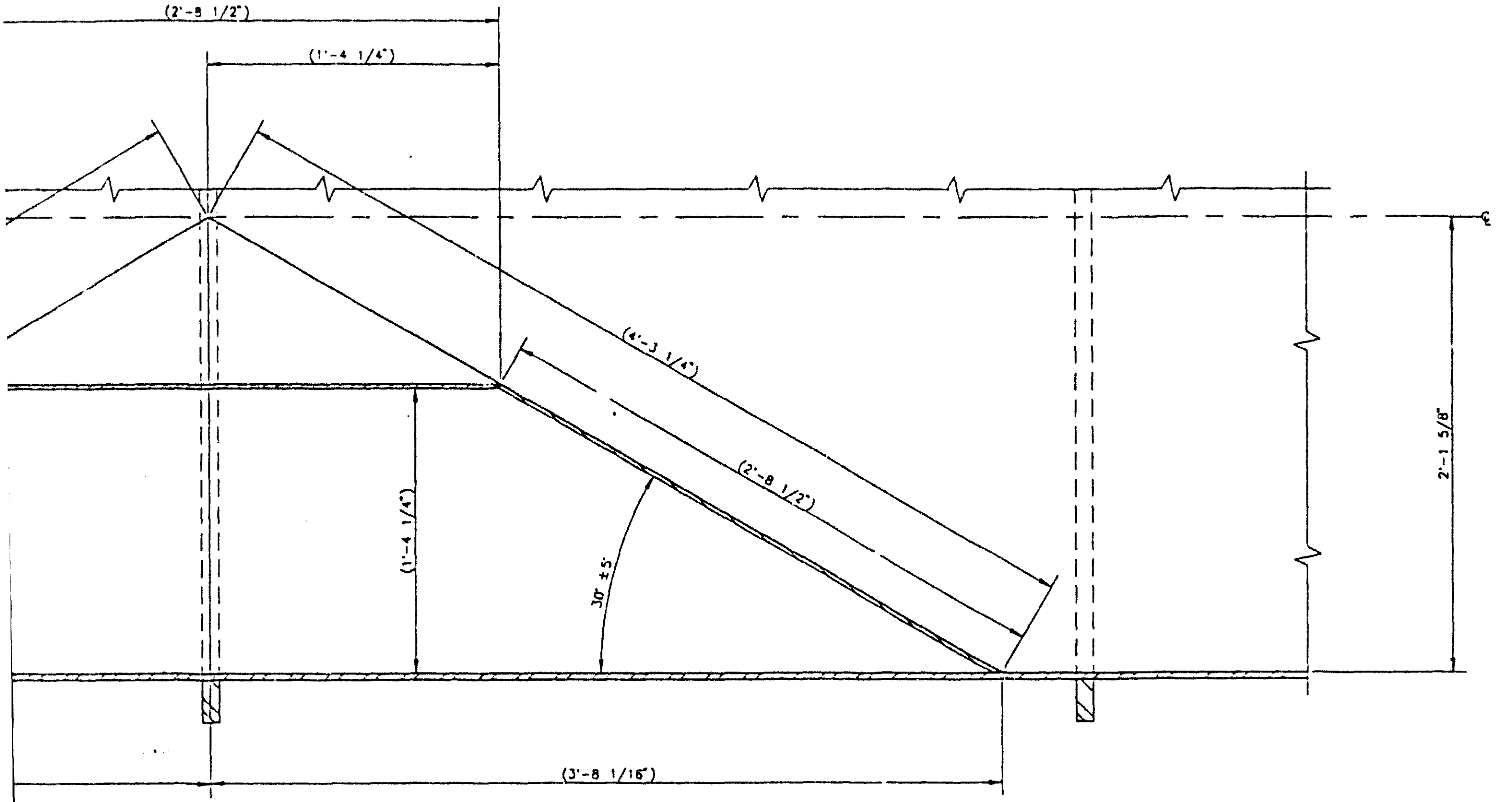
SCALE: SHOWN   700023   SHEET 8 OF

DRAWING TRACEABILITY LIST: NEXT USED ON H-2-83724 SH 1

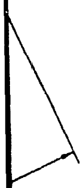
CADFILE 9083724H   CADCODE 225.5 AC02.12 CO 55



(4'-3 1/4")
(2'-8 1/2")
30° ±5°
(3'-8 1/16")
(1'-9 3/4")
(1'-9 3/4")
6"
1'-0"
K
8
SECTION
SCALE: 3" = 1'-0"




L/8 SECTION
SCALE: 3" = 1'-0"



FOR GENERAL NOTES SEE SH 1

| | |
|---|---|
| DRAWN | KD JUNT 1-94 |
| CHECKED | D. HAVENS 5-94 |
| CDS ENGR | JR BELLOMY 1-94 |

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

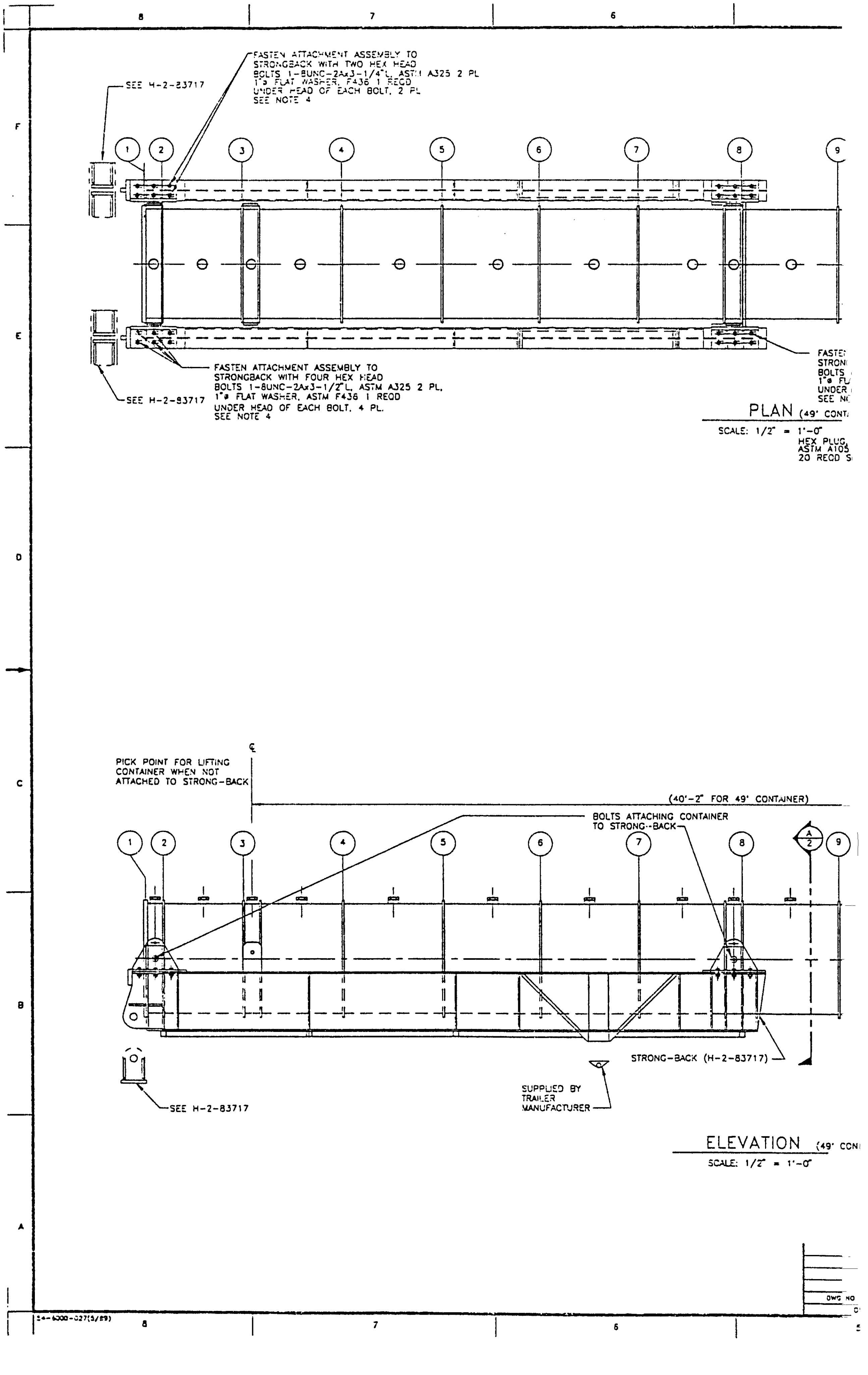
49' X 52" DIAMETER TRANSPORT ASSEMBLY INTERNAL SUPPORT

| SIZE | BLDG NO | INDEX NO | DWG NO | REV |
|---|---|---|---|---|
| F | 200G | 2302 | H-2-83724 | 0 |

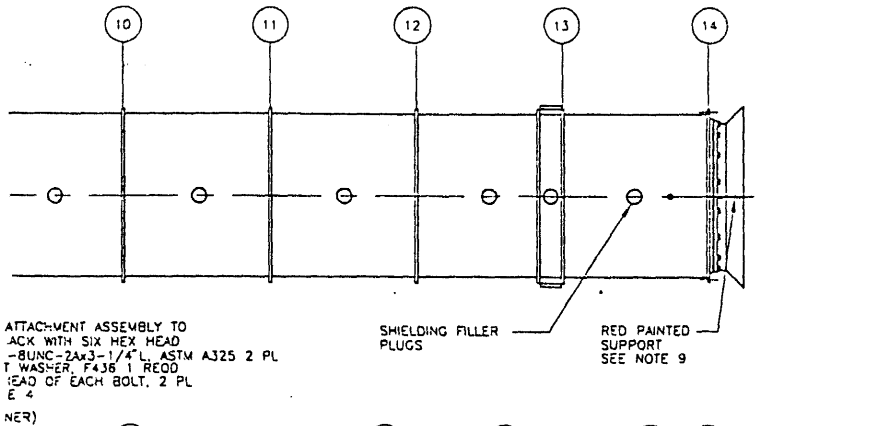
SCALE SHOWN | CPY 700023 | SHEET 9

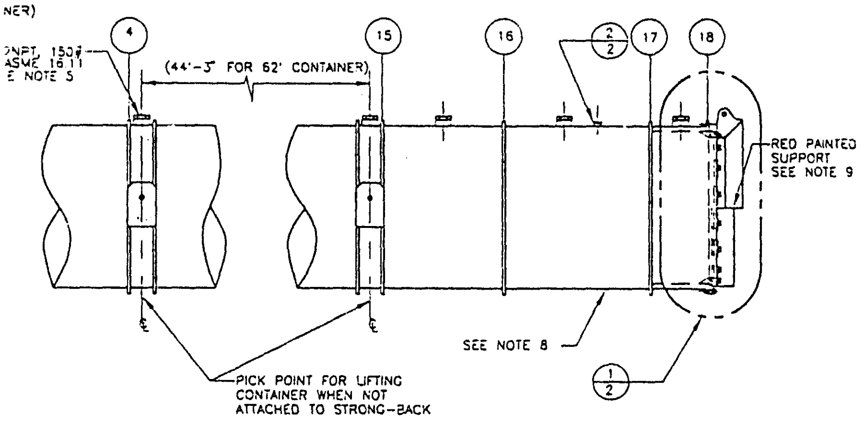
DRAWING TRACEABILITY LIST | NEXT USED ON H-2-83724 SH 1 | CADFILE 9083724J | CADCODE CDS 5 ACD2:12.00:SS

REVISIONS



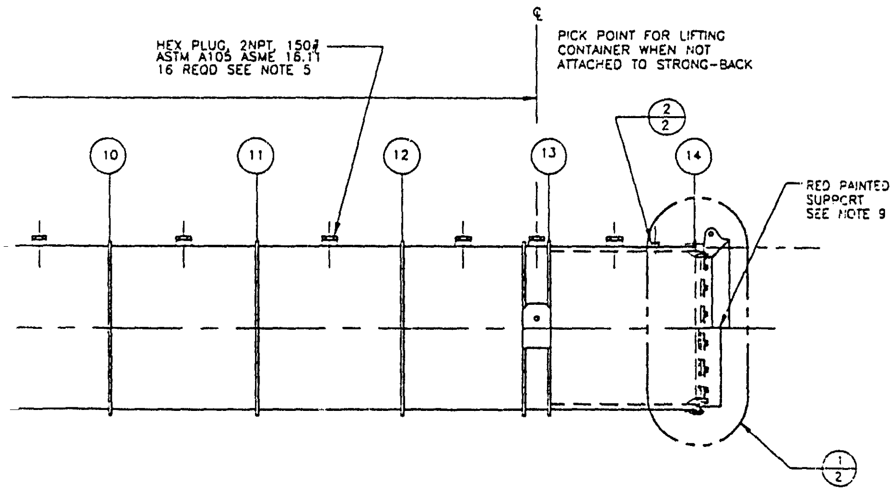
8
7
6
F
E
D
C
B
A
FASTEN ATTACHMENT ASSEMBLY TO STRONGBACK WITH TWO HEX HEAD BOLTS 1-8UNC-2Ax3-1/4"L. ASTM A325 2 PL 1"ø FLAT WASHER, F436 1 REQD UNDER HEAD OF EACH BOLT, 2 PL SEE NOTE 4
SEE H-2-83717
1
2
3
4
5
6
7
8
9
FASTEN ATTACHMENT ASSEMBLY TO STRONGBACK WITH FOUR HEX HEAD BOLTS 1-8UNC-2Ax3-1/2"L. ASTM A325 2 PL. 1"ø FLAT WASHER, ASTM F436 1 REQD UNDER HEAD OF EACH BOLT. 4 PL. SEE NOTE 4
SEE H-2-83717
PLAN (49' CONT
SCALE: 1/2" = 1'-0"
HEX PLUG, ASTM A105 20 REQD S
PICK POINT FOR LIFTING CONTAINER WHEN NOT ATTACHED TO STRONG-BACK
(40'-2" FOR 49' CONTAINER)
BOLTS ATTACHING CONTAINER TO STRONG-BACK
A 2
STRONG-BACK (H-2-83717)
SUPPLIED BY TRAILER MANUFACTURER
SEE H-2-83717
ELEVATION (49' CON
SCALE: 1/2" = 1'-0"
DWG NO
54-6300-027(5/89)




ELEVATION (62' CONTAINER)

SCALE: 1/2" = 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

   3/4"-10 UNC-2B ASTM A307 GR B = 118-128 ft/lbs
   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 A490 BOLTS FROM MANUAL OF STEEL CONSTRUCTION, ALLOWABLE STRESS DESIGN, 9TH EDITION. 1 1/2" ø BOLTS SHALL BE INSTALLED USING TURN--OF-NUT TIGHTENING METHOD, AS SPECIFIED IN 8(d). TIGHTEN BOLTS TO SNUG TIGHT CONDITION, THEN ROTATE NUT 1/3 TURN MORE ±30°. 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 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.
5. SHIELD WITH LEAD (Pb) SHOT OR STEEL SHOT. SHIELDING SHALL BE FIELD INSTALLED PER WHC-SD-TP-SEP-024.
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 49' CONTAINER SHALL BE SUPPORTED DURING STORAGE AT COLUMNS 2, 4, 5, 6, 8, 10, 12, AND 13. DURING TRANSPORT THE 49' CONTAINER SHALL BE SUPPORTED AT COLUMNS 2 AND 13.
   THE 62' CONTAINER SHALL BE SUPPORTED DURING STORAGE AT COLUMNS 2, 4, 6, 8, 10, 12, 14, AND 16. DURING TRANSPORT THE 62' CONTAINER SHALL BE SUPPORTED COLUMNS 2 AND 15.
8. CONNECTIONS OF THE 49' CONTAINER TO THE STRONGBACK AND SECTION A SHOWN IN THE PLAN AND ELEVATION OF THE 49' CONTAINER ARE THE SAME FOR THE 62' CONTAINER
9. FOR ALIGNMENT OF THE CONTAINER AND STRONG-BACK IN THE VERTICAL POSITION THE RED PAINTED SUPPORT ON THE TOP OF THE CONTAINER SHALL BE IN LINE WITH THE SHIELDING FILLER PLUGS. THE RED PAINTED SUPPORTS ON THE SIDES OF THE THE CONTAINER SHALL BE IN LINE WITH 1 1/2" BOLTS ATTACHING THE CONTAINER TO THE STRONG-BACK.
10. ALIGNMENT OF CONTAINER WITH STRONG-BACK AT ASSEMBLY: LONGITUDINAL CENTER LINES OF THE CONTAINER AND STRONG-BACK SHALL BE EQUAL ±1/8".
11. 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

| REF NUMBER | TITLE |
|---|---|
| WHC-SD-W320-DA-001 | SUPPORTING DOC |
| H-2-83731 | LIFTING BEAM |
| H-2-83717 | STRONG-BACK DRAWING |
| H-2-83722 | 52" DIA TOP CAP |
| H-2-83723 | 52" DIA TOP FUNNEL |
| H-2-83724 | 52" DIA MAIN ASSEMBLY |
| H-2-83725 | SUPPORT |
| H-2-83727 | 52" DIA BLIND FLANGE |

NEXT USED ON: END ITEM

DRAWING TRACEABILITY LIST

REVISIONS

CADFILE 8083726A | CADCODE DOS 5ACD2 12.00.SS

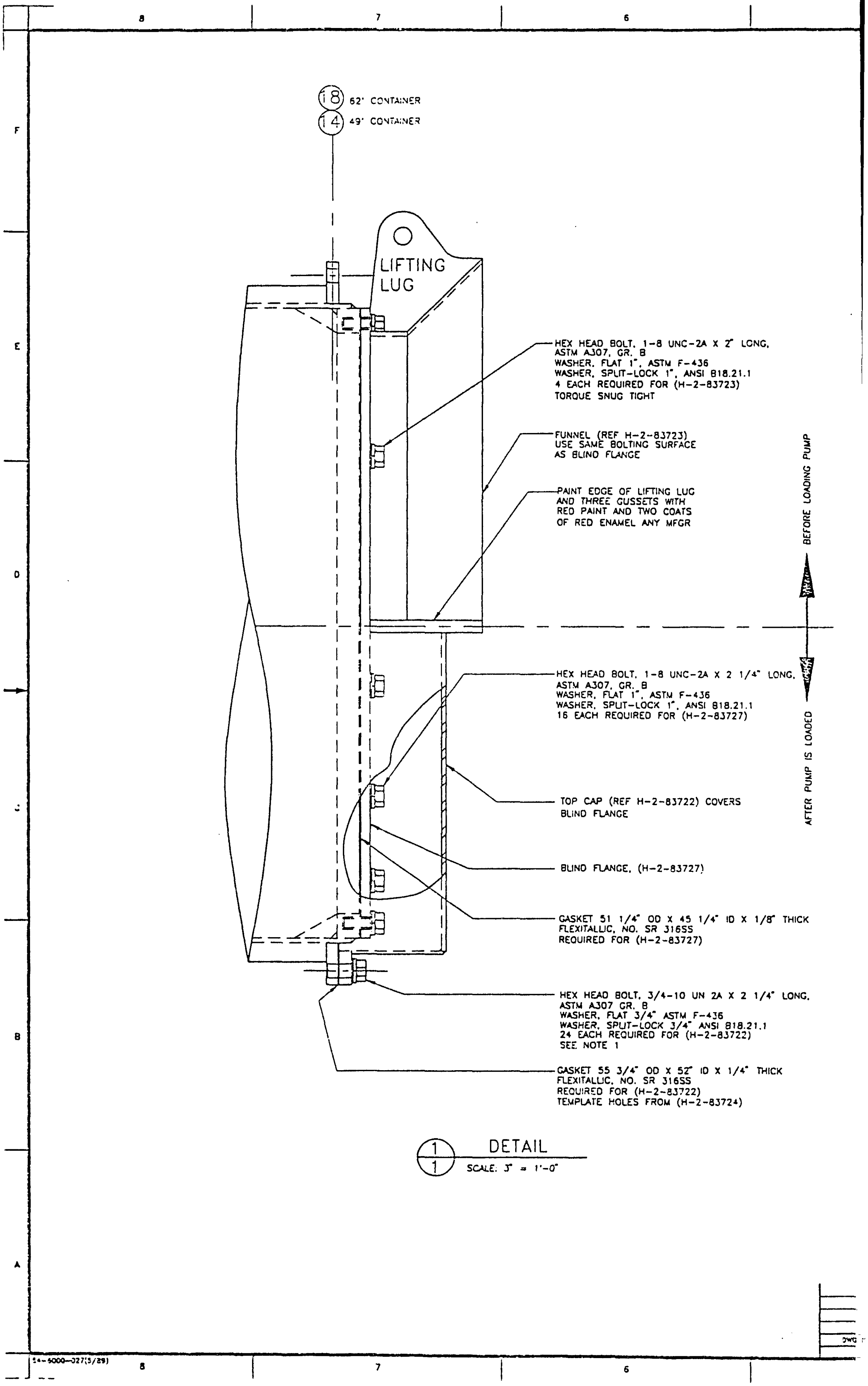
DRAWN SW WILLIS 1-94
CHECKED 1-94
JR BELLOMY 1-94

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

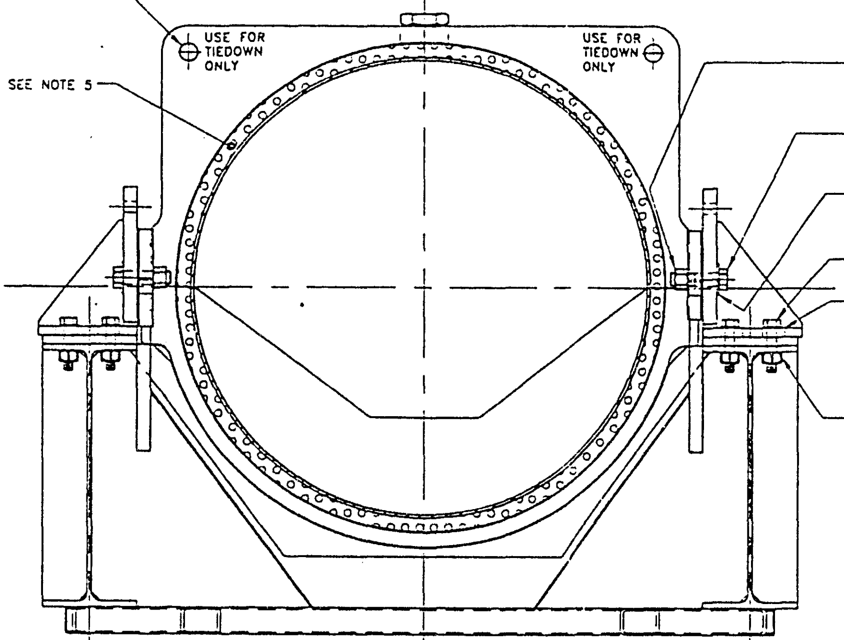
49'& 62'x 52" DIAMETER TRANSPORT ASSEMBLY ARRANGEMENT

SIZE F | 200C | 2303 | H-2-83726 | REV 0

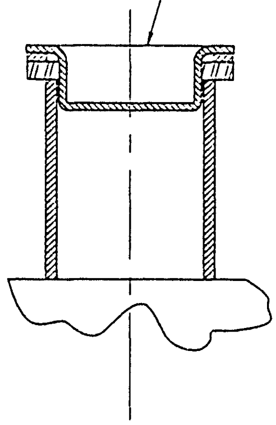
SCALE SHOWN | 700427 | SHEET 1 OF 3



8
7
6
F
E
D
C
B
A
18 62' CONTAINER
14 49' CONTAINER
LIFTING LUG
HEX HEAD BOLT, 1-8 UNC-2A X 2" LONG, ASTM A307, GR. B
WASHER, FLAT 1", ASTM F-436
WASHER, SPLIT-LOCK 1", ANSI B18.21.1
4 EACH REQUIRED FOR (H-2-83723)
TORQUE SNUG TIGHT
FUNNEL (REF H-2-83723) USE SAME BOLTING SURFACE AS BLIND FLANGE
PAINT EDGE OF LIFTING LUG AND THREE GUSSETS WITH RED PAINT AND TWO COATS OF RED ENAMEL ANY MFGR
BEFORE LOADING PUMP
AFTER PUMP IS LOADED
HEX HEAD BOLT, 1-8 UNC-2A X 2 1/4" LONG, ASTM A307, GR. B
WASHER, FLAT 1", ASTM F-436
WASHER, SPLIT-LOCK 1", ANSI B18.21.1
16 EACH REQUIRED FOR (H-2-83727)
TOP CAP (REF H-2-83722) COVERS BLIND FLANGE
BLIND FLANGE, (H-2-83727)
GASKET 51 1/4" OD X 45 1/4" ID X 1/8" THICK FLEXITALLIC, NO. SR 316SS REQUIRED FOR (H-2-83727)
HEX HEAD BOLT, 3/4-10 UN 2A X 2 1/4" LONG, ASTM A307 GR. B
WASHER, FLAT 3/4" ASTM F-436
WASHER, SPLIT-LOCK 3/4" ANSI B18.21.1
24 EACH REQUIRED FOR (H-2-83722)
SEE NOTE 1
GASKET 55 3/4" OD X 52" ID X 1/4" THICK FLEXITALLIC, NO. SR 316SS REQUIRED FOR (H-2-83722)
TEMPLATE HOLES FROM (H-2-83724)
1/1 DETAIL
SCALE: 3" = 1'-0"
54-5000-027(5/89)




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




2 DETAIL 1
SCALE: FULL SIZE

FOR GENERAL NOTES SEE SHEET 1

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

49'-62' X 52" DIAMETER TRANSPORT ASSEMBLY ARRANGEMENT

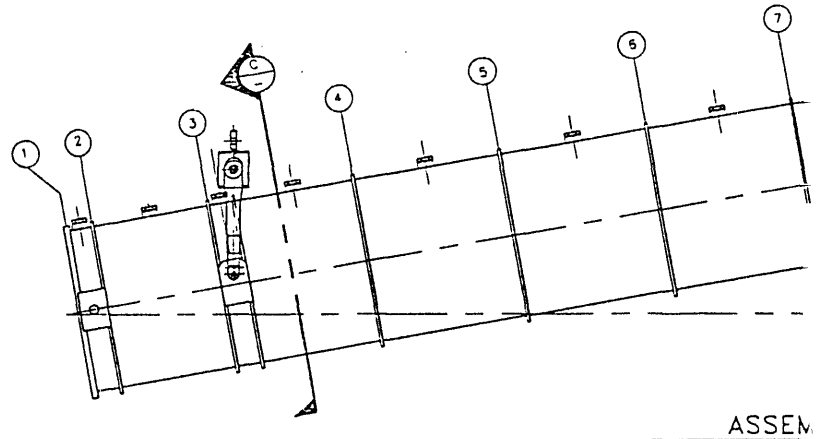
| | |
|---|---|
| DRAWN | SW WILLIS 4-94 |
| CHECKED | 6-94 |
| APPD | A WATSON 6/94 |
| DOE CHCK | JR BELLCMY 4-94 |

| SIZE | BLDG NO | INDEX NO | DWG NO | REV |
|---|---|---|---|---|
| F | 200C | 2302 | H-2-83726 | 0 |

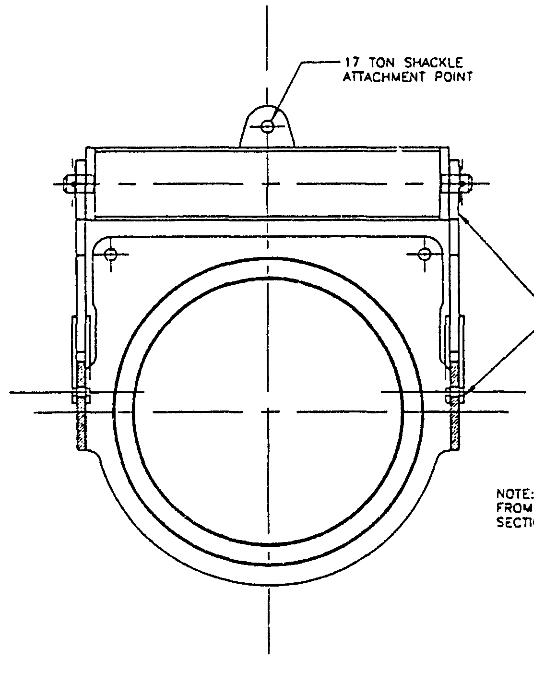
SCALE SHOWN | 700427 | SHEET 2

DRAWING TRACEABILITY LIST | NEXT USED ON SEE SHEET 1 | REF NUMBER | TITLE

REVISIONS | CADFILE 90837268 | CADCODE 00S 5 AC02:12:55

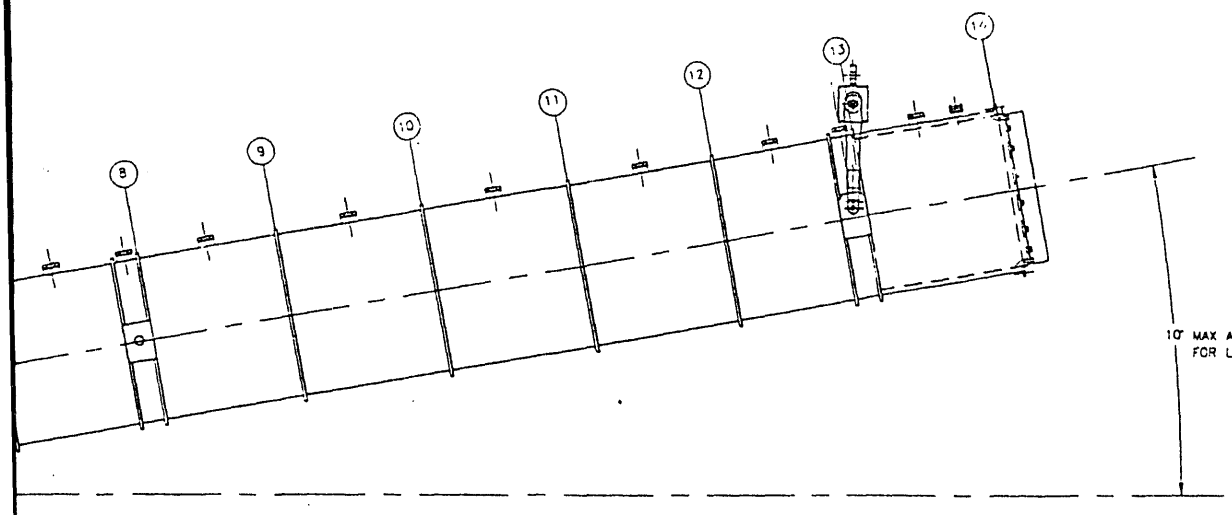



ASSEM
SCALE: 1/2"




NOTE: EMPTY CONTAINER MAY BE LIFTED FROM TIEDOWN LUGS SHOWN IN SECTION "A" ON SHEET 2.

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




BLY (49' CONTAINER)

1'-0"

NOTE: USE 10° MAX ANGLE FROM HORIZONTAL FOR 62' CONTAINER

FOR GENERAL NOTES SEE SHEET 1

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

49'-62' X 52" DIAMETER TRANSPORT ASSEMBLY ARRANGEMENT

DRAWN S.Y. WILLIS 1-7-94
JR BELLOMY 4-94

| SIZE | FSCM NO | INDEX NO | DWG NO | REV |
|---|---|---|---|---|
| F | 2000 | 2302 | H-2-83726 | 0 |

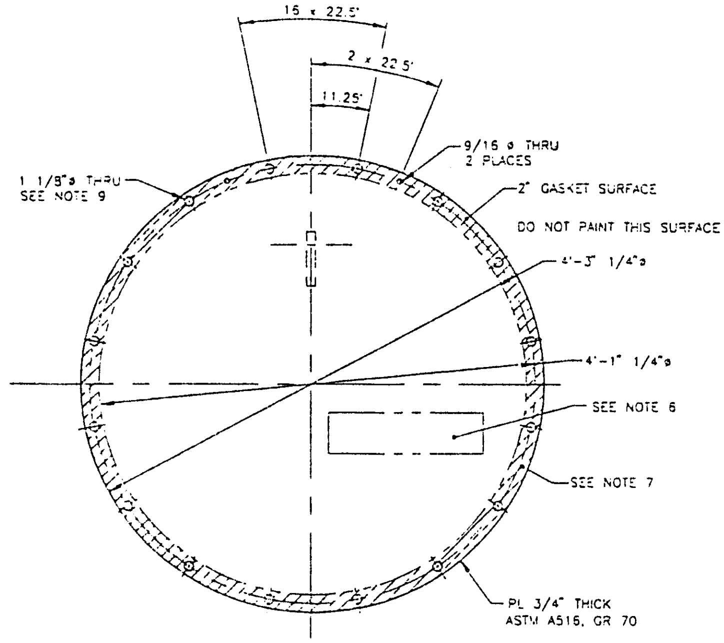
SCALE SHOWN SHEET 3

REF NUMBER | TITLE

DRAWING TRACEABILITY LIST | NEXT USED ON

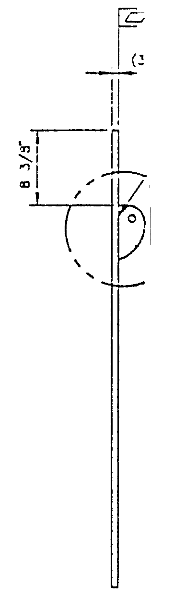
REVISIONS

CADFILE 6083726C CADCODE



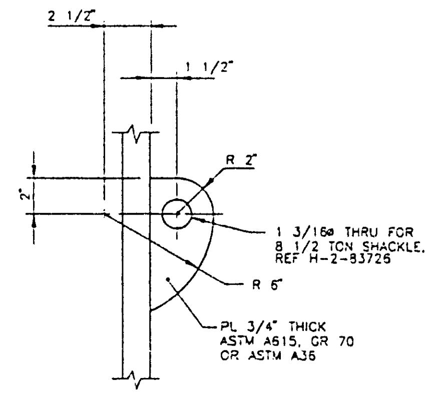

BLIND FLANGE

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




SIDE VI

SCALE: 1 1/2"




A DETAIL

SCALE: 3" = 1'-0"


## GENERAL NOTES (UNLESS OTHERWISE SPECIFIED)

1. TOLERANCING IN FRACTIONS ARE:
   FRAC ±1/16.
   TOLERANCING IN DECIMAL ARE PER ANSI Y14.5M-82
   DEC XX ±.01, XXX ±.005, ANLR ± 1°.
2. ALL MACHINED SURFACES 125√ IN ACCORDANCE WITH ANSI B46.1. (LATEST REV).
3. REMOVE ALL BURRS AND SHARP EDGES.
4. ALL MACHINED TOOL R .03 MAX.
5. WELD AND INSPECT PER AWS D1.1. VT ALL WELDS FINAL PASS. WELDER QUALIFICATION AND WELDING PROCEDURES PER ASME SECTION IX ARE AN APPROVED SUBSTITUTION.
6. MARK PER HS-BS-0015 TYPE 8, IN LOCATION INDICATED USING 1" HIGH BLACK CHARACTERS.
   DWG NO. & REV NO ____________
7. SURFACE PREPARATION SHALL BE IN ACCORDANCE WITH SSPC-SP-6, BY GRIT BLAST. PROTECT FLANGE SEAL SURFACES.
8. PAINT ALL EXTERIOR SURFACES PER FEDERAL SPEC BELOW, WITH 1 ZINC-RICH CHROMATE FREE PRIMER COAT TT-P-6640, FOLLOWED WITH 2 TOP COATS TT-E-489H. COLOR SHALL BE YELLOW. MIN DRY FILM THICKNESS SHALL BE 4.5 MIL. PAINT BOLT HOLES AS WELL AS POSSIBLE
9. TEMPLATE HOLES FROM FLANGE RING DETAIL 11, SHEET 5 OF H-2-83724
10. ALL SPECIFICATIONS SHALL MEET THE FOLLOWING REVISIONS:
    ASTM A36/A36M-92
    ASTM A516/A516M-90
11. MATERIAL SHALL BE MARKED SUCH THAT IT IS TRACEABLE TO THE CHEMICAL ANALYSIS & MECHANICAL TEST REPORTS.
12. HEAT NUMBER TRACEABILITY OF MATERIAL SHALL BE MAINTAINED.
13. DOCUMENT ALL WELDING ON KEH 0433 FORM

| REF NUMBER | TITLE |
|---|---|
| WHC-SD-W320-DA-001 | SUPPORT DOCUMENT |
| H-2-83726 | ARRANGEMENT DRAWING |

REFERENCES

DRAWING TRACEABILITY LIST

NEXT USED ON H-2-83726

REVISIONS — CADFILE 2083727A — CADCODE [illegible]

| | | |
|---|---|---|
| DRAWN | SW WILLIS | 12/93 |
| CHECKED | J. HAVENS | 5-94 |
| DFTG APVD | [illegible] | 5-94 |
| COG ENGR | JR BELLCMY | 12/93 |

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

# 52" DIAMETER TRANSPORT ASSEMBLY BLIND FLANGE

| SIZE | BLDG NO | INDEX NO | DWG NO | REV |
|---|---|---|---|---|
| F | 2000 | 2302 | H-2-83727 | 0 |

SCALE SHOWN — 700023 — SHEET 1 OF 1

### 9.2.2 WSSP-2 PACKAGING (TBD)

*NOTE: DRAWINGS FOR THE WSSP-2 PACKAGING WILL BE PROVIDED AT A LATER DATE BY ISSUE OF AN ECN AGAINST THIS SEP.*

## 9.3 SAFETY CLASS ASSIGNMENT

**Westinghouse Hanford Company** **Internal Memo**

From: Radiation Physics and Shielding 22570-HJG-94-005
Phone: 6-3765 H0-35
Date: January 6, 1994
Subject: TANKS 106-C AND 102-AY EQUIPMENT PACKAGING DOSE CONSEQUENCE ANALYSIS FOR SAFETY CLASS ASSIGNMENT

To: D. B. Calmus G2-02

cc: J. G. Field G2-02
J. Greenborg H0-35
R. L. Simons H0-35
S. R. Gedeon H0-35
HJG File/LB

References: Internal Memo 22570-HJG-94-001, H.J.Goldberg to D.B.Calmus, "Tanks 106-C and 102-AY Equipment Packaging Dose Consequence Analysis", 7 October 1993

The following analysis is a modification of the analysis referenced above that was developed to support evaluations in the Safety Evaluation for Packaging(SEP) for the 106-C project. The present analysis is to facilitate the assignment of a safety classification to the packages. The release is assumed to be an unmitigated release and thus 100% of the inventories have been assumed to have been released in the accident scenario. In addition, the onsite worker has been assumed to be 100 m from the accident. These criteria were made to conform to WHC-CM-6-1; Section EP-1.4 Rev. 1, "Standard Engineering Practices; Safety Classification".

In the previous analysis the waste was in a solid crystalline form. As per WHC-CM-6-1, 100% of this material was assumed to be released from the shipping container. In order to ascertain the fraction in the respirable range that becomes airborne, the material was assumed to be in a powder form when released. Since the time of the original analysis, several questions have arisen which will be discussed below.

It can be argued that 100% of release from the shipping container does not imply 100% release of the material from the pump surface. This material was washed with a 3,000 psi water spray. While it was decided that no credit would be taken for the cleaning effect of this spray process, it can easily be argued that any material that remains on the pump after this treatment is relatively fixed. It boggles the mind to imagine that material that is so fixed could be completely dislodged by a fall of a meter or so from the shipping container on the back of a truck.

In addition, only a fraction of these crystals would be crushed to a powder that is respirable ($\leq 1\mu$). An analysis of an FFTF assembly came to the conclusion that, at most, only about 10% of the fuel would be powdered by being crushed between a transport vehicle and a concrete floor. I can dig this number out of the literature, but in the time available for this epistle necessitates that I must rely on my memory.

I would think that, if an accident were to occur, the pump slides out of the damaged container, and a portion of it is crushed by the overturned truck, a conservative estimate of that portion of the attached crystalline material that is removed from the pump might be 50%.

Of this material, it is also quite conservative if we assume that half of that released material is crushed into a powder of a respirable sized particles. The rest will be in the form of larger crystals. While I do not have very much experience with this material and its form on removed equipment, I do recall reading reports about the removal of the air lance from the 101-SY tank.

In that operation, large chunks of material, some solid and some in a more liquid form, fell to the ground. From what I read of the solids in that case it is extremely unlikely that crystals of that size would have become airborne in less than a tornado. In addition it takes an active imagination to imagine a nostril capable of inhaling such chunks.

Thus, I would not find it difficult to estimate that 25%-30% of the material were to be released to the ground in the form of particles that are respirable. To this inventory, the previously applied airborne fraction would be available for inhalation by persons standing 100 m from the accident site. With these changes in the parameters of the problem, the doses to a worker and to the maximally exposed individual are as follows;

| Effective Dose Equivalent (EDE) | | |
|---|---|---|
| | Dose to Worker (rem) (onsite) | Dose to Individual (rem) (offsite) |
| 106-C Heel Pump | 3.3 | 0.03 |
| 106-C Transfer Pump | 0.45 | 0.0039 |
| 102-AY Agitator Pump | 2.0 | 0.036 |

Thus, it would seem that all of the packages analyzed are in safety class three. This conclusion is based on safety class criteria presented in EP 1.4 indicating that estimated releases less than 0.5 rem for offsite workers and greater than 5 rem for onsite workers are safety class two and releases less than 5 rem to onsite workers are safety class three.

Harvey J. Goldberg
Principal Engineer

CONCURRENCE: ______________________
Jess Greenborg, Manager
Radiation Physics and Shielding

**CHECKLIST FOR CALCULATION REVIEW AND APPROVAL**

Document Reviewed (Complete reference) Tanks 106-C and 102-AY Equipment Packaging Shielding Analysis for Safety Class Assignment

Author(s) Harvey Goldberg

CHECKLIST FOR CALCULATION REVIEW

| Yes | No | N/A | General Considerations |
|---|---|---|---|
| [✓] | [ ] | [ ] | Problem completely defined. |
| [✓] | [ ] | [ ] | Necessary assumptions explicitly stated and supported. |
| [ ] | [ ] | [✓] | Computer codes and data files documented. |
| [✓] | [ ] | [ ] | Data used in calculations explicitly stated in document. |
| [✓] | [ ] | [ ] | Data checked for consistency with original source information as applicable. |
| [✓] | [ ] | [ ] | Mathematical derivations checked including dimensional consistency of results. |
| [✓] | [ ] | [ ] | Models appropriate and used within range of validity or use outside range of established validity justified. |
| [✓] | [ ] | [ ] | Hand calculations checked for errors. |
| [ ] | [ ] | [✓] | Code runstreams correct and consistent with analysis documentation. |
| [ ] | [ ] | [✓] | Code output consistent with input and with results reported in analysis documentation. |
| [✓] | [ ] | [ ] | Acceptability limits on analytical results applicable and supported. Limits checked against sources. |
| [✓] | [ ] | [ ] | Safety margins consistent with good engineering practices. |
| [✓] | [ ] | [ ] | Conclusions consistent with analytical results and applicable limits. |
| [✓] | [ ] | [ ] | Results and conclusions address all points required in the problem statement. |

Reviewer Name: Stephen R. Gedeon
(print or type)

[signature] 6 Jan 94
Technical Reviewer Approval Date

Note: Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

# PART B - PACKAGE EVALUATION

## 1.0 INTRODUCTION

### 1.1 SAFETY EVALUATION METHODOLOGY

Part B of this Safety Evaluation for Packaging (SEP) will identify and evaluate acceptance criteria considered applicable to a short-term, waste transfer campaign of the WSSP-1 package and will evaluate the adequacy and acceptability of the WSSP-1 packaging and transportation systems described in Part A of this SEP. As noted in Part A, Section 1.0 of this SEP, information required for a full evaluation of the WSSP-2 packaging is not available at this time. In cases where information for the WSSP-2 is not available in this part of the SEP it will designated by "TO BE DETERMINED" (TBD).

The SEP will demonstrate that the short-term onsite transfer campaign will provide an equivalent degree of safety as would be provided by packages meeting the U.S. Department of Transportation (DOT)/U.S. Nuclear Regulatory Commission (NRC) safety requirements. Methodology used in this SEP to evaluate the WSSP-1 packaging and transport system was as following:

A. Methodology used to evaluate the acceptability of the packages for safe onsite transfers was to first, determine the probability of an accident during transfers, and second, 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 relied on approved dose consequence limits listed in WHC-SD-TP-RPT-001, *Report on Equivalent Safety for Transportation and Packaging of Radioactive Materials* (WHC 1994). 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 release limit. For the short mileage requirements evaluated in this SEP, the probability of an accident during transfer of all three packages was determined to be "incredible" (less than $10^{-6}$/yr). Reference to the equivalent safety document indicated that the applicable dose release limits for accidents in the incredible range of events is 25 rem/yr to an offsite individual. This information was then compared to results of a dose consequence study to determine if estimated releases following designated accident conditions were within the acceptable release 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 packages 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 packages for this short-term transfer campaign indicate that the proposed packaging/transportation system for the WSSP-1 package is considered safe for the intended use.

An accident frequency assessment of WSSP-1 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 $10^{-6}$/yr). This was based on transferring three packages a total of 21 miles.

A dose consequence study shows that radiation dose rates and the release of radionuclides that may spill in the incredible event of accident will not exceed approved risk acceptance limits of 25 rem/yr to an offsite individual.

Conditions relating to normal handling of the WSSP-1 packages 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 WSSP-1 packages 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 WSSP-1 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 transuranic (TRU) waste.

The tiedown system design and analysis was evaluated and determined to be adequate to assure that the packages will be properly secured to the vehicle during transfers.

A structural analysis of the WSSP-1 packaging indicated that lifting attachments on the packaging have sufficient strength to safely lift a fully loaded package in the horizontal position.

# 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 transported. Three major concerns relating to transporting 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 transported as a Type A or Type B quantity of material. If the package contents are a Type B quantity of radioactive material, a Safety Analysis Report for Packaging (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 effective $A_{2e}$ 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 transport as "fissile" or "fissile exempt." 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.

Table B2-1 was developed to indicate the activity of radionulclides estimated to be attached to each pump. The activity in curies is shown for an estimated ¼ in. thick film of waste tank material attached to specific areas of each pump. This is considered the "worst case" waste that will be attached to the pumps and will be used throughout this SEP to assure that packaging is properly evaluated for the intended use. Information used to develop Table B2-1 is shown in the Packaging Design Criteria (PDC) (WHC 1993).

Tables B2-2, B2-3, and B2-4 were developed to determine the effective $A_{2e}$ values for the mixture of radionuclides attached to each type of pump. As noted above, if the total curies of waste material attached to each pump is greater than the effective $A_{2e}$ value of the mixture, the waste equipment must be transferred as a Type B quantity of waste.

**Table B2-1. Radionuclide Activity for Waste Equipment.**

| 106-C Equipment | | | 102-AY Equipment | |
|---|---|---|---|---|
| Radionuclides | Heel Pump (Ci) | Transfer Pump (Ci) | Radionuclides | Agitator Pump (Ci) |
| $^{227}Ac$ | 2.41 E-04 | 3.46 E-05 | $^{241}Am$ | 5.69 E-01 |
| $^{241}Am$ | 7.82 E-01 | 1.13 E-01 | $^{14}C$ | 3.10 E-05 |
| $^{243}Am$ | 5.70 E-03 | 8.20 E-04 | $^{242}Cm$ | 1.60 E-09 |
| $^{14}C$ | 5.35 E-05 | 7.70 E-06 | $^{244}Cm$ | 1.97 E-02 |
| $^{242}Cm$ | 3.00 E-03 | 4.32 E-04 | $^{60}Co$ | 1.60 E-06 |
| $^{244}Cm$ | 3.58 E-02 | 5.17 E-03 | $^{137}Cs$ | 1.53 E-01 |
| $^{60}Co$ | 3.10 E-01 | 4.47 E-02 | $^{154}Eu$ | 1.60 E+00 |
| $^{137}Cs$ | 1.35 E+02 | 1.94 E+01 | $^{129}I$ | 3.70 E-05 |
| $^{154}Eu$ | 2.14 E+00 | 3.07 E-01 | $^{238}Pu$ | 3.56 E-02 |
| $^{129}I$ | 2.14 E-05 | 3.08 E-06 | $^{239,240}Pu$ | 1.13 E-01 |
| $^{59}Ni$ | 2.19 E-02 | 3.16 E-03 | $^{125}Sb$ | 3.09 E-01 |
| $^{63}Ni$ | 2.49 E+00 | 3.57 E-01 | $^{79}Se$ | 1.70 E-04 |
| $^{210}Pb$ | 8.03 E-05 | 1.16 E-05 | $^{90}Sr$ | 9.24 E+02 |
| $^{210}Po$ | 5.36 E-07 | 7.70 E-08 | $^{99}Tc$ | 7.8 E-04 |
| $^{238}Pu$ | 1.16 E-01 | 1.67 E-02 | | |
| $^{239}Pu$ | 6.42 E-01 | 9.25 E-02 | | |
| $^{242}Pu$ | 1.07 E-04 | 1.54 E-05 | | |
| $^{226}Ra$ | 1.33 E-03 | 1.93 E-04 | | |
| $^{125}Sb$ | 1.52 E+00 | 2.19 E-01 | | |
| $^{79}Se$ | 2.54 E-04 | 3.66 E-05 | | |
| $^{90}Sr$ | 5.30 E+02 | 7.63 E+01 | | |
| $^{99}Tc$ | 3.75 E-02 | 5.39 E-03 | | |
| $^{233}U$ | 1.52 E-05 | 2.16 E-06 | | |
| $^{234}U$ | 9.1 E-05 | 1.31 E-05 | | |
| $^{235}U$ | 3.4 E-06 | 4.97 E-07 | | |
| $^{236}U$ | 1.83 E-06 | 2.64 E-07 | | |
| $^{238}U$ | 8.25 E-05 | 1.19 E-05 | | |

## Table B2-2. Effective $A_2$ -- 106-C Heel Pump.

| Radionuclide | $A_2$ Limit (Ci) | Heel Pump (Ci) | $f_i$ | $f_i/A_2$ |
|---|---|---|---|---|
| $^{227}Ac$ | 0.003 | 2.41 E-04 | 3.58 E-07 | 0 |
| $^{241}Am$ | 0.008 | 7.82 E-01 | 1.2 E-03 | 0.145 |
| $^{243}Am$ | 0.008 | 5.70 E-03 | 8.46 E-06 | 0.001 |
| $^{14}C$ | 60 | 5.35 E-05 | 7.90 E-08 | 0 |
| $^{242}Cm$ | 0.2 | 3.00 E-03 | 4.45 E-06 | 0 |
| $^{244}Cm$ | 0.01 | 3.58 E-02 | 5.32 E-05 | 0.0053 |
| $^{60}Co$ | 7 | 3.10 E-01 | 4.60 E-04 | 0 |
| $^{137}Cs$ | 10 | 1.35 E+02 | 2.00 E-01 | 0.020 |
| $^{154}Eu$ | 5 | 2.14 E+00 | 3.17 E-03 | 0 |
| $^{129}I$ | 2 | 2.14 E-05 | 3.17 E-08 | 0 |
| $^{59}Ni$ | 900 | 2.19 E-02 | 3.25 E-05 | 0 |
| $^{63}Ni$ | 100 | 2.49 E+00 | 3.69 E-03 | 0 |
| $^{210}Pb$ | 0.2 | 8.03 E-05 | 1.19 E-07 | 0 |
| $^{210}Po$ | 0.2 | 5.36 E-07 | 7.80 E-10 | 0 |
| $^{238}Pu$ | 0.003 | 1.16 E-01 | 1.72 E-04 | 0.0574 |
| $^{239}Pu$ | 0.002 | 6.42 E-01 | 9.53 E-04 | 0.476 |
| $^{242}Pu$ | 0.003 | 1.07 E-04 | 1.58 E-07 | 0 |
| $^{226}Ra$ | 0.05 | 1.33 E-03 | 1.57 E-06 | 0 |
| $^{125}Sb$ | 25 | 1.52 E+00 | 2.20 E-03 | 0 |
| $^{79}Se$ | N/A | 2.54 E-04 | 0 | 0 |
| $^{90}Sr$ | 0.4 | 5.30 E+02 | 7.87 E-01 | 1.968 |
| $^{99}Tc$ | 25 | 3.75 E-02 | 5.50 E-05 | 0 |
| $^{233}U$ | 0.1 | 1.52 E-05 | 2.2 E-08 | 0 |
| $^{234}U$ | 0.1 | 9.1 E-05 | 1.3 E-07 | 0 |
| $^{235}U$ | 0.2 | 3.4 E-06 | 5.0 E-09 | 0 |
| $^{336}U$ | 0.2 | 1.83 E-05 | 2.6 E-09 | 0 |
| $^{328}U$ | UNLIM. | 8.25 E-05 | 1.22 E-07 | 0 |
| TOTALS | | 673.09 | 1.00 | 2.673 |
| EFFECTIVE $A_2$ | | | | 0.373 |

Note: The effective $A_2$ value is 1/2.673 = 0.373 Ci. The total curies are greater than the effective $A_2$ value; therefore, the new transfer pump must be transferred as a Type B quantity of waste. The total activity in terms of $A_2$ is 673/0.373 = 1804 $A_2$.

## Table B2-3. Effective $A_2$ -- 106-C Transfer Pump.

| Radionuclide | $A_2$ Limit (Ci) | Transfer Pump (Ci) | $f_i$ | $f_i/A_2$ |
|---|---|---|---|---|
| $^{227}Ac$ | 0.003 | 3.46 E-05 | 3.49 E-07 | 0 |
| $^{241}Am$ | 0.008 | 1.13 E-01 | 1.10 E-03 | 0.142 |
| $^{243}Am$ | 0.008 | 8.20 E-04 | 8.30 E-06 | 0.001 |
| $^{14}C$ | 60 | 7.70 E-06 | 7.70 E-08 | 0 |
| $^{242}Cm$ | 0.2 | 4.32 E-04 | 4.36 E-06 | 0 |
| $^{244}Cm$ | 0.01 | 5.17 E-03 | 5.20 E-05 | 0.005 |
| $^{60}Co$ | 7 | 4.47 E-02 | 4.5 E-04 | 0 |
| $^{137}Cs$ | 10 | 1.94 E+01 | 1.96 E-01 | 0.019 |
| $^{154}Eu$ | 5 | 3.07 E-01 | 3.1 E-03 | 0 |
| $^{129}I$ | 2 | 3.08 E-06 | 3.1 E-08 | 0 |
| $^{59}Ni$ | 900 | 3.16 E-03 | 3.19 E-05 | 0 |
| $^{63}Ni$ | 100 | 3.57 E-01 | 3.6 E-03 | 0 |
| $^{210}Pb$ | 0.2 | 1.16 E-05 | 1.16 E-07 | 0 |
| $^{210}Po$ | 0.2 | 7.70 E-08 | 7.7 E-10 | 0 |
| $^{238}Pu$ | 0.003 | 1.67 E-02 | 1.68 E-04 | 0.056 |
| $^{239}Pu$ | 0.002 | 9.25 E-02 | 9.3 E-04 | 0.476 |
| $^{242}Pu$ | 0.003 | 1.54 E-05 | 1.55 E-07 | 0 |
| $^{226}Ra$ | 0.05 | 1.93 E-04 | 1.9 E-06 | 0 |
| $^{125}Sb$ | 25 | 2.19 E-01 | 0.0022 | 0 |
| $^{79}Se$ | N/A | 3.66 E-05 | 0 | 0 |
| $^{90}Sr$ | 0.4 | 7.63 E+01 | 7.71 E-01 | 1.929 |
| $^{99}Tc$ | 25 | 5.39 E-03 | 5.45 E-05 | 0 |
| $^{233}U$ | 0.1 | 2.16 E-06 | 2.2 E-08 | 0 |
| $^{234}U$ | 0.1 | 1.31 E-05 | 1.16 E-07 | 0 |
| $^{235}U$ | 0.2 | 4.97 E-07 | 5.13 E-09 | 0 |
| $^{236}U$ | 0.2 | 2.64 E-07 | 2.72 E-09 | 0 |
| $^{238}U$ | UNLIM. | 1.19 E-05 | 1.22 E-07 | 0 |
| TOTALS | | 96.86 | 1.00 | 2.62 |
| EFFECTIVE $A_2$ | | | | 0.381 |

Note: The effective $A_2$ value is 1/2.62 = 0.381 Ci. The total curies are greater than the effective $A_2$ value; therefore, the transfer pump must be transferred as a Type B quantity of waste. The total activity in terms of $A_2$ is 96.86/0.381 = 254 $A_2$.

**Table B2-4. Effective $A_2$ -- 102-AY Agitator Pump.**

| Radionuclides | $A_2$ Limit (Ci) | Agitator Pump (Ci) | $f_i$ | $f_i/A_2$ |
|---|---|---|---|---|
| $^{241}Am$ | 0.008 | 5.69 E-01 | 6.13 E-04 | 0.076 |
| $^{14}C$ | 60 | 3.10 E-05 | 3.34 E-08 | 0 |
| $^{242}Cm$ | 0.2 | 1.60 E-09 | 1.73 E-12 | 0 |
| $^{244}Cm$ | 0.01 | 1.97 E-02 | 2.12 E-05 | 0.0021 |
| $^{60}Co$ | 7 | 1.60 E-06 | 1.73 E-09 | 0 |
| $^{137}Cs$ | 10 | 1.53 E-01 | 1.65 E-04 | 0 |
| $^{154}Eu$ | 5 | 1.60 E+00 | 1.72 E-03 | 0.00034 |
| $^{129}I$ | 2 | 3.70 E-05 | 3.99 E-08 | 0 |
| $^{238}Pu$ | 0.003 | 3.56 E-02 | 3.8 E-05 | 0.0128 |
| $^{239,240}Pu$ | 0.002 | 1.13 E-01 | 1.22 E-04 | 0.060 |
| $^{125}Sb$ | 25 | 3.09 E-01 | 3.33 E-04 | 0 |
| $^{79}Se$ | N/A | 1.70 E-04 | 0 | 0 |
| $^{90}Sr$ | 0.4 | 9.24 E+02 | 9.97 E-01 | 2.49 |
| $^{99}Tc$ | 25 | 7.8 E-04 | 0 | 0 |
| TOTALS | | 926.8 | 1.00 | 2.64 |
| EFFECTIVE $A_2$ | | | | 0.378 |

Note: The effective $A_2$ value is 1/2.64 = 0.378 Ci. The total curies are greater than the effective $A_2$ value; therefore, the agitator pump must be transferred as a Type B quantity of waste. The total activity in terms of $A_2$ is 926/0.378 = 2450 $A_2$.

In the three cases shown, the total estimated curies of material in the package contents is greater than the effective $A_{2e}$ value of the mixture of radionuclides indicating that all three pumps 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 $f_i$ a fraction of activity of nuclides in the mixture and $A_2$ is the appropriate Type A curie limit for each nuclide.

Fissile materials present in the waste are $^{238}$Pu, $^{239}$Pu, $^{233}$U, 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 B2-5 was developed to determine the total grams of fissile materials in each package evaluated in this SEP. The specific activity of $^{238}$Pu is 17 Ci/g, $^{239}$Pu is 6.2 x $10^{-2}$ Ci/g, $^{233}$U is 9.5 x $10^{-3}$ Ci/g and $^{235}$U is 2.1 x $10^{-6}$ Ci/g.

**Table B2-5. Fissile Content.**

| Waste Equipment | $^{238}$Pu | | $^{239}$Pu | | $^{233}$U | | $^{235}$U | |
|---|---|---|---|---|---|---|---|---|
| | Curies | Grams | Curies | Grams | Curies | Grams | Curies | Grams |
| Heel Pump | 1.2E-01 | 0.007 | 6.4E-01 | 10 | 1.5E-05 | .0016 | 3.4E-06 | 1.62 |
| Transfer Pump | 1.7E-02 | 0.001 | 9.2E-02 | 1.50 | 2.2E-06 | 0.0002 | 5.0E-07 | 0.24 |
| Agitator Pump | 3.6E-02 | 0.002 | 1.1E-01 | 1.80 | N/A | N/A | N/A | N/A |

As shown in Table B2-5, the total quantity of the radionuclides estimated to be attached to the heel pump is 11.6 g, the transfer pump is 1.7 g, and the agitator pump is 1.80 g. Radioactive waste is exempted from fissile classification if the total quantity of fissile components are less than 15 g (49 CFR 173) in each package. Under the conditions stated above, waste packages containing any one of the three pumps will be considered as "fissile exempt." Based on the "fissile exempt" 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 during removal.

For purposes of evaluating the packages for transport, 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 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 each type of equipment is shown in Table B2-1. The estimated maximum quantities of fissile materials for each type of equipment is shown in Table B2-5.

## 2.3 CONCLUSIONS

Package contents as characterized in the waste generation study shown in Part A of the PDC document (WHC 1993) and evaluated in this section of the SEP are considered to be properly identified and sufficiently analyzed to be considered acceptable for evaluation in this SEP.

# 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 packages 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 1994). 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 is shown in the *Report on Equivalent Safety for Transportation and Packaging of Radioactive Materials* (WHC 1994); however, for purposes of evaluations in this SEP, specific criteria data from the referenced document are shown in Table B3-1 below:

**Table B3-1. Risk Acceptance Criteria.**

| Accident Condition | Annual Accident Frequency | Dose Limits Onsite Worker | Dose Limits Offsite Individual |
|---|---|---|---|
| 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 (Part B, Section 3.6) was performed to determined the probability of an accident for the short-term transfer campaign described in this SEP. Results of the accident frequency assessment indicated that the short-term milage of this campaign precludes the activity from falling within the credible or probable frequency range for accidents. That is, the annual accident frequency for this transfer campaign was calculated to be $1.77 \times 10^{-7}$ indicating that the probability of an accident is considered incredible for the onsite transfer of the three packages described in this SEP. As noted in Table B3-1, only radiation release limits to an offsite individual are considered applicable for a calculated annual accident frequency of 1.77 x $10^{-7}$.

### 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 individual from a package in the unlikely event of an accident. Data sheets indicated that an offsite individual would be subjected to the following dose rates for an accident with an estimated 20% release of radioactive materials.

**Table B3-2. Expected Dose Consequences from Equipment Shipping Accidents.**

| Package Contents | Dose to Offsite Individual | |
|---|---|---|
| | EDE | Organ |
| 106-C Heel Pump | 0.019 | 0.18 Bone Surface |
| 106-C Transfer Pump | 0.0026 | 0.026 Bone Surface |
| 102-AY Agitator Pump | 0.023 | 0.26 Bone Surface |

### 3.5 RISK EVALUATION AND CONCLUSIONS

The calculated 0.019 rem release for the heel pump, 0.0026 rem release for the transfer pump, and 0.023 rem release for the agitator pump are well within the 25 rem limit for incredible accident conditions shown in Table B3-1 (acceptable release limits at the Hanford Site). The conclusions of this evaluation are that the identified radiological risks associated with the short-term transfers of radioactive materials in the WSSP-1 and WSSP-2 packages described in this SEP are considered to be acceptable.

## 3.6 ACCIDENT FREQUENCY

# PUMP TRANSPORT FROM C AND AY TANK FARMS TO CENTRAL WASTE COMPLEX AND T PLANT

## 1.0 INTRODUCTION

This report contains an accident frequency assessment for transferring packages containing contaminated equipment removed from Tanks 106-C and 102-AY to the Central Waste Complex (CWC) and eventually to T Plant for treatment/processing. The analysis assumes that each package will be transferred separately. 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 waste packages by trucks. The event tree 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 C tank farm and going East on 7th Street to Buffalo Ave. Turn South on Buffalo Ave. to 4th Street. Leaving the AY tank farm will put one on Buffalo Ave. also. Turn West on 4th Street and follow straight to the 200-W area. When one goes through the West main gate, one will be on 20th Street. Follow 20th Street to Beliot Ave. and turn North on Beliot Ave. Follow Beliot Ave to 23rd Street. Turn West on 23rd Street to Dayton Ave. On Daton Ave. turn South to the CWC. From the East area C farm, it is 6.8 miles to the CWC. From the West area AY tank farm, it is 6.6 miles. It has been estimated that it is an additional 0.25 miles from the CWC to T plant. Therefore, the total mileage for each trip is 7.05 and 6.85 miles each. 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 will be multiplied by these mileages 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 Figures 3-1 and 3-2 for pathway driven).

Figure 2-1. Onsite Transfer Pumps from C or AY Tank Farms.

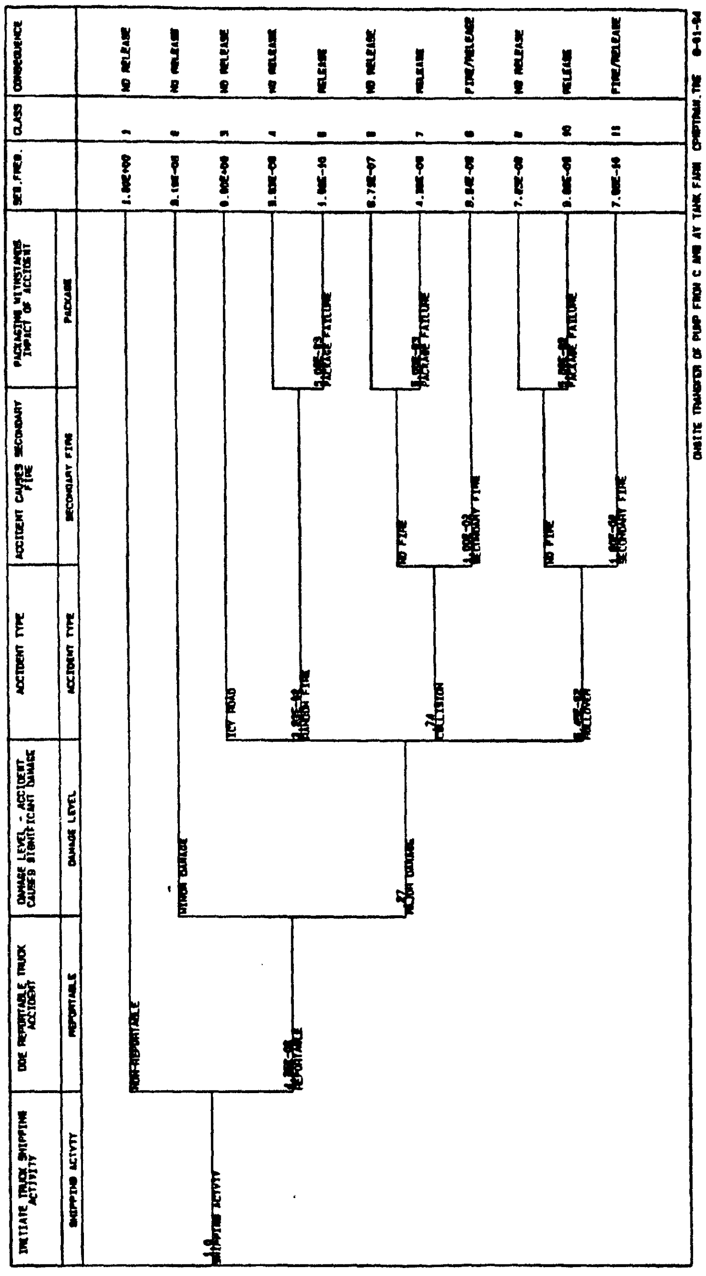


**Figure 3-1. Transportation of Pumps From AY to AX (200 East).**

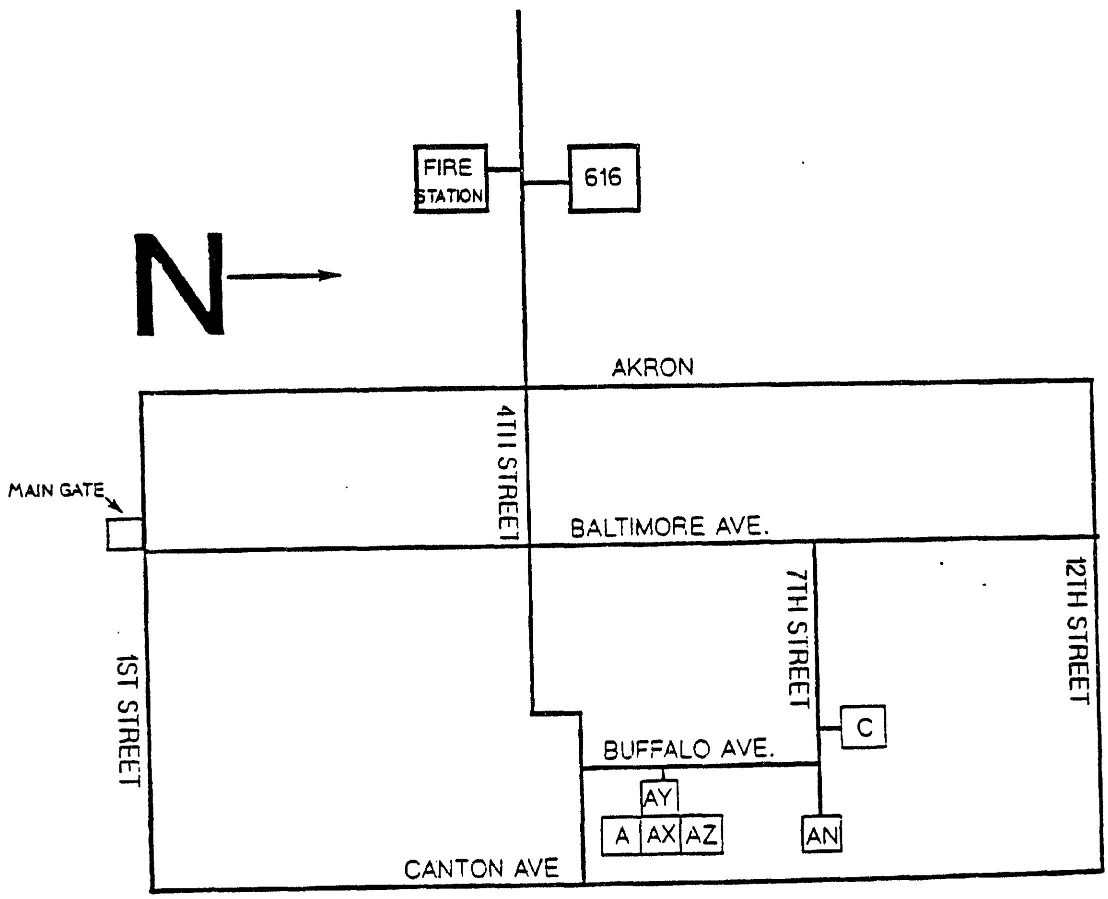
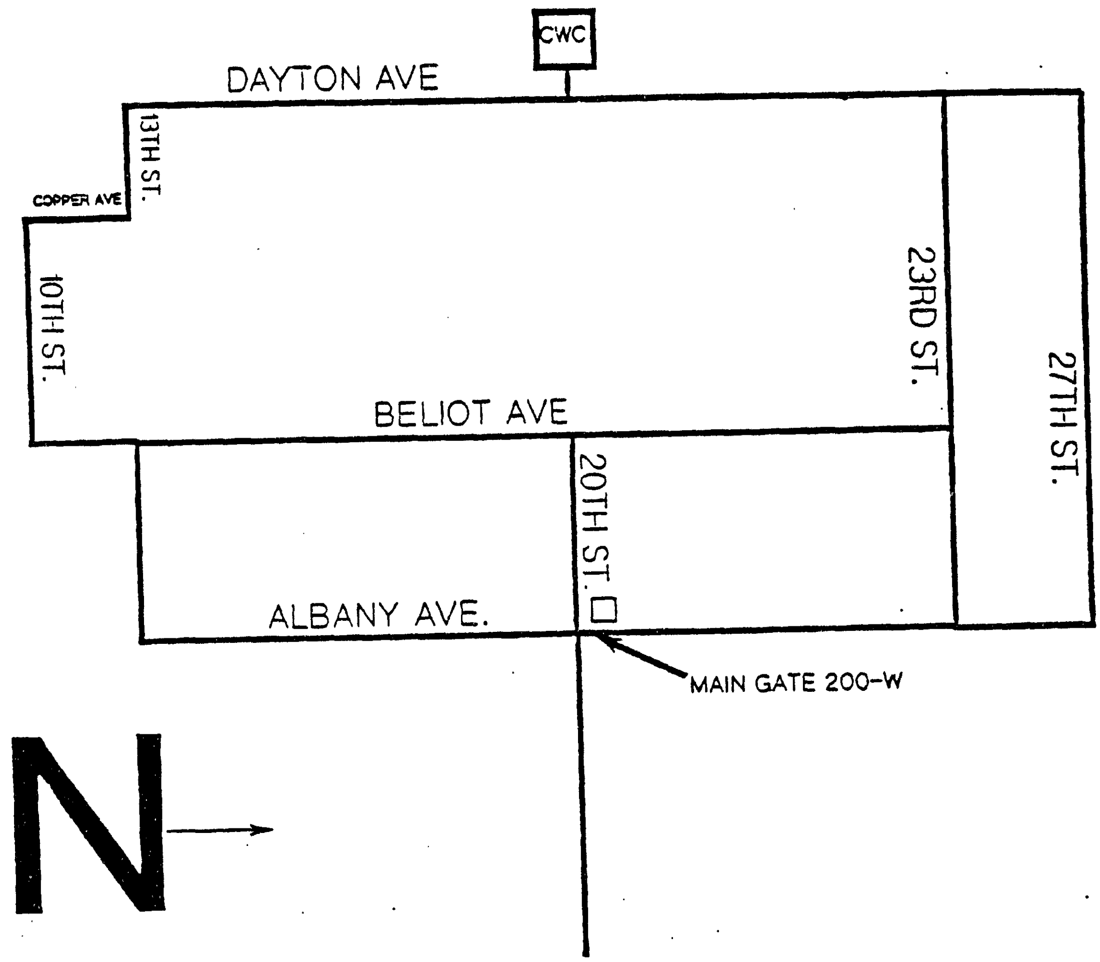


**Figure 3-2. Transportation of Pumps to 200 West.**



## 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 Appendix A for a list of the accidents and Appendix B for 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**, will be evaluated using the one percent data.

The final event, **PACKAGE**, on the event tree evaluates the proposed packaging. Based on the packaging design criteria, WHC-SD-TP-015, Draft, the heel pump located in tank 241-C-106 weighs 1730 lbs., the transfer pump in tank 241-C-106 weighs 1000 lbs., and the agitator pump in tank 241-AY-102 weighs 2000 lbs.. The packages for these pumps will be analyzed for a drop of one foot. The packages will be tied down to the vehicle. The tiedown assemblies 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 against movement in any direction have the aggregate static breaking strength of at least 1 1/2 times the weight of the package. 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 the random fire stress or collision at 5.0E-03, and 5.0E-02 due to a rollover. These values appear on the event tree. In the case of the random fire, it is presumed that the fire will be initiated on the tractor and not the trailer where the load is. If it is observed by the driver or escort, there would be time to stop the vehicle before the tiedowns might fail preventing the package from falling off the trailer and possibly being dropped beyond the one foot testing criteria.

## 4.1 EVENT TREE EVALUATION

Eleven accident sequences are defined by the event tree. Six of these result in no release. It should be noted that it was assumed that the transfer would not take place on icy road conditions. Three sequences result in a release, and two more result in a fire release. One of the combinations of releases is caused by a random fire where the fire is not controlled but the packaging remains in tact or the packaging fails due to the fire controlled. The accident frequency where the packaging has failed is 1.92E-10 per mile and results in a release. 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 a secondary fire has a frequency of 4.84E-09 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 7.88E-10 per mile with an uncontrolled fire. Summing the three accidents without a fire results in a frequency of 8.37E-09 accidents per mile. When this is multiplied by the worst case distance of 7.05 miles results in an accident frequency of 5.90E-08 per transfer. The two accidents with a fire release sum to 9.61E-09 accidents per mile. Again using 7.05 miles, results in a frequency of 6.77E-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

Clarke, R. K., *Severities of Transportation Accidents*, SLA-74-0001, Sandia Laboratories, Albuquerque, New Mexico, September 1976.

WHC-SD-TP-RPT-007, Standard Transportation Risk Assessment Methodology, December 20, 1993.

WHC-SD-TP-015, Accident Frequency Assessment Tanks 106-C and 102-AY Equipment Packaging, Draft June 25, 1993.

# APPENDIX A

## CASE NUMBERS AND BRIEF DESCRIPTIONS OF HANFORD TRUCK ACCIDENTS

## CASE NUMBERS AND BRIEF DESCRIPTIONS OF HANFORD TRUCK ACCIDENTS

† - Rollover
‡ - Collision
* - Fire
✓ - Icy Conditions

| | DATE | DESCRIPTION |
|---|---|---|
| 1. | 01/04/83 ✓ | Snow plow truck skidded on ice and struck private car while removing snow |
| 2. | 01/19/83 | Main gate struck truck while being driven to garage for repairs |
| 3. | 02/29/83 | Truck struck 2' riser while backing from area |
| 4. | 03/24/83 ‡ | Foot slipped off clutch due to existing back injury, truck struck barrier post |
| 5. | 04/21/83 | Paint stripper struck private car while backing up during paint activity |
| 6. | 05/12/83 | Fuel truck backed into Courier; driver did not monitor before backing |
| 7. | 05/31/83 | Post on fire truck caught against gate while exiting; bent fence post |
| 8. | 05/31/83 | Fire truck damaged when driver negotiated right turn from station |
| 9. | 06/08/83 | Truck struck parked vehicle while backing from building |
| 10. | 06/25/83 | Grab handles were torn off fire truck as it was driven through narrow lane |
| 11. | 06/28/83 | Spray truck backed into building while refueling in confined area |
| 12. | 07/15/83 | Pickup struck pole while being driven in reverse; damaged door panel |
| 13. | 07/16/83 | Driver of dump truck released brake and rolled into 2nd dump truck |
| 14. | 07/20/83 | Sample truck struck steam line in unspecified occurrence |
| 15. | 07/23/83 | Top of fire truck damaged when exiting before door had completely opened |
| 16. | 12/15/83 | Fire truck struck telephone pole while moving in reverse; operator error |
| 17. | 01/21/84 ✓ | Truck damaged while turning off icy road to deliver store material |
| 18. | 01/21/84 ✓ | Tractor/trailer jack-knifed on icy road; damaged cab and equipment |
| 19. | 01/26/84 | Truck damaged while backing up to loading dock; struck post |
| 20. | 02/24/84 | Backing into unloading door; struck government car and private car |
| 21. | 02/29/84 | Truck pulled out of parking lot and struck fire hydrant; inattentive driver |
| 22. | 11/02/84 | PUD truck backed into bump post and fire cabinet; congested area, no spotter |
| 23. | 02/01/85 ✓ | Truck slid out of control and struck gate post; snow-covered road |
| 24. | 02/25/85 | Water wagon struck utility pole and caused failure of ventilation fan |
| 25. | 04/25/85 | Truck backed into parked private vehicle; congested area |
| 26. | 05/08/85 ‡ | Struck private car during 3-car collision in construction area; no signs |
| 27. | 05/24/85 | Truck rolled down incline and struck dump truck; brake not set |
| 28. | 07/19/85 | Protruding doors on truck struck parked van while being backed in lot |
| 29. | 09/04/85 | Tractor trailer struck parked private vehicle in congested parking lot |
| 30. | 09/09/85 | Pickup struck corner of badge house while pulling out from road side |

| | | |
|---|---|---|
| 31. | 09/20/85 | Fire truck struck large rock while being backed from confined area |
| 32. | 11/05/85 | Fire truck struck telephone pole when driver attempted to reposition truck |
| 33. | 01/10/86 | Fire pumper struck rail on small bridge while attempting to exit |
| 34. | 03/14/86 | Lugger struck back of truck cab while being loaded |
| 35. | 04/10/86 † | Truck tipped over when rear wheels rolled off driveway depression |
| 36. | 06/25/86 | Truck struck steel post while backing to turn around |
| 37. | 07/01/86 | Fuel tank struck partially covered valve handle while backing tractor |
| 38. | 08/05/86 | Truck turned too short on narrow one-lane bridge and struck corner rail |
| 39. | 09/11/86 | Truck rounded corner and struck protruding roof support beam; driver error |
| 40. | 12/22/86 | Truck crane struck traffic light while being moved to equipment shops |
| 41. | 02/19/87 * | Lift bucket hydraulic fluid leaked and ignited |
| 42. | 04/16/87 † | Truck overturned when driver lost control while attempting to retrieve keys |
| 43. | 07/12/87 | Open compartment on fire truck struck door frame when driven from station |
| 44. | 07/31/87 | Truck contacted riser and damaged undercarriage |
| 45. | 08/11/87 | Truck struck and damaged section of boom crane while being backed |
| 46. | 04/22/88 | Truck struck light pole while being backed from driveway |
| 47. | 04/26/88 | Truck contacted overhead piping and damaged cargo during delivery |
| 48. | 05/04/88 | Pickup struck pole while being backed, damaging both vehicle and guy wire |
| 49. | 09/30/88 | Truck struck post when driver misjudged turning radius |
| 50. | 12/22/88 | Truck drove under steam line and totally destroyed air conditioner on top |
| 51. | 12/29/88 ‡ | Private car damaged when driver lost control while swerving to avoid GMC |
| 52. | 01/05/89 | Truck struck post and fire hydrant after crossing inclined railroad tracks |
| 53. | 01/20/89 ‡ | Truck struck metal post, breaking fiberglass on hood and denting bumper |
| 54. | 02/07/89 | Vehicle struck railroad crossing sign while being backed to access roadway |
| 55. | 03/03/89 | Metal detector on bed of truck struck overhead steam line during delivery |
| 56. | 04/21/89 | Truck struck against vehicle while being backed in parking lot |
| 57. | 06/15/89 | Truck struck parked private vehicle when driver failed to monitor area |
| 58. | 07/17/89 | Truck hoist I-beam severed power line when driver misjudged distance |
| 59. | 08/21/89 | Truck struck roll-up dock door when operator failed to fully open door |
| 60. | 11/17/89 | Truck struck parked private vehicle while being backed from driveway |
| 61. | 04/02/90 | Vehicle's tire tread separated while en route, striking fender and panel |
| 62. | 05/29/90 | Truck rolled and struck private vehicle when driver failed to secure brakes |
| 63. | 07/11/90 | Van struck partially closed door while being driven into fire station |
| 64. | 07/13/90 ‡ | Fender of private vehicle was struck by van crossing intersection |
| 65. | 08/07/90 ‡ | Door of towed unit hooked bumper of pickup, initiating 4-vehicle accident |

| | | |
|---|---|---|
| 66. | 08/23/90 | Truck with idle set too high shot backwards and struck private vehicle |
| 67. | 09/26/90 | Private vehicle backed and caught door |
| 68. | 10/14/90 | Backed into pole |
| 69. | 11/08/90 | Hit by another vehicle going in reverse |
| 70. | 11/26/90 ‡ | Hit by private vehicle |
| 71. | 12/19/90 | Backed into post |
| 72. | 01/11/91 ✓ | Slid through intersection and hit private vehicle |
| 73. | 02/20/91 | Boom crushed top of truck |
| 74. | 02/22/91 | Backed into by another vehicle |
| 75. | 02/28/91 | Drove vehicle into hole |
| 76. | 03/01/91 | Backed into pole |
| 77. | 03/07/91 | Hit underground radiation marker |
| 78. | 04/11/91 | Backed into forklift |
| 79. | 04/24/91 ‡ | Private vehicle ran red light and broadsided van |
| 80. | 05/13/91 | Open door caught on building |
| 81. | 05/17/91 | Private vehicle pulled in front of government vehicle |
| 82. | 06/25/91 | Lift ran into dumpster and pallet hit truck |
| 83. | 07/03/91 | Vehicle backed into another vehicle |
| 84. | 07/06/91 | Door caught shop door, employee hit gear |
| 85. | 07/09/91 | Backing private and government vehicles collided |
| 86. | 07/11/91 | Vehicle scraped gate |
| 87. | 08/10/91 | Backed into phone pole |
| 88. | 08/16/91 | Clipped road block |
| 89. | 09/19/91 | Backed into by water truck |
| 90. | 09/21/91 ‡ | Hit by deer |
| 91. | 09/28/91 ‡ | Ran into telephone pole |
| 92. | 10/01/91 ‡ | Hit fence swerving to avoid vehicle |
| 93. | 10/22/91 ‡ | Hit by private vehicle |
| 94. | 01/22/92 ‡ | Hit another government vehicle |
| 95. | 02/28/92 | Backed into another government vehicle |
| 96. | 03/12/92 | Bumper hooked hand rail upright when backing vehicle |
| 97. | 04/01/92 ‡ | Unknown cause, Repair left box and right tail lamp. Repair cost - $1,839 |
| 98. | 04/13/92 ‡ | Hit by private vehicle |
| 99. | 04/25/92 ‡ | Struck deer |
| 100. | 05/07/92 | Backed into pole |

| | | |
|---|---|---|
| 101. | 05/27/92 | Backed into pole |
| 102. | 06/01/92 ‡ | Government and private vehicles collided |
| 103. | 06/05/92 ‡ | Unknown cause, Repair front grill, bumper, and hood. Repair cost - $1,730 |
| 104. | 06/15/92 | Backed into pole |
| 105. | 07/13/92 | Backed into post - gas pedal stuck |
| 106. | 07/15/92 ‡ | Truck slid into fence |
| 107. | 07/18/92 ‡ | Turned too sharp and hit another government vehicle |
| 108. | 08/09/92 | Rear ended by private vehicle |
| 109. | 08/21/92 | Backed and scraped another government vehicle |
| 110. | 10/09/92 | Hit post with door |
| 111. | 10/20/92 ‡ | Hit steel (RR track) post |
| 112. | 11/05/92 ‡ | Collided with private vehicle |
| 113. | 11/17/92 ‡ | Hit deer |
| 114. | 12/07/92 | Hit by another government vehicle |

# APPENDIX B

## SUMMARY OF MILES TRAVELLED AT HANFORD BY GOVERNMENT VEHICLES

Summary of Miles Travelled at Hanford by Government Vehicles

Table B.1 Total Mileage and Accident Rate

| Year | Mileage | Accidents | | Accident Rate (Accidents/mile) | |
|---|---|---|---|---|---|
| | | Total | Major | Total | Major |
| 1983--1991 | 24,753,416<br>$2.5x10^{7}$ | 93 | 20 | $3.8x10^{-6}$ | $8.1x10^{-7}$ |
| 1992 | 1,249,617<br>$1.2x10^{6}$ | 21 | 11 | $1.7x10^{-5}$ | $8.8x10^{-6}$ |
| Total | 26,003,033<br>$2.6x10^{7}$ | 114 | 31 | $4.4x10^{-6}$ | $1.2x10^{-6}$ |

| SAFETY ANALYSIS AND REGULATION WORK PROCEDURES | Manual | WHC-CM-6-32 |
|---|---|---|
| | Section | WP-6.2 |
| | Appendix | A, REV 0 |
| | Page | 1 of 2 |
| TECHNICAL PEER REVIEWS AND HEDOP REVIEWS | Effective Date | March 31, 1992 |

**CHECKLIST FOR TECHNICAL PEER REVIEW**
**(Sheet 1 of 2)**

A. Document Reviewed: (include complete reference--author, addressee, letterbook number, title or description of calculation, document number, and date, as applicable): TRANSPORTATION RISK ASSESSMENT TANK FARM PUMPS

B. Scope of Review: COMPLETE REPORT

C.

| | Yes | No* | NA | |
|---|---|---|---|---|
| | [X] | [ ] | [ ] | Problem completely defined. |
| ✓ | [X] | [ ] | [ ] | Accident scenarios developed in a clear and logical manner. |
| ✓✓ | [X] | [ ] | [ ] | Necessary assumptions explicitly stated and supported. |
| | [ ] | [ ] | [X] | Computer codes and data files documented. |
| | [X] | [ ] | [ ] | Data used in calculations explicitly stated in document. |
| | [X] | [ ] | [ ] | Data checked for consistency with original source information as applicable. |
| | [X] | [ ] | [ ] | Mathematical derivations checked including dimensional consistency of results. |
| | [ ] | [ ] | [X] | Models appropriate and used within range of validity or use outside range of established validity justified. |
| | [ ] | [ ] | [X] | Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations. |
| | [ ] | [ ] | [X] | Software input correct and consistent with document reviewed. |
| | [ ] | [ ] | [X] | Software output consistent with input and with results reported in document reviewed. |
| ✓✓✓ | [X] | [ ] | [ ] | Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references. |
| | [ ] | [ ] | [X] | Safety margins consistent with good engineering practices. |
| | [X] | [ ] | [ ] | Conclusions consistent with analytical results and applicable limits. |

* All "NO" responses must be explained below or on an additional page.

**CHECKLIST FOR TECHNICAL PEER REVIEW**
**(Sheet 2 of 2)**

[X] [ ] [ ] Results and conclusions address all points required in the problem statement.

[X] [ ] ** Review calculations, comments, and/or notes are attached.

[X] [ ] Document approved (i.e., the reviewer affirms the technical accuracy of the document).

[ ] [ ] [X] Traceability

COMMENTS (Add additional signed and dated pages, if necessary):

(+) The description of the event tree top events is contained in parts of section 3.0 & 4.0.

(++) Some probability numbers appear to be assumptions but are not exactly called that.

(+++) The criteria of 1E-6/year is not referenced but it is common knowledge that this is the accepted criteria.

JOHN E KELLY John E Kelly — 10/8/93
AUTHOR — DATE

Thomas B. Powers — 10/11/93
Reviewer (Printed Name and Signature) — Date
THOMAS B. POWERS

** Any calculations, comments, or notes which the reviewer feels should be part of the review record should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

## 3.7 DOSE CONSEQUENCE ANALYSIS DATA SHEETS

**Westinghouse Hanford Company** **Internal Memo**

From: Radiation Physics and Shielding 8D530-HJG-94-024
Phone: 6-3765 H0-35
Date: August 3, 1994
Subject: TANKS 106-C AND 102-AY EQUIPMENT PACKAGING DOSE CONSEQUENCE ANALYSIS

To: D. B. Calmus G2-02

cc: J. G. Field G2-02
J. Greenborg H0-35
HJG File/LB

### The Problem

The introduction of a waste sluicing system in tanks 106-C and 102-AY has necessitated the removal and disposal of two pumps from 106-C and one pump from 102-AY. These pumps will be shipped from the 200-East area to the Central Waste Complex in the 200-West area and thence to T-Plant. An analysis was performed (22570-HJG-94-001)to ascertain the expected dose to the most exposed worker and to the hypothetical worst case farmer. Since that time it has been ascertained that the probability of the postulated accident is less than $10^{-6}$/yr. Thus, only the dose to the maximally exposed off site individual need be used. This report is an extraction of the necessary data from the original report which is appended for comoleteness.

### The Analysis

The dimensions of the pumps in centimeters, are given in WHC-SD-TP-PDC-015 as follows;

| | 106-C Heel Pump | 106-C Transfer Pump | 102-AY Agitator Pump |
|---|---|---|---|
| Maximum Length | 1,149 | 1,164 | 1,630 |
| Maximum Diameter | 91.5 | 80.5 | 107.8 |

The above cited document also documents worst case estimates of the isotopic inventory assuming a 0.32 cm thick layer of waste on each of the pumps. These are tabulated below;

| Radionuclide Inventory for Waste Equipment | | | |
|---|---|---|---|
| Isotopes | 106-C | | 102-AY |
| | Heel Pump (Bq) | Transfer Pump (Bq) | Agitator Pump (Bq) |
| $^{227}Ac$ | 8.92E+06 | 1.28E+06 | |
| $^{241}Am$ | 2.89E+10 | 4.18E+09 | 2.11E+10 |
| $^{243}Am$ | 2.11E+08 | 3.03E+07 | |
| $^{137m}Ba$* | 4.73E+12 | 6.79E+11 | 5.36E+09 |
| $^{210}Bi$* | 1.98E+04 | 2.85E+03 | |
| $^{14}C$ | 1.98E+06 | 2.85E+05 | 1.15E+06 |
| $^{242}Cm$ | 1.11E+08 | 1.60E+07 | 5.92E+01 |
| $^{244}Cm$ | 1.32E+09 | 1.91E+08 | 7.29E+08 |
| $^{60}Co$ | 1.15E+10 | 1.65E+09 | 5.92E+04 |
| $^{137}Cs$ | 5.00E+12 | 7.03E+11 | 5.66E+09 |
| $^{154}Eu$ | 7.92E+10 | 1.14E+10 | 5.92E+10 |
| $^{129}I$ | 7.92E+05 | 1.14E+05 | 1.37E+06 |
| $^{59}Ni$ | 8.10E+08 | 1.17E+08 | |
| $^{63}Ni$ | 9.21E+10 | 1.32E+10 | |
| $^{239}Np$* | 2.11E+08 | 3.03E+07 | |
| $^{210}Pb$ | 2.97E+06 | 4.29E+05 | |
| $^{210}Po$ | 1.98E+04 | 2.85E+03 | |
| $^{238}Pu$ | 4.29E+09 | 6.18E+08 | 1.32E+09 |
| $^{239}Pu$ | 2.38E+10 | 3.42E+09 | 4.18E+09** |
| $^{242}Pu$ | 3.96E+06 | 5.70E+05 | |
| $^{226}Ra$ | 4.92E+07 | 7.14E+06 | |
| $^{125}Sb$ | 5.62E+10 | 8.10E+09 | 1.14E+10 |
| $^{79}Se$ | 9.40E+06 | 1.35E+06 | 6.29E+06 |
| $^{90}Sr$ | 1.96E+13 | 2.82E+12 | 3.42E+13 |
| $^{99}Tc$ | 1.39E+09 | 1.99E+08 | 2.89E+07 |
| $^{125m}Te$* | 1.38E+10 | 1.98E+09 | 2.80E+09 |
| $^{227}Th$* | 8.92E+06 | 1.28E+06 | |

| Radionuclide Inventory for Waste Equipment (Cont.) | | | |
|---|---|---|---|
| Isotopes | 106-C | | 102-AY |
| | Heel Pump (Bq) | Transfer Pump (Bq) | Agitator Pump (Bq) |
| $^{233}U$ | 5.62E+05 | 1.88E+05 | |
| $^{234}U$ | 3.37E+06 | 4.85E+05 | |
| $^{235}U$ | 1.26E+05 | 1.84E+04 | |
| $^{236}U$ | 6.77E+04 | 9.10E+03 | |
| $^{238}U$ | 3.06E+06 | 4.37E+05 | |
| $^{90}Y$* | 1.96E+13 | 2.82E+12 | 3.42E+13 |

* These isotopes were not in the original table but are daughters of listed isotopes.

** This was listed as $^{239/240}Pu$. The entire inventory was modeled as $^{239}Pu$ as the ALIs for these two isotopes are identical.

After the calculations had been performed, the activity for $^{233}U$ for the 106-C Transfer pump was found to be incorrect in the list provided. However, the value used is higher than the correct value and it's influence on the doses was so small that it was decided that redoing the calculations would not be called for. In addition, the daughters of the uranium was not included due to its small influence on the answer.

The computer cose GENII (December 1990) was run on a desktop personal computer. The release was assumed to have happened in the 200-West. As stated in your correspondence of 30 July 20% of the material is assumed to be released to the environment. Of this amount, $1.2 \times 10^{-3}$ of this amount is assumed to be airborne within the respirable range. This figure was gleaned from "Aerosols Generated by Free Fall Spills of Powders and Solutions in Static Air" (NUREG/CR-2139 [PNL-3786]) by Sutter, Johnson, and Mishima. The dose to the worker is multiplied by an arbitrary factor of 30 to compensate for the fact that the dose is calculated at 100 m rather than at 1 m.

The maximally exposed offsite individual is assumed to be 11.3 km to the west of a postulated accident in the 200 West area.

| Expected Dose Consequences From Equipment Shipping Accidents | | |
|---|---|---|
| | Dose to Farmer (rem) | |
| | EDE | Organ |
| 106-C Heel Pump | 0.019 | 0.18 Bone Surface |
| 106-C Transfer Pump | 0.0026 | 0.026 Bone Surface |
| 102-AY Agitator Pump | 0.023 | 0.26 Bone Surface |

CONCURRENCE:

Harvey J. Goldberg
Principal Engineer

Jess Greenborg, Manager
Radiation Physics and Shielding

Sample Input Deck

```
########################## Program GENII Input File ############  8 Jul 88 ####
Title: 106-C Heel Pump - Dose to Farmer
       \GENII\ch-f.in                         Created on 09-07-1993 at 08:13
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=======================   T  Drinking water ingestion    7,8
T  Report AEDE only                     T  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     5.4E-05
     NI59     2.2E-02
     NI63     2.5E+00
     SR90     5.3E+02
     Y 90     5.3E+02
     TC99     3.8E-02
     SB125    1.5E+00
     I 129    2.1E-05
     CS137    1.4E+02
     EU154    2.1E+00
     PB210    8.0E-05
     PO210    5.4E-07
     RA226    1.3E-03
     AC227    2.4E-04
     PU238    1.2E-01
     PU239    6.4E-01
     PU242    1.1E-04
     AM241    7.8E-01
     AM243    5.7E-03
     CM242    3.0E-03
     CM244    3.6E-02
```

```
        --------|----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)
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
0          Source area for external dose modification factor (m2)
TRANSPORT ###############################################################
           ====AIR TRANSPORT===================================SECTION 1=====
                   0-Calculate PM              |0        Release type (0-3)
3          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)
0          Chi/Q or PM value                   |0        Stack radius (m)
6          MI sector index (1=S)               |0        Effluent temp. (C)
11300.0    MI distance from release point (m)  |0        Building x-section (m2)
T          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
         --- ------ -----  -------  ------  ----- |-------------------------
         T   FISH   0.00   0.0E+00    1.00   40.0 | 0      Source (see above)
         T   MOLLUS 0.00   0.0E+00    0.00    6.9 | T      Treatment? T/F
         T   CRUSTA 0.00   0.0E+00    0.00    6.9 | 1.0    Holdup/transit(da)
         T   PLANTS 0.00   0.0E+00    0.00    6.9 | 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

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

```
0        2  106-C and 102-AY Equipment Packaging Shielding Analysis
One Meter from the 106-C Heel Pump Release
 &INPUT NEXT=1, IGEOM=3, NTHETA=15, NPSI=9, DELR=5.0,
  NSHLD=1, JBUF=1, IPRNT=0 OPTION=1,
  X=100.62, T(1)=0.620,
  WEIGHT(487)=2.41E-04, WEIGHT(496)=7.82E-01,
  WEIGHT(505)=5.70E-03, WEIGHT(451)=5.35E-05,
  WEIGHT(504)=3.00E-03, WEIGHT(500)=3.58E-02,
  WEIGHT(472)=3.10E-01, WEIGHT(335)=1.35E+02,
  WEIGHT(336)=1.28E+02, WEIGHT(415)=2.14E+00,
  WEIGHT(290)=2.14E-05, WEIGHT(508)=8.03E-05,
  WEIGHT(484)=5.36E-07, WEIGHT(492)=1.16E-01,
  WEIGHT(493)=6.42E-01, WEIGHT(492)=4.97E-04,
  WEIGHT(485)=1.33E-03, WEIGHT(269)=1.52E+00,
  WEIGHT(027)=2.54E-04, WEIGHT(082)=5.30E+02,
  WEIGHT(084)=5.30E+02, WEIGHT(141)=3.75E-02, &
1 SOURCE 9 1.6
 One Meter from the 106-C Transfer Pump Release
 &INPUT NEXT=1, IGEOM=3, NTHETA=15, NPSI=9, DELR=5.0,
  NSHLD=1, JBUF=1, IPRNT=0, OPTION=1,
  X=100.62, T(1)=0.620,
  WEIGHT(487)=3.46E-05, WEIGHT(496)=1.13E-01,
  WEIGHT(505)=8.20E-04, WEIGHT(451)=7.70E-06,
  WEIGHT(504)=4.32E-04, WEIGHT(500)=5.17E-03,
  WEIGHT(472)=4.47E-02, WEIGHT(335)=1.94E+01,
  WEIGHT(336)=1.84E+01, WEIGHT(415)=3.07E-01,
  WEIGHT(290)=3.08E-06, WEIGHT(508)=1.16E-05,
  WEIGHT(484)=7.70E-08, WEIGHT(492)=1.67E-02,
  WEIGHT(493)=9.25E-02, WEIGHT(492)=1.54E-05,
  WEIGHT(485)=1.93E-04, WEIGHT(269)=2.19E-01,
  WEIGHT(027)=3.66E-05, WEIGHT(082)=7.63E+01,
  WEIGHT(084)=7.63E+01, WEIGHT(141)=5.39E-03, &
1 SOURCE 9 1.6
 One Meter from the 102-AY Agitator Pump Release
 &INPUT NEXT=1, IGEOM=3, NTHETA=15, NPSI=9, DELR=5.0,
  NSHLD=1, JBUF=1, IPRNT=0, OPTION=1,
  X=100.62, T(1)=0.620,
  WEIGHT(496)=5.69E-01, WEIGHT(451)=3.10E-05,
  WEIGHT(504)=1.60E-09, WEIGHT(500)=1.97E-02,
  WEIGHT(472)=1.60E-06, WEIGHT(335)=1.53E-01,
  WEIGHT(336)=1.45E-01, WEIGHT(415)=1.60E+00,
  WEIGHT(290)=3.70E-05, WEIGHT(492)=3.56E-02,
  WEIGHT(493)=1.13E-01, WEIGHT(269)=3.09E-01,
  WEIGHT(027)=1.70E-04, WEIGHT(082)=9.24E+02,
  WEIGHT(084)=9.24E+02, WEIGHT(141)=7.80E-04,&
1 SOURCE 9 1.6
DAT'S ALL PHOLQUES!!!!!!!
 &INPUT NEXT=6, &
```

# 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 package from a horizontal position onto a 12 in. thick steel reinforced concrete slab. 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.

Packaging shall be evaluated to determine the effects of a reduction in external pressure of 3.5 psi absolute and a 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 puncture. 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 -10 °F and 115 °F.

## 4.3 CONTAINMENT EVALUATION AND CONCLUSIONS

Evaluations to assure that the WSSP-1 packaging containment system is acceptable for safe transfer of the pump packages was based on results of Normal Transfer Condition testing analyses (Part B, Section 6.4), results of a radiological risk evaluation (Part B, Section 3.0) and a gas generation study (Part B, Section 8.3).

Results of the simulated free drop, vibration, penetration, and pressure tests indicated that the WSSP-1 package will not lose integrity of the containment barrier during normal transfer operations. **Results of similar testing for the WSSP-2 package will be determined (TBD) and included in this SEP at a later date by issue of an ECN.**

Results of the risk evaluation indicated that a release of the WSSP-1 package contents is extremely unlikely, and if a release was made, the dose consequence would not exceed acceptable Hanford Site limits shown in Part B, Section 3.0, Table B3-1 for an incredible accident assessment.

Results of a gas generation study (Part B, Section 8.3) indicated that hydrogen gas build-up in a package containing the heel and agitator pump could exceed 5% (for "worst case" waste material attached to a pump) within the twenty year service life of the packaging. To prevent the possibility of hydrogen build-up in excess of 5%, the flexible receiver assembly and the packaging for the heel and agitator pumps are fitted with approved filters.

Conclusions of this evaluation are that the packaging containment system for a WSSP-1 package 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 design is adequate to provide sufficient shielding of the packages during designated normal conditions of transfer. Since the packages will be transferred to the CWC for storage, the lowest acceptable dose rate at the surface of the packages for either transfer or storage of the packages 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 packages to 200 mrem/h and 10 mrem/h at 1 m from the vehicle for transfer of the packages. For storage of mixed TRU waste, the dose rate on the surface of the packages shall be limited to 100 mrem/h. Shielding material shall be secured to 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 transfers 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 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 to determine the thickness of solid lead required on the outside of the packaging 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 to a pump in the packaging containers. Considerations were made for the approximate location of pumps with respect to the ends of the packaging container to assure that the dose rate limits were not exceeded for the total length of the packaging.

Results of the shielding analysis indicated that the package containing the 102-AY agitator pump will probably not require shielding, the package containing the 106-C transfer pump will require a maximum 0.125 in. thick layer of solid lead shielding and the package containing the 106-C heel pump will require a maximum 0.75 in. thick layer of solid lead shielding. If lead shot is used as the shielding material, the shielding thickness should be increased conservatively by a factor of 1.54. If steel shot is use, a factor of 4.6 should be applied for the increased thickness of shielding. This would result in a maximum required lead shot thickness of 1.155 in. for the WSSP-1 package containing the heel pump and 0.190 in. for the WSSP-1 package containing the transfer pump. The maximum required thickness using steel shot is 3.45 in. for the WSSP-1 package containing the heel pump and 0.57 in. for the WSSP-1 package containing the transfer pump.

Considering that the annulus for shielding is 1½ in. thick and that the pumps will be rinsed during removal from the tanks, the packaging design is considered to be more than adequate to assure that the dose rates on the surface of the package can be limited to 100 mrem/h. This will satisfy all requirements for transfer and storage of the packages 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 were evaluated in the shielding report and indicated that actual dose rates will be less than 2 mrem/h. This will be verified in the field prior to transfer of the packages.

## 5.4 SHIELDING ANALYSIS

**Westinghouse Hanford Company** **Internal Memo**

From: Radiation Physics and Shielding 22570-HJG-93-019
Phone: 376-3765 H0-35
Date: September 7, 1993
Subject: TANKS 106-C AND 102-AY EQUIPMENT PACKAGING SHIELDING ANALYSIS

To: D. B. Calmus G2-02

cc: J. G. Field G2-02
J. Greenborg H0-35
HJG File/LB

**The Problem**

The introduction of a waste sluicing system in tanks 106-C and 102-AY has necessitated the removal and disposal of two pumps from 106-C and one pump from 102-AY. These pumps will be shipped in stainless steel cylinders which are themselves encased in larger stainless steel cylinders. The space between the two cylinders will be filled with lead shot.

This analysis was performed to ascertain if the absorbed dose rate at the surface of the outer cylinder does not exceed 1mSv/h (100 mrem/h).

**The Analysis**

The dimensions of the pumps in centimeters, are given in WHC-SD-TP-PDC-015 as follows;

| | 106-C Heel Pump | 106-C Transfer Pump | 102-AY Agitator Pump |
|---|---|---|---|
| Maximum Length | 1,149 | 1,164 | 1,630 |
| Maximum Diameter | 91.5 | 80.5 | 107.8 |

The above cited document also documents worst case estimates of the isotopic inventory assuming a 0.32 cm thick layer of waste on each of the pumps. These are tabulated below;

| Radionuclide Inventory for Waste Equipment | | | |
|---|---|---|---|
| Isotopes | 106-C | | 102-AY |
| | Heel Pump (Bq) | Transfer Pump (Bq) | Agitator Pump (Bq) |
| $^{227}$Ac | 8.92E+06 | 1.28E+06 | |
| $^{241}$Am | 2.89E+10 | 4.18E+09 | 2.11E+10 |
| $^{243}$Am | 2.11E+08 | 3.03E+07 | |
| $^{137m}$Ba* | 4.73E+12 | 6.79E+11 | 5.36E+09 |
| $^{14}$C | 1.98E+06 | 2.85E+05 | 1.15E+06 |
| $^{242}$Cm | 1.11E+08 | 1.60E+07 | 5.92E+01 |
| $^{244}$Cm | 1.32E+09 | 1.91E+08 | 7.29E+08 |
| $^{60}$Co | 1.15E+10 | 1.65E+09 | 5.92E+04 |
| $^{137}$Cs | 5.00E+12 | 7.03E+11 | 5.66E+09 |
| $^{154}$Eu | 7.92E+10 | 1.14E+10 | 5.92E+10 |
| $^{129}$I | 7.92E+05 | 1.14E+05 | 1.37E+06 |
| $^{59}$Ni | 8.10E+08 | 1.17E+08 | |
| $^{63}$Ni | 9.21E+10 | 1.32E+10 | |
| $^{210}$Pb | 2.97E+06 | 4.29E+05 | |
| $^{210}$Po | 1.98E+04 | 2.85E+03 | |
| $^{238}$Pu | 4.29E+09 | 6.18E+08 | 1.32E+09 |
| $^{239}$Pu | 2.38E+10 | 3.42E+09 | 4.18E+09** |
| $^{242}$Pu | 3.96E+06 | 5.70E+05 | |
| $^{226}$Ra | 4.92E+07 | 7.14E+06 | |
| $^{125}$Sb | 5.62E+10 | 8.10E+09 | 1.14E+10 |
| $^{79}$Se | 9.40E+06 | 1.35E+06 | 6.29E+06 |
| $^{90}$Sr | 1.96E+13 | 2.82E+12 | 3.42E+13 |
| $^{99}$Tc | 1.39E+09 | 1.99E+08 | 2.89E+07 |
| $^{90}$Y* | 1.96E+13 | 2.82E+12 | 3.42E+13 |

* These isotopes were not in the original table but are daughters of listed isotopes.

** This was listed as $^{239/240}$Pu. The entire inventory was modeled as $^{239}$Pu as a conservative limit for the shielding studies.

The problem was run utilizing the program ISOSHLD on a Cray mainframe computer. The hardware was modeled as a cylinder of waste of density $\rho$=1.2 g/cm$^3$, surrounded by a cylinder of air, two shielding cylinders, and a steel cylinder whose thickness equaled the sum of the two packages. The shielding cylinders were run as an inner cylinder of lead and an outer cylinder of air. The thicknesses of these two cylinders were varied from all air to almost all lead. In all cases, the thickness of these two cylinders combined remained the same. The exposure rate was taken at the center of the length of these cylinders at the outer surface.

**The Results**

ISOSHLD Results
Results are in rem/hr rather than the Sv/hr required by WHC

| Lead Thickness (cm) | 106-C | 106-C | 102-AY |
|---|---|---|---|
| | Heel Pump | Transfer Pump | Agitator Pump |
| No Lead | 1.130 | 0.1458 | 0.07419 |
| 0.5 | 0.5840 | 0.0741 | 0.03631 |
| 1.0 | 0.3036 | 0.03800 | 0.02129 |
| 1.5 | 0.15907 | 0.01969 | 0.01326 |
| 2.0 | 0.08437 | 0.01036 | 0.008543 |
| 2.5 | 0.04552 | 0.005556 | 0.005634 |
| 3.0 | 0.02511 | 0.003053 | 0.003780 |
| 3.5 | 0.01422 | 0.001724 | 0.002568 |
| 4.0 | 0.008291 | 0.001003 | 0.001763 |
| 4.5 | 0.004983 | 0.0006026 | 0.001292 |
| 5.0 | 0.003088 | 0.0003731 | 0.0008491 |
| 5.5 | 0.001969 | 0.0002377 | 0.0005946 |
| 6.0 | 0.001287 | 0.0001552 | 0.0004185 |
| 6.5 | 0.0008597 | 0.0001036 | 0.0002958 |
| 7.0 | 0.0005844 | 0.00007034 | 0.0002098 |
| 7.5 | 0.0004028 | 0.00004843 | 0.0001494 |
| 8.0 | 0.0002808 | 0.00003372 | 0.0001067 |

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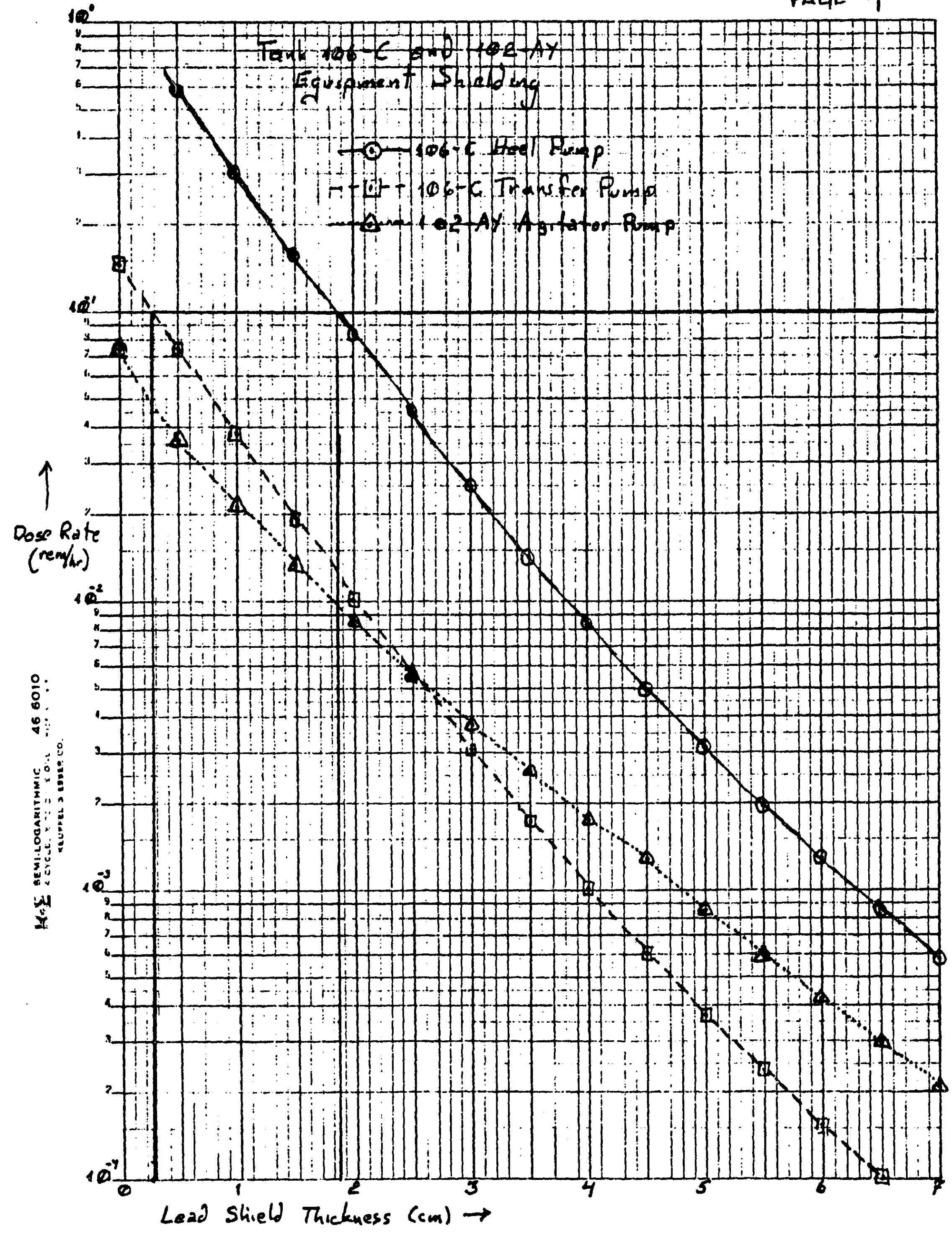
Tank 106-C and 102-AY
Equipment Shielding
106-C Heel Pump
106-C Transfer Pump
102-AY Agitator Pump
Dose Rate (rem/hr)
Lead Shield Thickness (cm)
0
1
2
3
4
5
6
7
K&E SEMI-LOGARITHMIC 46 6010

Despite the fact that the U.S.Department of Energy and WHC have mandated the use of S.I. units, I have presented the results in the older units. These results are presented more visually in the accompanying graph. Note that the 102-AY agitator pump should not need any further shielding. The 106-C transfer pump will need about 0.3 cm (~1/8") of lead shielding to meet the limit and the 106-C heel pump will need 1.85 cm (~3/4").

Note that these thicknesses are in terms of solid lead. Theoretically the packing ratio for close packed spheres is 0.74, this assumes perfectly packed spheres. When pouring lead shot into the shipping container, the shot often is less than perfectly arrayed, and thus the packing ratio is less than ideal. I have heard numbers in the mid to high sixties for this number.

Recently I called Non-Ferrous Metals, in Seattle. Although Jeff McGee was not there, the person I talked with gave me numbers of .8 to .9. I was told that the shot used was reclaimed shot, and thus not spherical in shape. These numbers are believable if the shot is in the form of flattened spheres or some other odd shape.

Of course, if the space between the two cylinders is not filled, the shot will bunch up and leave sections with less than the required amount of shielding. I thus assume that the whole space will be filled with lead shot. At this point any packing ratio above 0.25 will be adequate.

This package is being planned as a one-time use container. One drawback of lead shot is that over time the shot will become deformed and packed down. This may leave sections with less than the required amount of shielding. If these packages are to be used again the adequacy of the shielding will have to be verified.

Harvey J. Goldberg
Principal Engineer

CONCURRENCE:
Jess Greenborg, Manager
Radiation Physics and Shielding

**Sample Output Deck**

```
0       2  106-C and 102-AY Equipment Packaging Shielding Analysis
106-C Heel Pump-no lead
 &INPUT NEXT=1, IGEOM=7, NTHETA=15, NPSI=9, DELR=5.0,
  NSHLD=5, JBUF=5, IPRNT=0 OPTION=1,
  SLTH=1148.72, Y=574.36, X=75.6, T(1)=45.86,
  T(2)=19.7, T(3)=0.0, T(4)=8.1, T(5)=1.91,
  WEIGHT(487)=2.41E-04, WEIGHT(496)=7.82E-01,
  WEIGHT(505)=5.70E-03, WEIGHT(451)=5.35E-05,
  WEIGHT(504)=3.00E-03, WEIGHT(500)=3.58E-02,
  WEIGHT(472)=3.10E-01, WEIGHT(335)=1.35E+02,
  WEIGHT(336)=1.28E+02, WEIGHT(415)=2.14E+00,
  WEIGHT(290)=2.14E-05, WEIGHT(508)=8.03E-05,
  WEIGHT(484)=5.36E-07, WEIGHT(492)=1.16E-01,
  WEIGHT(493)=6.42E-01, WEIGHT(492)=4.97E-04,
  WEIGHT(485)=1.33E-03, WEIGHT(269)=1.52E+00,
  WEIGHT(027)=2.54E-04, WEIGHT(082)=5.30E+02,
  WEIGHT(084)=5.30E+02, WEIGHT(141)=3.75E-02, &
  SOURCE 9 1.6
  AIR    3          0.00129
  LEAD  14                    11.35
  AIR    3                                0.00129
1 STEEL  9                                          7.8
106-C Heel Pump-0.5 cm lead
 &INPUT Next=4, T(3)=0.5, T(4)=7.6, &
106-C Heel Pump-1.0 cm lead
 &INPUT Next=4, T(3)=1.0, T(4)=7.1, &
106-C Heel Pump-1.5 cm lead
 &INPUT Next=4, T(3)=1.5, T(4)=6.6, &
106-C Heel Pump-2.0 cm lead
 &INPUT Next=4, T(3)=2.0, T(4)=6.1, &
106-C Heel Pump-2.5 cm lead
 &INPUT Next=4, T(3)=2.5, T(4)=5.6, &
106-C Heel Pump-3.0 cm lead
 &INPUT Next=4, T(3)=3.0, T(4)=5.1, &
106-C Heel Pump-3.5 cm lead
 &INPUT Next=4, T(3)=3.5, T(4)=4.6, &
106-C Heel Pump-4.0 cm lead
 &INPUT Next=4, T(3)=4.0, T(4)=4.1, &
106-C Heel Pump-4.5 cm lead
 &INPUT Next=4, T(3)=4.5, T(4)=3.6, &
106-C Heel Pump-5.0 cm lead
 &INPUT Next=4, T(3)=5.0, T(4)=3.1, &
106-C Heel Pump-5.5 cm lead
 &INPUT Next=4, T(3)=5.5, T(4)=2.6, &
106-C Heel Pump-6.0 cm lead
 &INPUT Next=4, T(3)=6.0, T(4)=2.1, &
106-C Heel Pump-6.5 cm lead
 &INPUT Next=4, T(3)=6.5, T(4)=1.6, &
106-C Heel Pump-7.0 cm lead
 &INPUT Next=4, T(3)=7.0, T(4)=1.1, &
106-C Heel Pump-7.5 cm lead
 &INPUT Next=4, T(3)=7.5, T(4)=0.6, &
106-C Heel Pump-8.0 cm lead
 &INPUT Next=4, T(3)=8.0, T(4)=0.1, &
106-C Transfer Pump-no lead
 &INPUT NEXT=1, IGEOM=7, NTHETA=15, NPSI=9, DELR=5.0,
  NSHLD=5, JBUF=5, IPRNT=0, OPTION=1,
  SLTH=1163.96, Y=581.98, X=75.6, T(1)=50.48,
  T(2)=15.08, T(3)=0.0, T(4)=8.1, T(5)=1.91,
  WEIGHT(487)=3.46E-05, WEIGHT(496)=1.13E-01,
  WEIGHT(505)=8.20E-04, WEIGHT(451)=7.70E-06,
  WEIGHT(504)=4.32E-04, WEIGHT(500)=5.17E-03,
  WEIGHT(472)=4.47E-02, WEIGHT(335)=1.94E+01,
  WEIGHT(336)=1.84E+01, WEIGHT(415)=3.07E-01,
  WEIGHT(290)=3.08E-06, WEIGHT(508)=1.16E-05,
  WEIGHT(484)=7.70E-08, WEIGHT(492)=1.67E-02,
  WEIGHT(493)=9.25E-02, WEIGHT(492)=1.54E-05,
```

```
 WEIGHT(485)=1.93E-04, WEIGHT(269)=2.19E-01,
 WEIGHT(027)=3.66E-05, WEIGHT(082)=7.63E+01,
 WEIGHT(084)=7.63E+01, WEIGHT(141)=5.39E-03, &
 SOURCE 9 1.6
 AIR    3          0.00129
 LEAD  14                   11.35
 AIR    3                            0.00129
1 STEEL  9                                    7.8
106-C Transfer Pump-0.5 cm lead
 &INPUT Next=4, T(3)=0.5, T(4)=7.6, &
106-C Transfer Pump-1.0 cm lead
 &INPUT Next=4, T(3)=1.0, T(4)=7.1, &
106-C Transfer Pump-1.5 cm lead
 &INPUT Next=4, T(3)=1.5, T(4)=6.6, &
106-C Transfer Pump-2.0 cm lead
 &INPUT Next=4, T(3)=2.0, T(4)=6.1, &
106-C Transfer Pump-2.5 cm lead
 &INPUT Next=4, T(3)=2.5, T(4)=5.6, &
106-C Transfer Pump-3.0 cm lead
 &INPUT Next=4, T(3)=3.0, T(4)=5.1, &
106-C Transfer Pump-3.5 cm lead
 &INPUT Next=4, T(3)=3.5, T(4)=4.6, &
106-C Transfer Pump-4.0 cm lead
 &INPUT Next=4, T(3)=4.0, T(4)=4.1, &
106-C Transfer Pump-4.5 cm lead
 &INPUT Next=4, T(3)=4.5, T(4)=3.6, &
106-C Transfer Pump-5.0 cm lead
 &INPUT Next=4, T(3)=5.0, T(4)=3.1, &
106-C Transfer Pump-5.5 cm lead
 &INPUT Next=4, T(3)=5.5, T(4)=2.6, &
106-C Transfer Pump-6.0 cm lead
 &INPUT Next=4, T(3)=6.0, T(4)=2.1, &
106-C Transfer Pump-6.5 cm lead
 &INPUT Next=4, T(3)=6.5, T(4)=1.6, &
106-C Transfer Pump-7.0 cm lead
 &INPUT Next=4, T(3)=7.0, T(4)=1.1, &
106-C Transfer Pump-7.5 cm lead
 &INPUT Next=4, T(3)=7.5, T(4)=0.6, &
```

```
106-C Transfer Pump-8.0 cm lead
 &INPUT Next=4, T(3)=8.0, T(4)=0.1, &
102-AY Agitator Pump-no lead
 &INPUT NEXT=1, IGEOM=7, NTHETA=15, NPSI=9, DELR=5.0,
  NSHLD=5, JBUF=5, IPRNT=0, OPTION=1,
  SLTH=1630.68, Y=815.34, X=75.6, T(1)=53.89,
  T(2)=11.67, T(3)=0.0, T(4)=8.1, T(5)=1.91,
  WEIGHT(496)=5.69E-01, WEIGHT(451)=3.10E-05,
  WEIGHT(504)=1.60E-09, WEIGHT(500)=1.97E-02,
  WEIGHT(472)=1.60E-06, WEIGHT(335)=1.53E-01,
  WEIGHT(336)=1.45E-01, WEIGHT(415)=1.60E+00,
  WEIGHT(290)=3.70E-05, WEIGHT(492)=3.56E-02,
  WEIGHT(493)=1.13E-01, WEIGHT(269)=3.09E-01,
  WEIGHT(027)=1.70E-04, WEIGHT(082)=9.24E+02,
  WEIGHT(084)=9.24E+02, WEIGHT(141)=7.80E-04,&
  SOURCE 9 1.6
  AIR    3          0.00129
  LEAD  14                    11.35
  AIR    3                              0.00129
1 STEEL  9                                        7.8
102-AY Agitator Pump-0.5 cm lead
 &INPUT Next=4, T(3)=0.5, T(4)=7.6, &
102-AY Agitator Pump-1.0 cm lead
 &INPUT Next=4, T(3)=1.0, T(4)=7.1, &
102-AY Agitator Pump-1.5 cm lead
 &INPUT Next=4, T(3)=1.5, T(4)=6.6, &
102-AY Agitator Pump-2.0 cm lead
 &INPUT Next=4, T(3)=2.0, T(4)=6.1, &
102-AY Agitator Pump-2.5 cm lead
 &INPUT Next=4, T(3)=2.5, T(4)=5.6, &
102-AY Agitator Pump-3.0 cm lead
 &INPUT Next=4, T(3)=3.0, T(4)=5.1, &
102-AY Agitator Pump-3.5 cm lead
 &INPUT Next=4, T(3)=3.5, T(4)=4.6, &
102-AY Agitator Pump-4.0 cm lead
 &INPUT Next=4, T(3)=4.0, T(4)=4.1, &
102-AY Agitator Pump-4.5 cm lead
 &INPUT Next=4, T(3)=4.5, T(4)=3.6, &
102-AY Agitator Pump-5.0 cm lead
 &INPUT Next=4, T(3)=5.0, T(4)=3.1, &
102-AY Agitator Pump-5.5 cm lead
 &INPUT Next=4, T(3)=5.5, T(4)=2.6, &
102-AY Agitator Pump-6.0 cm lead
 &INPUT Next=4, T(3)=6.0, T(4)=2.1, &
102-AY Agitator Pump-6.5 cm lead
 &INPUT Next=4, T(3)=6.5, T(4)=1.6, &
102-AY Agitator Pump-7.0 cm lead
 &INPUT Next=4, T(3)=7.0, T(4)=1.1, &
102-AY Agitator Pump-7.5 cm lead
 &INPUT Next=4, T(3)=7.5, T(4)=0.6, &
102-AY Agitator Pump-8.0 cm lead
 &INPUT Next=4, T(3)=8.0, T(4)=0.1, &
DAT'S ALL PHOLQUES!!!!!!!
 &INPUT NEXT=6, &
```

## CHECKLIST FOR CALCULATION REVIEW AND APPROVAL

Document Reviewed (Complete reference) Tanks 106-C and 102-AY Equipment Packaging Shielding Analysis

Author(s) Harvey Goldberg

### CHECKLIST FOR CALCULATION REVIEW

| Yes | No | N/A | General Considerations |
|---|---|---|---|
| [✓] | [ ] | [ ] | Problem completely defined. |
| [✓] | [ ] | [ ] | Necessary assumptions explicitly stated and supported. |
| [✓] | [ ] | [ ] | Computer codes and data files documented. |
| [✓] | [ ] | [ ] | Data used in calculations explicitly stated in document. |
| [✓] | [ ] | [ ] | Data checked for consistency with original source information as applicable. |
| [ ] | [ ] | [✓] | Mathematical derivations checked including dimensional consistency of results. |
| [ ] | [ ] | [✓] | Models appropriate and used within range of validity or use outside range of established validity justified. |
| [✓] | [ ] | [ ] | Hand calculations checked for errors. |
| [✓] | [ ] | [ ] | Code runstreams correct and consistent with analysis documentation. |
| [✓] | [ ] | [ ] | Code output consistent with input and with results reported in analysis documentation. |
| [ ] | [ ] | [✓] | Acceptability limits on analytical results applicable and supported. Limits checked against sources. |
| [✓] | [ ] | [ ] | Safety margins consistent with good engineering practices. |
| [✓] | [ ] | [ ] | Conclusions consistent with analytical results and applicable limits. |
| [✓] | [ ] | [ ] | Results and conclusions address all points required in the problem statement. |

Reviewer Name: Steven R. Gedeon
(print or type)

[signature] 3 Sept 93
Technical Reviewer Approval Date

Note: Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

# 6.0 STRUCTURAL EVALUATION

## 6.1 INTRODUCTION

Evaluations in this section are provided to assure that the WSSP-1 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 subsections. **Similar structural evaluations for the WSSP-2 package will be determined (TBD) and included in this SEP at a later date by issue of an ECN.**

## 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 packages.

1. Packaging construction materials shall be selected to assure that there will be no significant chemical, galvanic, or other reactions 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 0.19 in. and 4.0 in. shall meet packaging category II fracture toughness requirements shown in Table 5 of NUREG/CR-1815. The lowest service temperature (LST) for design purposes shall be -10 °F.

### 6.2.2 Packaging Dimensions

Waste packaging containers shall be sized to transfer and contain for storage the "package contents" described in Part A, Section 3.0 of the SEP. Specifically, a designated pump placed in a flexible receiver assembly. Clearance dimensions required for the packaging enclosure cavity shall consider adequate clearance for installing the flexible receiver assembly.

### 6.2.3 Tiedown System

Tiedown devices that are attached to the packaging 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 packaging 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 packaging 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 3 against yielding.
- A safety factor of 5 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 packaging shall have positive closure assemblies that cannot be opened unintentionally and will meet the acceptance requirements of the normal conditions of transfer test per Part B, Section 4.2. Any penetrations on the packagings 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 testing of the packagings is shown in Part B, Section 4.2. The drop test for structural evaluations shall consist of a simulated drop of a unshielded WSSP-1 package and a drop of a fully shielded WSSP-1 package from a horizontal position. 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 packaging 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 external surfaces are painted to prevent external corrosion during the specified packaging lifetime. The structural strength of the packaging materials required to safely contain and lift the packaging 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 66,300 lb for the WSSP-1 package.

Evaluation of packaging containment materials to meet the required brittle fracture criteria was based on an analysis of 2 in. thick 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*. An evaluation of the brittle fracture guidelines in NUREG 1815 for onsite transfers of radioactive materials under the conditions of this SEP is shown in Part B, Section 6.6. The evaluation indicates that the specified ASTM A516 is considered acceptable to meet designated brittle fracture criteria without requiring specific Nil Ductility Testing (NDT) by the manufacturer of the material.

### 6.3.2 Packaging Dimensions

The packaging internal cavity dimensions for the WSSP-1 packaging is 51¼ in. diameter and is 49 ft in length. The internal cavities of the packaging is considered sufficient to install and remove each of the two types of pumps (heel and transfer) placed in the flexible receivers.

### 6.3.3 Tiedown System

A tiedown analysis for devices attached to the packaging 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 strongback/trailer assembly to transport the package to the CWC (a standard trailer bed may also be used if required). Analysis of the tiedown system indicates that the proposed system is considered safe to secure shielded or unshielded WSSP-1 package on the transport vehicle during normal transfer operations. The tiedown system for the strongback/trailer assembly is based on six (6) tiedown points on the WSSP-1 package and eight tiedown points on the trailer. The nominal breaking strength (NBS) of tiedown cables must be equal to or exceed 14,500 lb.

### 6.3.4 Lifting Devices

Evaluation of the lifting attachment analysis provided in Part B, Section 6.5 and indicates that the strength of the attachments meet the above design requirements and are considered safe for the intended use. Other parts of the package not approved for lifting are not readily assessable 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 designated concrete surface. This test is considered sufficient to assure that the package closures will not open during normal conditions of transfer. 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 openings 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 WSSP-1 package is shown in Part B, Section 6.4. The analysis was based on the determining if critical structural components of the package will exceed yield stresses during impact of the package onto a concrete surface 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 packages successfully passed the drop tests.

Evaluation of assumed vibration movements of the WSSP-1 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 will not be considered as a critical factor during transfer of this package. One conclusion of the structural analysis indicated that the contents of the package should be restrained prior to transfer and this concern was addressed in the operation procedure guidelines shown in Part A, Section 6.2, item 3.

The WSSP-1 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 3.1. Results of an assimilated penetration test are shown in Part B, Section 6.4, and indicated that the packaging containment barrier would not be damaged following the assimilated test.

Criteria (Part B, Section 3.1) for normal transfer condition tests requires that the packaging 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 is shown in Part B, Section 6.4 and indicates that the WSSP-1 packaging will safely withstand the specified pressure tests without damage to the containment barrier.

## 6.4 STRUCTURAL ANALYSIS

**Westinghouse Hanford Company**

**Internal Memo**

84100-94-PMN-259

From: Packaging Safety Engineering
Phone: 376-3702 G2-02
Date: August 16, 1994
Subject: ENGINEERING SAFETY EVALUATIONS

To:
D. B. Calmus G2-02
L. M. Hay G2-02
S. S. Shiraga N1-40
106-C 49 Foot Package Structural Analysis Files
PMN File/PSE Route/LB

This memo is issued in regards to the safety evaluation of the 49 foot 106-C container which was based on the shop copy of the development control drawings.

The shop copy of the development control drawings has been checked for consistency with the approved final formal drawings. Therefore, this memo is superseding memo number 84100-94-PMN-193 in its entirety.

PMNguyen

P. M. Nguyen
Advanced Engineer

dmr

CONCURRENCE:

[signature] Date 8/16/94
S. S. Shiraga
Senior Principal Engineer

## ENGINEERING ANALYSIS

| | | |
|---|---|---|
| Drawing H-2-83724 | Doc. No. PMN-WTCG-049 | Page 1 of 24 |
| Building Tank 241-C-106 (106C) | Rev. 0 | Job No. |
| Subject Weight and Center of Gravity | | |
| Originator P. M. Nguyen | | Date 05/25/94 |
| Checker S. S. Shiraga | | Date 06/15/94 |

I. **Objectives:**

The objective of this analysis is to determine the weight and center of gravity of the 106-C 49 foot long container for transport of the Heel and Transfer Pumps.

II. **References:**

1. Industrial Press, Machinery's Handbook, 23rd Edition.

2. AISC, Manual of Steel Construction, Ninth Edition.

3. WHC Drawing No., H-2-83722, H-2-83724, H-2-83725, H-2-83726 and H-2-83727.

4. KEH, Design Analysis, Calc. No. W320-25-004, Dated 11-10-93.

III. **Results and Conclusions:**

The weight and center of gravity calculated are estimates from the basis for other engineering evaluations applicable to this container. These calculated estimates are the primary input parameters for the drop, lifting and vibration calculations. Results of these calculations are:

1. Weight of empty container: 25,086 lbs.

2. Weight of the non-shielded loaded container: 28,238 lbs.

3. Weight of the shielded loaded container: 65,884 lbs.

4. Weight of container without support rings or shielding:

   20,503 lbs

5. The center of gravity of the top cap is:

   2.5 inches from the flange bolting surface

6. The center of gravity of the container is:

   288.4 inches from the closed end of the container (welded end).

The estimated weights have been rounded off to the nearest pound.

**ENGINEERING ANALYSIS**

Drawing H-2-83724 Doc. No. PMN-WTCG-049 Page 2 of 24
Building Tank 241-C-106 (106C) Rev. 0 Job No.
Subject Weight and Center of Gravity
Originator P. M. Nguyen PMN Date 05/25/94
Checker S. S. Shiraga SSS Date 06/15/94

IV. Engineering Evaluation:

1. **Weight of 52" diameter pipe:**

Length: $l_{pipe} = 49$ ft

Outside diameter: $d_o = 52$ inch

Inside diameter: $d_i = (52 - .75)$ inch

Area:

$$A_{pipe} = \frac{\pi}{4}\left(d_o^2 - d_i^2\right)$$

Pipe density (Reference 1, p.398): $\rho_{pipe} = 0.284$ lbs/in$^3$

Weight per foot of pipe: $w_{pipe} = A_{pipe} \cdot \rho_{pipe} \cdot 12$ in/ft

Weight of pipe: $W_{pipe} = l_{pipe} \cdot w_{pipe}$

$W_{pipe} = 10{,}156$ lbs

2. **Weight of outer skinl (item 8):**

Length:

$l_1 = 38.875$ inch $l_2 = 39.75$ inch $l_3 = 48$ inch $l_4 = 48$ inch

$l_5 = 48$ inch $l_6 = 45.75$ inch $l_7 = 48$ inch $l_8 = 48$ inch

$l_9 = 48$ inch $l_{10} = 39.75$ inch

$$L_1 = l_1 + l_2 + l_3 + l_4 + l_5 + l_6 + l_7 + l_8 + l_9 + l_{10}$$

$L_1 = 37.68$ ft

Thickness: $t_{cstl1} = 0.1875$ inch

**ENGINEERING ANALYSIS**

| | | | |
|---|---|---|---|
| Drawing H-2-83724 | Doc. No. PMN-WTCG-049 | Page 3 of 24 | |
| Building Tank 241-C-106 (106C) | Rev. 0 | Job No. | |
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| Originator P. M. Nguyen PMN | | Date 05/25/94 | |
| Checker S. S. Shiraga SSS | | Date 06/15/94 | |

$$d_{o1} = 52\ inch + 2 \cdot (t_{cstl1} + 1.5\ inch)$$

$$d_{i1} = (52 + 2 \cdot 1.5)\ inch$$

Area:

$$A_{cstl1} = \frac{\pi}{4} \cdot (d_{o1}^2 - d_{i1}^2)$$

Density: (Reference 1, page 398) $\rho_{cstl} = 0.284\ lbs/in^3$

**Weight of skin1:**

$$W_{cstl1} = \rho_{cstl} \cdot A_{cstl1} \cdot L_1$$

$$W_{cstl1} = 4{,}195\ lbs$$

3. **Weight of outer skin2 (item 9):**

Length of skin2: $l_{21} = 48$ inch

$l_{22} = 42.75$ inch

$$L_{cstl2} = l_{21} + l_{22}$$

$$t_{cstl2} = 3/8\ inch$$

$$d_{o2} = 52\ inch + 2 \cdot (t_{cstl2} + 1.5\ inch)$$

**ENGINEERING ANALYSIS**

Drawing H-2-83724 Doc. No. PMN-WTCG-049 Page 4 of 24
Building Tank 241-C-106 (106C) Rev. 0 Job No.
Subject Weight and Center of Gravity
Originator P. M. Nguyen PMN Date 05/25/94
Checker S. S. Shiraga Date 06/15/94

$$d_{i2} = (52 + 2 \cdot 1.5)\ inch$$

Area:

$$A_{cstl2} = \frac{\pi}{4} \cdot (d_{o2}^2 - d_{i2}^2)$$

Weight of skin2:

$$W_{cstl2} = \rho_{cstl} \cdot A_{cstl2} \cdot L_2$$

$$W_{cstl2} = 1{,}640\ lbs$$

4. Weight of item 7:

Length: $l_7 = 7$ inch

Thickness: $t_7 = 3/8$ inch

$$d_{i7} = 52\ inch + 2 \cdot (1.5\ inch)$$

$$d_{o7} = (d_{i7} + 2 \cdot t_7)\ inch$$

Area:

$$A_7 = \frac{\pi}{4} \cdot (d_{o7}^2 - d_{i7}^2)$$

Weight of skin2:

**ENGINEERING ANALYSIS**

| | | | |
|---|---|---|---|
| Drawing H-2-83724 | Doc. No. PMN-WTCG-049 | Page 5 of 24 | |
| Building Tank 241-C-106 (106C) | Rev. 0 | Job No. | |
| Subject Weight and Center of Gravity | | | |
| Originator P. M. Nguyen PMN | | Date 05/25/94 | |
| Checker S. S. Shiraga SSS | | Date 06/15/94 | |

$$W_7 = \rho_{cstl} \cdot A_7 \cdot l_7 \cdot 12 \cdot \frac{inch}{ft}$$

$$W_7 = 130 \text{ lbs}$$

5. **Weight of item 6 (3 ea):**

Length: $l_6 = 7$ inch

Thickness: $t_6 = 3/16$ inch

$$d_{i6} = 52\ inch + 2 \cdot (1.5\ inch)$$

$$d_{o6} = (d_{i6} + 2 \cdot t_6)\ inch$$

Area:

$$A_6 = \frac{\pi}{4} \cdot (d_{o6}{}^2 - d_{i6}{}^2)$$

Weight of skin2:

$$w_6 = \rho_{cstl} \cdot A_6 \cdot l_6 \cdot 12 \cdot \frac{inch}{ft}$$

$$W_6 = 3 \cdot w_6$$

$$W_6 = 194 \text{ lbs}$$

6. **Weight of item 5 (2 ea):**

(a) 1" thick plate: $d_{o5} = 58.5$ inch

$d_{i5} = 52$ inch

Area:

**ENGINEERING ANALYSIS**

Drawing H-2-83724 Doc. No. PMN-WTCG-049 Page 6 of 24
Building Tank 241-C-106 (106C) Rev. 0 Job No.
Subject Weight and Center of Gravity
Originator P. M. Nguyen Date 05/25/94
Checker S. S. Shiraga Date 06/15/94

$$A_a = \frac{1}{2} \cdot \left(d_{o5}^2 - \frac{\pi}{4} d_{i5}^2\right) + \frac{1}{2} \cdot \left(\frac{\pi}{4} d_{o5}^2 - d_{i5}^2\right)$$

Thickness: $t_{a5} = 1$ inch

Weight:

$$W_a = \rho_{cstl} \cdot A_a \cdot t_{a5}$$

$W_a = 265$ lbs

(b) 1 1/2" thick plate (2 ea):

Area: $A_b = 9.14$ inch · 15 inch

Thickness: $t_{b5} = 1.5$ inch

Weight:

$$W_b = \rho_{cstl} \cdot A_b \cdot t_{b5}$$

$$w_5 = W_a + 2 \cdot W_b$$

**Weight of item 5:**

$$W_5 = 2 \cdot w_5$$

$W_5 = 763$ lbs

7. **Weight of item 3 (1 ea):**

(a) 2" thick plate:

Area: $d_{o3} = 58.5$ inch

$A_a = 3{,}055.04$ in$^2$

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$$A_a = \frac{1}{2}\cdot\left(d_{o3}^2\right) + \frac{1}{2}\cdot\left(\frac{\pi}{4}d_{o3}^2\right)$$

Thickness: $t_{a3}$ = 2 inch

Weight:

$$W_a = \rho_{cstl}\cdot A_a\cdot t_{a3}$$

$W_a$ = 1,735 lbs

(b) 1 " thick plate:

$d_{o3}$ = 58.5 inch

$d_{i3}$ = 52 inch

Area:

$$A_b = \frac{1}{2}\cdot\left(d_{o3}^2 - \frac{\pi}{4}d_{i3}^2\right) + \frac{1}{2}\cdot\left(\frac{\pi}{4}d_{o3}^2 - d_{i3}^2\right)$$

Thickness: $t_{b3}$ = 1 inch

Weight:

$$W_b = \rho_{cstl}\cdot A_b\cdot t_{b3}$$

$W_b$ = 265 lbs

(c) 1 1/2" thick plate (2 ea):

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$$W_c = \rho_{cstl} \cdot A_c \cdot t_{c3}$$

$$W_{c3} = 2 \cdot W_c$$

$$W_{c3} = 62 \text{ lbs}$$

(d) 1" thick plate (2 ea):

Area:

$$A_d = 8.25 \ inch \cdot 3 \ inch$$

Thickness: $t_{d3} = 1$ inch

Weight:

$$W_d = \rho_{cstl} \cdot A_d \cdot t_{d3}$$

$$W_d = 7 \text{ lbs}$$

$$W_{d3} = 2 \cdot W_d$$

$$W_{d3} = 14 \text{ lbs}$$

(e) 1 1/4" thick plate (1 ea):

Area:

$$A_e = \frac{\pi}{4} \cdot (51.25 \ inch)^2$$

Thickness: $t_{e3} = 1.25$ inch

Weight:

$$W_e = \rho_{cstl} \cdot A_e \cdot t_{e3}$$

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$$W_e = 732 \text{ lbs}$$

**Weight of item 3:**

$$W_3 = W_a + W_B + W_{c3} + W_{d3} + W_e$$

$$W_3 = 2{,}808 \text{ lbs}$$

Weight of item 3 minus support ring: $W_{31} = W_3 - W_a$

7. **Weight of item 4 (1 ea):**

(a) 1" thick (2 ea): $d_{o4} = 58.5$ inch

$d_{i4} = 52$ inch

Area:

$$A_a = \frac{1}{2} \cdot \left(d_{o4}{}^2 - \frac{\pi}{4} d_{i4}{}^2\right) + \frac{1}{2} \cdot \left(\frac{\pi}{4} d_{o4}{}^2 - d_{i4}{}^2\right)$$

Thickness: $t_{a4} = 1$ inch

Weight:

$$W_a = \rho_{cstl} \cdot A_a \cdot t_{a4}$$

$$W_a = 265 \text{ lbs}$$

$$W_{a4} = 2 \cdot W_e$$

$$W_{a4} = 529 \text{ lbs}$$

(b) 1 1/2" thick plate (2 ea):

Area: $A_b = 7.25 \text{ inch} \cdot (13 - 3) \text{ inch}$

Thickness: $t_{b4} = 1.5$ inch

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Weight:

$$W_b = \rho_{cstl} \cdot A_b \cdot t_{b4}$$

$$W_b = 31 \text{ lbs}$$

$$W_{b4} = 2 \cdot W_b$$

$$W_{b4} = 62 \text{ lbs}$$

c) 1" thick plate (2 ea):

Area:

$$A_c = 8.25\ inch \cdot 3\ inch$$

Thickness: $t_{c4} = 1$ inch

Weight:

$$W_c = \rho_{cstl} \cdot A_c \cdot t_{c4}$$

$$W_c = 7 \text{ lbs}$$

$$W_{c4} = 2 \cdot W_c$$

$$W_{c4} = 14 \text{ lbs}$$

**Weight of item 4:**

$$W_4 = W_{a4} + W_{b4} + W_{c4}$$

$$W_4 = 605 \text{ lbs}$$

**Weight of item 4 minus support ring:**

$$W_{41} = W_4 - W_{a4}$$

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**8. Weight of item 12 (8 ea):**

(a) 1" thick plate: $d_{o12} = 58.5$ inch

$d_{i12} = 52$ inch

Area:

$$A_{12} = \frac{1}{2} \cdot \left(d_{o12}^2 - \frac{\pi}{4} d_{i12}^2\right) + \frac{1}{2} \cdot \left(\frac{\pi}{4} d_{o12}^2 - d_{i12}^2\right)$$

Thickness: $t_{12} = 1$ inch

Weight:

$$W_a = \rho_{cstl} \cdot A_{12} \cdot t_{12}$$

$W_a = 265$ lbs

$W_{12} = 8 \cdot W_a$

$W_{12} = 2{,}116$ lbs

**9. Weight of item 18 (3 ea):**

(a) 1/4" thick plate:

Area:

$$A_a = 2 \cdot \left[18.875\ inch \cdot \frac{11}{2}\ inch\right] + 2\ inch \cdot 11\ inch$$

Weight:

$$W_a = A_a \cdot \rho_{cstl} \cdot 0.25\ inch$$

$W_a = 16$ lbs

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(b) 1/4" thick (4 ea):

Area:

$$A_b = \frac{1}{2} \cdot 18.875\ inch \cdot 12.875\ inch \cdot \cos(5\ °)$$

Weight:

$$W_b = A_b \cdot \rho_{cstl} \cdot 0.25\ inch$$

$$W_b = 9\ \mathrm{lbs}$$

$$W_{b4} = 4 \cdot W_b$$

$$W_{b4} = 34\ \mathrm{lbs}$$

(c) 1/4" thick plate (2 ea):

Area:

$$A_c = 2 \cdot \left[\frac{1}{2} \cdot 12.875\ inch \cdot \cos(15\ °) \cdot 12.875\ inch \cdot \sin(15\ °)\right] \ldots$$
$$+ 12\ inch \cdot 12.875\ inch \cdot \cos(15\ °)$$

Weight:

$$W_c = A_c \cdot \rho_{cstl} \cdot 0.25\ inch$$

$$W_c = 13.5\ \mathrm{lbs}$$

$$W_{c2} = 2 \cdot W_c$$

$$W_{c2} = 27\ \mathrm{lbs}$$

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**Weight of item 18:**

$$W_{18} = W_a + W_{b4} + W_{c2}$$

$$w_{18} = 78 \text{ lbs}$$

$$W_{18} = 3 \cdot w_{18}$$

$$W_{18} = 233 \text{ lbs}$$

10. **Weight of item 15:**

(a) 1/4" thick plate:

Area: $A_a = 12 \text{ inch} \cdot 32.5 \text{ inch}$

Weight: $W_a = A_a \cdot \rho_{cstl} \cdot 0.25 \text{ inch}$

$$W_a = 28 \text{ lbs}$$

(b) 1/4" thick plate (2 ea):

Area:

$$A_b = \frac{1}{2} \cdot 21.75\ inch \cdot \frac{1}{2} \cdot 32.5\ inch$$

Weight: $w_b = A_b \cdot \rho_{cstl} \cdot 0.25 \text{ inch}$

$$w_b = 12.6 \text{ lbs}$$

$$W_b = 2 \cdot w_b$$

$$W_b = 25 \text{ lbs}$$

(c) 1/4" thk (2 ea)

Major diameter: $d_{mj} = 32.5 \text{ in}$

Minor diameter: $d_{mr} = 25.625 \text{ in}$

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Area:

$$A_c = \frac{\pi}{2} 32.5\ inch \cdot 25.625\ inch$$

Weight:

$$w_c = A_c\ \rho_{cstl} \cdot 0.25\ inch$$

$$w_c = 93 \text{ lbs}$$

$$W_c = 2 \cdot w_c$$

$$W_c = 186 \text{ lbs}$$

Weight of item 15:

$$W_{15} = W_a + W_b + W_c$$

$$W_{15} = 239 \text{ lbs}$$

11. Weight of item 11:

Thickness: $t_{11} = 1.75$ in

Area:

$$A_{11} = \frac{\pi}{4} \cdot [(51.25\ inch)^2 - (47.25\ inch)^2]$$

Weight:

$$W_{11} = A_{11} \cdot \rho_{cstl} \cdot 1.75\ inch$$

$$W_{11} = 154 \text{ lbs}$$

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**12. Weight of item 14:**

Thickness: $t_{14} = 1.75$ in

Area:

$$A_{14} = \frac{\pi}{4} \cdot [(58.5\ inch)^2 - (52\ inch)^2]$$

Weight:

$$W_{14} = A_{14} \cdot \rho_{cstl} \cdot 1.75\ inch$$

$$W_{14} = 280 \text{ lbs}$$

**13. Weight of item 13 (8 ea):**

Thickness: $t_{13} = 0.25$ in

Area:

$$A_{13} = \frac{1}{2} \cdot [(2\ inch \cdot 3.5\ inch) - (0.53\ inch)^2]$$

Weight:

$$w_{13} = A_{13} \cdot \rho_{cstl} \cdot t_{13}$$

$$w_{13} = 0.24 \text{ lbs}$$

$$W_{13} = 8 \cdot w_{13}$$

$$W_{13} = 2 \text{ lbs}$$

**14. Weight of blind flange (1 ea):**

a) Plate: $d_{p1} = 51.25$ in

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$t_{p1} = 0.75$ in

Area:

$$A_{p1} = \frac{\pi}{4} \cdot (51.25\ inch)^2$$

Weight: $W_{pl} = A_{pl} \cdot \rho_{cstl} \cdot t_{pl}$

$W_{pl} = 439$ lbs

b) Shackle lift plate, assume it is a rectangle:

$l_{slift} = 6$ in

$w_{slift} = 3$ in

$t_{slift} = 0.25$ in

Area: $A_{slift} = l_{slift} \cdot w_{slift}$

Weight: $W_{slift} = A_{slift} \cdot \rho_{cstl} \cdot t_{slift}$

$W_{slift} = 1.3$ lbs

c) Weight of blind flange: $W_{blflange} = W_{pl} + W_{slift}$

$W_{blflange} = 441$ lbs

**15. Weight of top cap (1 ea):**

a) Item 1 - 1/2" thick plate (2 ea):

Thickness: $t_1 = 0.25$ in

Area:

$$A_1 = (7.56 \cdot 5.94) - \frac{1}{2} \cdot [(7.94 \cdot 7.94 \cdot \tan(24°)) + (2 \cdot 2 \cdot \cot(32°))]$$

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Weight: $w_1 = A_1 \cdot \rho_{cstl} \cdot t_1$

$W_1 = 2 \cdot w_1$

$W_1 = 4$ lbs

b) Bar - 1" diameter & 8" long (1 ea):

Area: $A_{bar} = (\pi/4) \cdot (1\ in)^2$

Length: $l_{bar} = 8$ in

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

$W_{bar} = 2$ lbs

c) Item 2 - Inner plate 1" thick (1 ea):

Area:

$$A_2 = (14.625\ inch \cdot 4.125\ inch) + \frac{\pi}{4} \cdot (58.5\ inch)^2$$

Thickness: $t_2 = 1$ in

Weight: $W_2 = A_2 \cdot \rho_{cstl} \cdot t_2$

$W_2 = 780$ lbs

d) B-Section plate, 1/2" thick (2 ea):

$l_{bsec} = 7.7$ in

$w_{bsec} = 5.9$ in

$t_{bsec} = 0.5$ in

Area: $A_{bsec} = l_{bsec} \cdot w_{bsec}$

Weight: $w_{bsec} = A_{bsec} \cdot \rho_{cstl} \cdot t_{bsec}$

$w_{bsec} = 6.5$ lbs

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$$W_{bsec} = 2 \cdot w_{bsec}$$

$$W_{bsec} = 13 \text{ lbs}$$

e) Outer plate, 3/8" thick (1 ea):

Diameter: $d_{outpl} = 53.5$ in

Thickness: $t_{outpl} = 0.38$ in

Area:

$$A_{outpl} = \frac{\pi}{4} \cdot (53.5\ inch)^2$$

Weight: $W_{outpl} = A_{outpl} \cdot \rho_{cstl} \cdot t_{outpl}$

$$W_{outpl} = 239 \text{ lbs}$$

f) Weight of top plate: $W_{tplate} = W_{outpl} + W_{bsec} + W_2 + W_{bar} + W_1$

$$W_{tplate} = 1{,}039 \text{ lbs}$$

16. **Weight of shielding:**

Lead density (Reference 1, p. 398):

$$\rho_{Pb} = 0.41 \text{ lb/in}^3$$

Assume 62% lead density of lead:

$$\rho_{sh} = 0.62 \cdot \rho_{Pb}$$

$$\rho_{sh} = 0.25 \text{ lb/in}^3$$

Total length of shielding: $l_{tsh} = 49$ ft

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Volume of shielding:

$id_{sh} = 52$ in $\qquad od_{sh} = 55$ in

$$Vol_{sh} = \pi \cdot \frac{(od_{sh}^2 - id_{sh}^2)}{4} \cdot l_{sh1}$$

**Weight of shielding:** $W_{sh} = \rho_{sh} \cdot Vol_{sh}$

$W_{sh} = 37{,}650$ lbs

17. **Weight of bolts:**

Number of 3/4" bolts: $n_{b1} = 24$

Number of 1" bolts: $n_{b2} = 16$

Weight per 100 of Hex bolts and nuts (3/4"), Reference 2, p.4-144 and 4-145:

$w_{b1} = 52.3$ lbs

Weight of 3/4" bolts:

$$W_{b1} = \frac{52.3}{100} \cdot n_{b1}$$

$W_{b1} = 12.6$ lbs

Weight per 100 of Hex bolts and nuts (1"), Reference 2, p.4-144 and 4-145:

$w_{b2} = 108.8$ lbs

Weight of 1" bolts:

$$W_{b2} = \frac{108.8}{100} \cdot n_{b2}$$

$W_{b2} = 17.41$ lbs

Total weight of bolts: $W_b = W_{b1} + W_{b2}$

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$$W_b = 30 \text{ lbs}$$

18. Weight of vent (1 ea):

$$W_{vent} = 15 \text{ lbs}$$

19. Weight of plug (16 ea):

$$w_{plug} = 3 \text{ lbs}$$

$$W_{plug} = 16 \cdot w_{plug}$$

$$W_{plug} = 48 \text{ lbs}$$

20. Maximum Weight of payload: (Reference 4, page 5)

$$W_{pload} = 3{,}152 \text{ lbs}$$

21. Weight of empty container:

$$W_{cont} = W_{pipe} + W_{cstl1} + W_{cstl2} + W_7 + W_6 + W_5 + W_3 + W_4 \ldots$$
$$+ W_{12} + W_{18} + W_{15} + W_{11} + W_{14} + W_{13} + W_{blflange} + W_{tplate} + W_b + W_{vent} + W_{plug}$$

$$W_{cont} = 25{,}086 \text{ lbs}$$

22. Weight of non-shielded loaded container:

$$W_{nscont} = W_{cont} + W_{pload}$$

$$W_{nscont} = 28{,}238 \text{ lbs}$$

23. Weight of shielded loaded container:

$$W_{scont} = W_{cont} + W_{pload} + W_{sh}$$

$$W_{scont} = 65{,}884 \text{ lbs}$$

24. Weight of container without support rings or shielding:

$$W_{norings} = W_{nscont} - W_{31} - W_{pload} - W_{41} - W_{12} - W_{tplate} - W_{14}$$

$$W_{norings} = 20{,}503 \text{ lbs}$$

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**25. Center of gravity of top cap:**

| | x (in) | w (lbs) | x·w (in.lbs) |
|---|---|---|---|
| 1 | 0.5 | 908 | 454 |
| 2 | $\left(8 + \frac{3}{16}\right)$ | $\frac{1}{2} \cdot 3.93$ | 16.1 |
| 3 | $\left(8 + \frac{3}{16}\right)$ | 239.4 | 1,960 |
| 4 | $\left(8 + \frac{3}{16}\right) - \left(5 - \frac{1}{16}\right)$ | 1.8 | 5.6 |
| 5 | $\frac{1}{2} \cdot \left(7 + \frac{3}{16}\right) + 1$ | 13 | 59.5 |

Center of Gravity:

$$CG_{ct} = \frac{xw_1 + 2 \cdot xw_2 + xw_3 + xw_4 + 2 \cdot xw_5}{W_{tplate}}$$

$CG_{ct}$ = 2.5 in, from the bolting surface

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**26. Package center of gravity:**

| | x | w |
|---|---|---|
| 1 | 1 | 1,735 |
| 2 | 3.13 | 732 |
| 3 | 5.6 | 31 |
| 4 | 5.6 | 31 |
| 5 | 10.8 | 265 |
| 6 | 5.5 | 65 |
| 7 | 29.7 | 359 |
| 8 | 49.13 | 265 |
| 9 | 57.6 | 265 |
| 10 | 68.5 | 367 |
| 11 | 88.4 | 265 |
| 12 | 112.4 | 443 |
| 13 | 136.4 | 265 |
| 14 | 160.4 | 443 |
| 15 | 184.4 | 265 |
| 16 | 208.4 | 443 |
| 17 | 232.4 | 265 |
| 18 | 253.8 | 792 |
| 19 | 267 | 265 |
| 20 | 275 | 265 |
| 21 | 299 | 890 |
| 22 | 323 | 265 |
| 23 | 34.6 | 422 |
| 24 | 368.9 | 265 |
| 25 | 393 | 443 |

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| | | |
|---|---|---|
| 26 | 417 | 265 |
| 27 | 441 | 443 |
| 28 | 465 | 265 |
| 29 | 489 | 443 |
| 30 | 505 | 265 |
| 31 | 553 | 265 |
| 32 | 513 | 367 |
| 33 | 533 | 280 |
| 34 | 295 | 10,180 |
| 35 | 594 | 1,000 |
| 36 | 148 | 239 |
| 37 | 467 | 233 |
| 38 | 467 | 233 |
| 39 | 467 | 233 |

$$\sum_{i=1}^{39} w = 23{,}087\,lbs$$

$$\sum_{i=1}^{39} (w \cdot x) = 6.7 \cdot 10^{6}\ lbs \cdot inch$$

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$$CG_{pkg} = \frac{\sum_{i=1}^{39} (w \cdot x)}{\sum_{i=1}^{39} w}$$

$CG_{pkg}$ = 288.4 in from the closed end of the container (welded end).

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| Checker S. S. Shiraga [signature] | | Date 06/13/94 | |

I. **Objective:**

The objective of this analysis is to determine the g loading for the 106C 49 foot package when subjected to a simulated drop onto a flat horizontal 12-inch thick reinforced concrete slab per Reference 2.

II. **Reference:**


1. US-NRC, 10 CFR Part 71, "Packaging and Transportation of Radioactive Materials".
2. WHC-SD-TP-PDC-015, Rev. 0-A, "Packaging Design Criteria Transfer Disposal of Equipment, Tank 241-C-106 Waste Sluicing System".
3. 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.
4. American Concrete Institute, Manual of Concrete Practice 1989, Part III.
5. Engineering Change Notice, No. 606658, dated May 02, 1994.
6. WHC Drawing No., H-2-83722, H-2-83724, H-2-83725, H-2-83726 and H-2-83727.


III. **Results and Conclusions:**

As a result of preliminary analysis, it was determined that the container as designed could not withstand a drop of 1 foot onto a hard unyielding surface as specified in Reference 1. Although this criterion is not specifically stated in Reference 2, it is standard practice within the precepts of Equivalent Safety to perform an analysis on this basis to show structural integrity of the container. However, since the container was already constructed, an alternative criteria was needed to show structural integrity of the container for conditions which exist within the site boundary. It was determined that by using the EPRI Report (Reference 3), a credible criterion to show container structural integrity could be developed by dropping the container onto a thick concrete pad. This was justified on the basis that the container is similar to a spent fuel container with a substantial all steel construction with a relative overall hardness greater than concrete. Consequently, Reference 2, was revised via an ECN (Reference 5) to reflect this change.

## ENGINEERING ANALYSIS

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Based upon the EPRI Report, the analysis result shows a g loading on the package of 42, as a result of a 12 inch drop. This g loading will be used in subsequent drop calculations for the container.

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Checker S. S. Shiraga SSS Date 06/13/94

IV. **Engineering Evaluation:**

**LOAD CALCULATION AT A 1-FT FLAT DROP OF THE 106C PACKAGE ONTO A FLAT 12-IN THICK CONCRETE.**

Calculations based on Reference 2.

Assumptions:

Concrete thickness: $h = 12$ in

Cover over rebar: $c = 2$

Concrete strength: $\sigma_u = 4{,}000$ psi

$f_c = \sigma_u$

Soil Modulus of Elasticity: $E_s = 25 \times 10^3$ psi

$S_y = 60 \times 10^3$ psi

For normal weight concrete (Reference 4, p. 318/318R-83), concrete modulus of elasticity:

$E_c = (57{,}000 \cdot f_c^{0.5}) \cdot psi^{0.5}$, forced $E_c$ to have "psi" unit, since the constant 57,000 has the built-in "$psi^{0.5}$" unit.

$$E_c = 3.605 \times 10^6 \text{ psi}$$

#9 rebar (Reference 4, Tbl B.1, Part III):

$$A_9 = \frac{\pi \cdot (1.13)^2}{4}$$

Package length (Reference 6): $L = 589.5$ in

Package weight: $W_{cont} = 65{,}884$ lbs

Width of footprint: $d = 10$ in

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**For edge drop:**

$$a = \frac{A_s \cdot S_y}{0.85 \cdot f_c \cdot h}$$

$$a = 1.48 \text{ in}$$

$$I_c = L \cdot (h^3) \cdot \frac{1}{12}$$

$$I_c = 8.49 \text{ X } 10^4 \text{ in}^4$$

Ultimate moment capacity of the concrete slab:

$$M_u = A_s \cdot S_y \cdot \left(d - \frac{a}{2}\right)$$

$$M_u = 5.57 \text{ X } 10^5 \text{ in} \cdot \text{lbs}$$

$$\beta = \left[\frac{E_s}{(4 \cdot E_c \cdot I_c)}\right]^{0.25}$$

$$\beta = 0.012 \text{ in}^{-1}$$

Foot print area: $A = L \cdot d$

$$A = 5.90 \text{ X } 10^3 \text{ in}^2$$

Target hardness number (non-dimensional) which uniquely characterizes the target.

**ENGINEERING ANALYSIS**

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$$S = \frac{2 \cdot A \cdot E_s \cdot M_u \cdot \sigma_u}{W_{cont}^3 \cdot \beta}$$

$$S = 1.92 \times 10^5$$

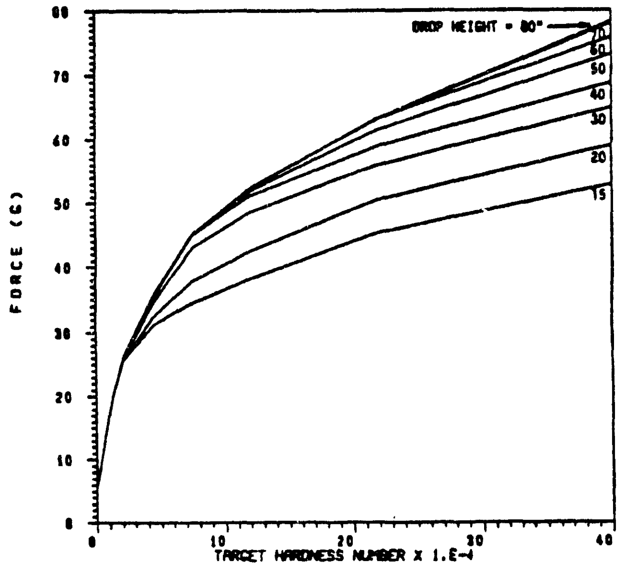


Figure 1

Using Figure 1 above from Ref. 2, p. 2-32, the g loading is approximately 42.

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Subject Penetration Evaluation
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Checker S. S. Shiraga Date 06/14/94

## I. Objectives:

The objective of this evaluation is to determine the ability of the 106C-49 foot packaging to withstand the stress induced by the dropping of a 13 lbs steel bar onto the packaging as required by Reference 5.

## II. References:


1. WHC-SD-TP-PDC-015, Rev. 0-A, "Packaging Design Criteria Transfer and Disposal of Equipment, Tank 241-C-106 Waste Sluicing System".

2. WHC Drawing No. H-2-83722, H-2-83724, H-2-83725, H-2-83726, and H-2-83727.

3. "Structures to Resist the Effects of Accidental Explosion - Department of the Army, Navy and Air Force", PM 5-1300 June 1969.

4. "Fundamentals of Protective Design", US Army Corps of Engineers (1943).

5. US-NRC, 10 CFR Part 71, "Packaging and Transportation of Radioactive Materials".


## III. Results and Conclusions:

The penetration analysis was performed for the thin skin shielding material retaining section of the packaging per the requirements Reference 5. This is determined as the weakest exposed section of the packaging.

This evaluation is based on empirical projectile penetration data provided in References 3 and 4. The analysis shows the thinnest section of the container resists penetration by a 13 lbs projectile falling onto it from a height of 40 inches. The calculated estimated margin of safety is 0.15. Subsequently, it is concluded that the package design is adequate.

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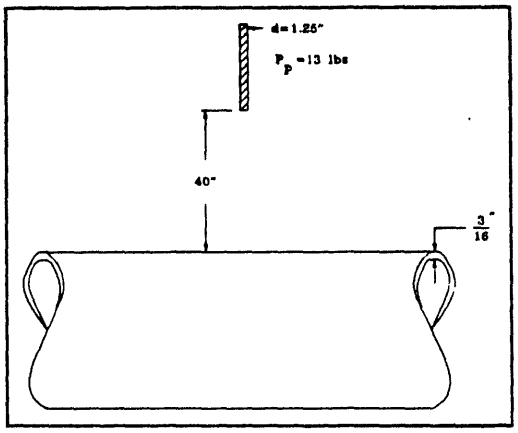
## IV. Engineering Evaluation:




| | |
|---|---|
| Diameter of projectile (Ref. 1): | d = 1.25 in. |
| Height of projectile object (Ref. 1): | h = 40 in |
| Mass of projectile object (Ref. 1): | p = 13 lbs |
| Outer skin thickness (Ref. 2): | $t_{sk}$ = 3/16 in |
| Gravitational constant: | g = 32.2 ft/sec$^2$ |

Velocity of a free falling object:

$$v = \sqrt{2\,g\,h}$$

$$v = 15\ ft/sec$$

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Penetration distance into reinforced concrete (Reference 3):

$$S = 5.423 \frac{p\, v^{1.33}}{10^4\, d^{1.8}}$$

$$S = 0.168\ inch$$

this is penetration distance into reinforced concrete.

This translate into the perforation limit for steel (Reference 4),

$$t = \frac{1.216\ S + 1.4d}{12}$$

$$t = 0.163\ inch$$

This is the penetration distance into steel.

Margin of Safety,

$$MS = \frac{t_{sk}}{t} - 1$$

$$MS = 0.15$$

*OK, Package has sufficient skin thickness.*

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Subject Drop Calculation for the 49 foot 106C Packaging
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Checker S. S. Shiraga Date 06/14/94

### I. Objective:

The objective of the drop analysis is to determine if the 106C-49 foot packaging could survive a 1-ft drop onto a flat, horizontal 12-in thick concrete (per Reference 1 & 2). Survival in this evaluation is defined as not losing structural integrity or breaching containment of the inner packaging as defined in 10CFR71.71 (Reference 10).

### II. References:


1. WHC-SD-TP-PDC-015, Rev. 0-A, Packaging Design Criteria Transfer and Disposal of Equipment, Tank 241-C-106 Waste Sluicing System.
2. Engineering Change Notice 606658, dated May 02, 1994.
3. American Society of Mechanical Engineers, Boiler Pressure and Vessels, Section VIII, Division 2, 1989.
4. Industrial Press, Machinery's Handbook, 23 rd edition.
5. WHC Drawing No., H-2-83722, H-2-83724, H-2-83725, H-2-83726 and H-2-83727.
6. EPRI NP-4830 "The Effect of Target Hardness on the Structural Design of Concrete Storage Pads for Spent Fuel Casks".
7. Design Analysis, WO/Job No. ER4289, Kaiser Engineers Hanford, Nov. 11, 1993.
8. Roark, Formulas for Stress and Strain, 4th edition.
9. American Institute of Steel Construction, Steel Construction Manual, 9th edition.
10. US-NRC, 10 CFR Part 71, "Packaging and Transportation of Radioactive Materials".
11. Engineering Change Notice W-320-23, dated June 06, 1994.
12. American Society of Mechanical Engineers, Boiler Pressure and Vessels, Section VIII, Division 1, 1989.


### III. Results and Conclusions:

This engineering evaluation is based upon classical methods, which models the dynamic loads as a static equivalent loads. The calculations are based on the assumption that the time of loading is long as compared to the natural period of

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the package. Also the calculations are based on elastic behavior of the material.

As stated in the G loading determination calculations, since the package as designed cannot meet the drop requirements of Reference 10. Subsequently alternate criteria were specified to evaluate package integrity in Reference 1 and 2. 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.

Results and conclusions of this evaluation are as follows:

1. The packaging material and welds have adequate margins of safety.

2. The packaging stiffener ring design is adequate with the margin of safety of 0.68.

3. The pipe joint weldment is adequate with the margin of safety of 2.41.

4. The package outer skin design is adequate with the safety margin of 1.3.

5. Blind flange bolts calculational results were as follows:

   * With all 16 bolts engaged in carrying the load, the Margin of Safety is 0.22. This adequate to insure containment of the package after a drop.

   * The minimum number of bolts required to be engaged in shear to provide sufficient strength is 3.

   * With only 1 bolt engaged, the Margin of Safety is -0.25. Therefore, a single bolt would not be able to provide containment.

   * Consequently, in order to provide containment after a 1 foot drop, at minimum 3 bolts of the 16 will need to engage the load. At present there is no sure method to insure that 3 bolts will engage the load, due to the variations in tolerance stackup of bolt to bolt holes. Subsequently, this evaluation cannot state with confidence that a leak path will not develop after a 1 foot drop onto a concrete slab, since the probability exists that only 1 bolt will initially carry the load. If that occurs a leak path may develop through failure of one of the bolts.

6. Previous guide pin design were analyzed, it was found that they could not bear the shear load. Accordingly, alternative materials were specified for the current guide pins as referenced in reference 11. With the modification, the guide pins will support the shear load of impact by a

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margin of safety of 0.08. Also since, at least one blind flange bolt will be engaged in conjunction with the guide pins which was ignored in the analysis, the evaluation is conservative.

7. The internal plate design is appropriate for the load.

8. The top cap bolts findings are as followed:

   * With one bolt engagement, margin of safety is -0.63. Therefore 1 bolt cannot carry the load.

   * There must be a minimum of 5 bolts engaging the load in order to maintain confinement.

   * With all 24 bolts in engagement the margin of safety is 0.53, the package secondary containment will be retained.

However, this is not containment boundary for transportation and consequently is considered adequate.

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## IV. Engineering Evaluation:

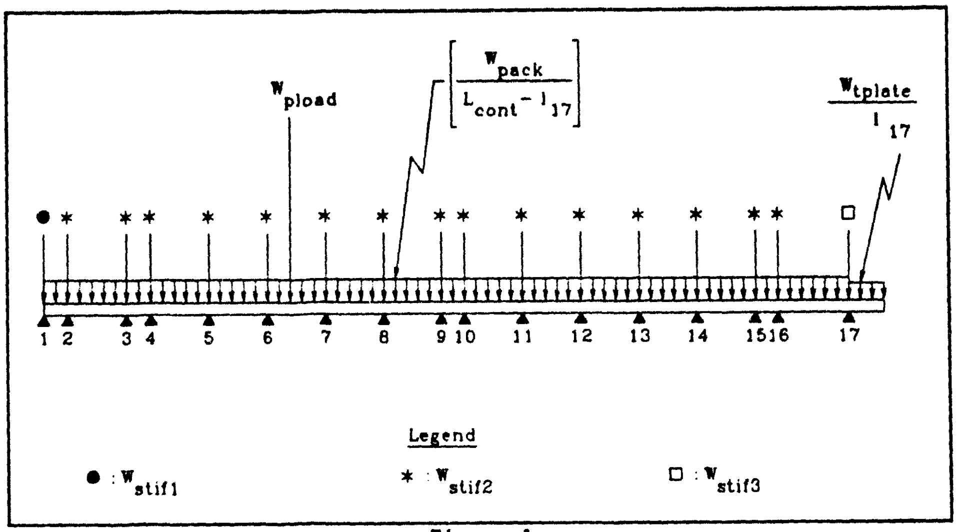


Figure 1

**Weights:**

Weight of container w/o ring supports: $W_{contl}$ = 20,503 lbs

Weight of payload: $W_{pc}$ = 3,152 lbs

Weight of shielding (62% density of Pb): $W_{sh}$ = 37,650 lbs

Weight of container: $W_{cont} = W_{contl} + W_{sh}$

$W_{cont}$ = 58,153 lbs

G loading factor for drop calculation on 12 inch thick concrete: $g_{load} = 42$
(Reference 6)

Weight of stiffeners:

1 inch thick: $w_{stif1}$ = 265 lbs

G loaded: $W_{stif1} = g_{load} \cdot w_{stif1}$ $W_{stif1}$ = 11,130 lbs

2 inch thick: $w_{stif2}$ = 1,736 lbs

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G loaded: $W_{stif2} = g_{load} \cdot W_{stif2}$ $W_{stif2} = 72{,}912$ lbs

Weight of package with G loading:

$W_{pack} = g_{load} \cdot W_{cont}$ $W_{pack} = 2.44 \times 10^6$ lbs

Weight of top cap: $W_{ctop} = 1{,}039$ lbs

Linear load per foot:

$$w_{ctop} = \frac{W_{ctop}}{\left(8 + \frac{3}{16}\right) inch}$$

$$w_{ctop} = 1{,}523 \text{ lbs/ft}$$

**Determine moments of drop:**

Model with assumption weight of pipe, internals, shielding and skin are uniformly distributed over the entire length of pipe, except top cap section. Load of rings are modeled as concentrated loads at their respective locations and payload is modeled as a concentrated load at the center of gravity.

**Geometric Parameters:**

Length between supports:

$l_1 = 8.75$ in $l_2 = 3$ ft + 3.875 in $l_4 = 41.25$ in

$l_3 = 8.5$ in $l_5 = 49$ in $l_7 = l_5$

$l_6 = l_5$ $l_8 = 43.75$ in $l_{11} = l_5$

$l_9 = 8.25$ in $l_{10} = 46.75$ in $l_{14} = l_5$

$l_{12} = l_5$ $l_{13} = l_5$ $l_{15} = l_9$

$l_{16} = l_5$ $l_{17} = 8.1875$ in

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Total length:

$$L_t = l_1 + l_2 + l_3 + l_4 + l_5 + l_6 + l_7 + l_8 + l_9 + l_{10} + l_{11} + l_{12} + l_{13} + l_{14} + l_{15} + l_{16} + l_{17}$$

$$L_t = 50.46 \text{ ft}$$

**Parameters of inner pipe section:**

Pipe od: $dp_{od} = 52$ in Wall thickness: $t_{pw} = 0.375$ in

Pipe id: $dp_{id} = dp_{od} + 2 \cdot t_{pw}$

Cross sectional area:

$$A_p = \frac{\pi\left(dp_{od}^2 - dp_{id}^2\right)}{4}$$

Moment of Inertia:

$$I_p = \frac{\pi\left(dp_{od}^4 - dp_{id}^4\right)}{64}$$

Parameters of outer pipe cross section (thin portion):

Gap between pipes: $d_{gap} = 1.5$ in Wall thickness: $t_{opipe} = 0.1875$ in

Outside radius of pipe: $R_{opipe} = 26 \text{ in} + d_{gap} + t_{opipe}$

Outside diameter: $od_{opipe} = 2 \cdot R_{opipe}$ Inside diameter: $id_{opipe} = 2 \cdot (R_{opipe} - t_{opipe})$

Cross sectional area:

$$A_{op1} = \frac{\pi\left(od_{opipe}^2 - id_{opipe}^2\right)}{4}$$

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Moment of Inertia:

$$I_{op1} = \frac{\pi\left(od_{opipe}^4 - id_{opipe}^4\right)}{64}$$

Total moment of inertia of inner and outer thin pipe:

$$I_{p1} = I_p + I_{op1}$$

Parameters of outer pipe cross section (thick portion):

Gap between pipes: $d_{gap} = 1.5$ in Wall thickness: $t_{opipe} = 0.375$ in

Outside radius of pipe: $R_{opipe} = 26 \text{ in} + d_{gap} + t_{opipe}$

Outside diameter: $od_{opipe} = 2 \cdot R_{opipe}$ Inside diameter: $id_{opipe} = 2 \cdot (R_{opipe} - t_{opipe})$

Cross sectional area:

$$A_{op2} = \frac{\pi\left(od_{opipe}^2 - id_{opipe}^2\right)}{4}$$

Moment of Inertia:

$$I_{op2} = \frac{\pi\left(od_{opipe}^4 - id_{opipe}^4\right)}{64}$$

Total moment of inertia of inner and outer thick pipe:

$$I_{p2} = I_p + I_{op2}$$

**Center of gravity of heel jet pump (Reference 7: KEH Analysis, ER 4289):**

CG = 13.47 ft

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G loaded weight: $W_{pload} = g_{load} \cdot W_{pc}$

$W_{pload} = 132{,}384$ lbs

Weight per unit length distributed between supports:

$$w_{pload} = \frac{W_{pload}}{l_5}$$

$w_{pload} = 2{,}702$ lbs/in

Distance of pump cg from supports:

From support 6 (P147.625, column 5):

a = (13.47 ft + 2 in + 0.5 in + 1.25 in) - 147.625 in

a = 18 in

From support 7 (P196.625, column 6):

b = 196.625 in - (13.47 ft + 2 in + 0.5 in + 1.25 in)

b = 31 in

Uniform loading due to pipes, shielding and internals:

$$w_{pack} = \frac{W_{pack}}{L_t - l_{17}}$$

$w_{pack} = 4{,}090$ lbs/in

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**Moment determination using Three Moment Theorem:** The package is modeled as a beam with uniformly distributed load, where the load is the impact load due to weight of the container plus the shielding. The stiffened ring and payload impact load were superimposed into the model.

End constraints:

End Moment due to top cap:

$$M_r = -\frac{g_{load}\ w_{ctop}\ l_{17}^2}{2}$$

$$M_r = -14{,}887 \text{ ft-lbs}$$

End Moment at closed end: $M_a = 0$ ft-lbs

Span 1 and 2

$$M_a \frac{l_1}{I_{p1}} + 2\,M_b\left(\frac{l_1}{I_{p1}} + \frac{l_2}{I_{p1}}\right) + M_c \frac{l_2}{I_{p1}} = -\frac{1}{4}\left(\frac{w_{pack}\ l_1^3}{I_{p1}} + \frac{w_{pack}\ l_2^3}{I_{p1}}\right)$$

Span 2 and 3

$$M_b \frac{l_2}{I_{p1}} + 2\,M_c\left(\frac{l_2}{I_{p1}} + \frac{l_3}{I_{p1}}\right) + M_d \frac{l_3}{I_{p1}} = -\frac{1}{4}\left(\frac{w_{pack}\ l_2^3}{I_{p1}} + \frac{w_{pack}\ l_3^3}{I_{p1}}\right)$$

Span 3 and 4

$$M_c \frac{l_3}{I_{p1}} + 2\,M_d\left(\frac{l_3}{I_{p1}} + \frac{l_4}{I_{p1}}\right) + M_e \frac{l_4}{I_{p1}} = -\frac{1}{4}\left(\frac{w_{pack}\ l_3^3}{I_{p1}} + \frac{w_{pack}\ l_4^3}{I_{p1}}\right)$$

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**Span 4 and 5**

$$M_d \frac{l_4}{I_{p1}} + 2\,M_e\left(\frac{l_4}{I_{p1}} + \frac{l_5}{I_{p1}}\right) + M_f \frac{l_5}{I_{p1}} = -\frac{1}{4}\left(\frac{w_{pack}\,l_4^3}{I_{p1}} + \frac{w_{pack}\,l_5^3}{I_{p1}}\right)$$

**Span 5 and 6**

$$M_e \frac{l_5}{I_{p1}} + 2\,M_f\left(\frac{l_5}{I_{p1}} + \frac{l_6}{I_{p1}}\right) + M_g \frac{l_6}{I_{p1}} = -\frac{1}{4}\left(\frac{w_{pack}\,l_5^3}{I_{p1}} + \frac{w_{pack}\,6_2^3}{I_{p1}}\right) - \frac{W_{pload}\,a\,(l_6^2 - a^2)}{l_6\,I_{p1}}$$

**Span 6 and 7**

$$M_f \frac{l_6}{I_{p1}} + 2\,M_g\left(\frac{l_6}{I_{p1}} + \frac{l_7}{I_{p1}}\right) + M_h \frac{l_7}{I_{p1}} = -\frac{1}{4}\left(\frac{w_{pack}\,l_6^3}{I_{p1}} + \frac{w_{pack}\,7_2^3}{I_{p1}}\right) - \frac{W_{pload}\,b\,(l_6^2 - b^2)}{l_6\,I_{p1}}$$

**Span 7 and 8**

$$M_g \frac{l_7}{I_{p1}} + 2\,M_h\left(\frac{l_7}{I_{p1}} + \frac{l_8}{I_{p2}}\right) + M_i \frac{l_8}{I_{p2}} = -\frac{1}{4}\left(\frac{w_{pack}\,l_7^3}{I_{p1}} + \frac{w_{pack}\,l_8^3}{I_{p2}}\right)$$

**Span 8 and 9**

$$M_h \frac{l_8}{I_{p2}} + 2\,M_i\left(\frac{l_8}{I_{p2}} + \frac{l_9}{I_{p2}}\right) + M_j \frac{l_9}{I_{p2}} = -\frac{1}{4}\left(\frac{w_{pack}\,l_8^3}{I_{p2}} + \frac{w_{pack}\,l_9^3}{I_{p2}}\right)$$

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**Span 9 and 10**

$$M_i \frac{l_9}{I_{p2}} + 2\,M_j\left(\frac{l_9}{I_{p2}} + \frac{l_{10}}{I_{p2}}\right) + M_k \frac{l_{10}}{I_{p2}} = -\frac{1}{4}\left(\frac{w_{pack}\, l_9^3}{I_{p2}} + \frac{w_{pack}\, l_{10}^3}{I_{p2}}\right)$$

**Span 10 and 11**

$$M_j \frac{l_{10}}{I_{p2}} + 2\,M_k\left(\frac{l_{10}}{I_{p2}} + \frac{l_{11}}{I_{p1}}\right) + M_l \frac{l_{11}}{I_{p1}} = -\frac{1}{4}\left(\frac{w_{pack}\, l_{10}^3}{I_{p2}} + \frac{w_{pack}\, l_{11}^3}{I_{p1}}\right)$$

**Span 11 and 12**

$$M_k \frac{l_{11}}{I_{p1}} + 2\,M_l\left(\frac{l_{11}}{I_{p1}} + \frac{l_{12}}{I_{p1}}\right) + M_m \frac{l_{12}}{I_{p1}} = -\frac{1}{4}\left(\frac{w_{pack}\, l_{11}^3}{I_{p1}} + \frac{w_{pack}\, l_{12}^3}{I_{p1}}\right)$$

**Span 12 and 13**

$$M_l \frac{l_{12}}{I_{p1}} + 2\,M_m\left(\frac{l_{12}}{I_{p1}} + \frac{l_{13}}{I_{p1}}\right) + M_n \frac{l_{13}}{I_{p1}} = -\frac{1}{4}\left(\frac{w_{pack}\, l_{12}^3}{I_{p1}} + \frac{w_{pack}\, l_{13}^3}{I_{p1}}\right)$$

**Span 13 and 14**

$$M_m \frac{l_{13}}{I_{p1}} + 2\,M_n\left(\frac{l_{13}}{I_{p1}} + \frac{l_{14}}{I_{p1}}\right) + M_o \frac{l_{14}}{I_{p1}} = -\frac{1}{4}\left(\frac{w_{pack}\, l_{13}^3}{I_{p1}} + \frac{w_{pack}\, l_{14}^3}{I_{p1}}\right)$$

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**Span 14 and 15**

$$M_n \frac{l_{14}}{I_{p1}} + 2\,M_o\left(\frac{l_{14}}{I_{p1}} + \frac{l_{15}}{I_{p1}}\right) + M_p \frac{l_{15}}{I_{p1}} = -\frac{1}{4}\left(\frac{w_{pack}\,l_{14}^3}{I_{p1}} + \frac{w_{pack}\,l_{15}^3}{I_{p1}}\right)$$

**Span 15 and 16**

$$M_o \frac{l_{15}}{I_{p1}} + 2\,M_p\left(\frac{l_{15}}{I_{p1}} + \frac{l_{16}}{I_{p1}}\right) + M_r \frac{l_{16}}{I_{p1}} = -\frac{1}{4}\left(\frac{w_{pack}\,l_{15}^3}{I_{p1}} + \frac{w_{pack}\,l_{16}^3}{I_{p1}}\right)$$

Results of solving simultaneous solutions:

| | | |
|---|---|---|
| $M_a$ = 0 ft-lbs | $M_b$ = -41,272 ft-lbs | $M_c$ = -36,210 ft-lbs |
| $M_d$ = -35,740 ft-lbs | $M_e$ = -52,535 ft-lbs | $M_f$ = -102,919 ft-lbs |
| $M_g$ = -115,041 ft-lbs | $M_h$ = -50,514 ft-lbs | $M_i$ = -44,063 ft-lbs |
| $M_j$ = -47,059 ft-lbs | $M_k$ = -68,686 ft-lbs | $M_l$ = -68,337 ft-lbs |
| $M_m$ = -66,997 ft-lbs | $M_n$ = -72,705 ft-lbs | $M_o$ = -51,214 ft-lbs |
| $M_p$ = -77,879 ft-lbs | $M_r$ = -14,887 ft-lbs | |

**Span Moment and Reaction Loads:**

$M_a < M_b$

$$M_1 = \left(\frac{w_{pack}\,l_1^2}{8} - \frac{M_a + M_b}{2}\right) + \frac{(M_a - M_b)^2}{2\,w_{pack}\,l_1^2}$$

$M_1$ = 56,546 ft-lbs

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$$R_1 = \frac{w_{pack}\, l_1}{2} - \frac{M_a - M_b}{l_1} + W_{stif2}$$

$R_1$ = 34,198 lbs

$M_b > M_c$

$$M_2 = \left(\frac{w_{pack}\, l_2^2}{8} - \frac{M_b - M_c}{2}\right) + \frac{(M_b - M_c)^2}{2\, w_{pack}\, l_2^2}$$

$M_2$ = 106,483 ft-lbs

$$R_2 = \left(\frac{w_{pack}\, l_1}{2} + \frac{M_a - M_b}{l_1}\right) + \left(\frac{w_{pack}\, l_2}{2} + \frac{M_b - M_c}{l_2}\right) + W_{stif1}$$

$R_2$ = 165,612 lbs

$M_c > M_d$

$$M_3 = \left(\frac{w_{pack}\, l_3^2}{8} - \frac{M_d + M_c}{2}\right) + \frac{(M_c - M_d)^2}{2\, w_{pack}\, l_3^2}$$

$M_3$ = 39,057 ft-lbs

$$R_3 = \left(\frac{w_{pack}\, l_2}{2} + \frac{M_b - M_c}{l_2}\right) + \left(\frac{w_{pack}\, l_3}{2} + \frac{M_c - M_d}{l_3}\right) + W_{stif1}$$

$R_3$ = 110,915 lbs

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$M_d < M_e$

$$M_4 = \left(\frac{w_{pack}\ l_4^2}{8} - \frac{M_d + M_e}{2}\right) + \frac{(M_d - M_e)^2}{2\ w_{pack}\ l_4^2}$$

$M_4$ = 116,850 ft-lbs

$$R_4 = \left(\frac{w_{pack}\ l_3}{2} + \frac{M_c - M_d}{l_3}\right) + \left(\frac{w_{pack}\ l_4}{2} + \frac{M_d - M_e}{l_4}\right) + W_{stif1}$$

$R_4$ = 108,612 lbs

$M_e < M_f$

$$M_5 = \left(\frac{w_{pack}\ l_5^2}{8} - \frac{M_e + M_f}{2}\right) + \frac{(M_e - M_f)^2}{2\ w_{pack}\ l_5^2}$$

$M_5$= 181,536 ft-lbs

$$R_5 = \left(\frac{w_{pack}\ l_4}{2} + \frac{M_d - M_e}{l_4}\right) + \left(\frac{w_{pack}\ l_5}{2} - \frac{M_e - M_f}{l_5}\right) + W_{stif1}$$

$R_5$ = 188,175 lbs

$M_f < M_g$

$$M_6 = \left(\frac{w_{pack}\ l_6^2}{8} - \frac{M_f + M_g}{2}\right) + \frac{(M_f - M_g)^2}{2\ w_{pack}\ l_6^2} + \frac{W_{pload}\ a\ b}{l_6}$$

$M_6$ = 336,257 ft-lbs

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$$R_6 = \left(\frac{w_{pack}\, l_5}{2} + \frac{W_{pload}\, b}{l_6} + \frac{M_e - M_f}{l_5}\right) + \left(\frac{w_{pack}\, l_6}{2} - \frac{M_f - M_g}{l_6}\right) + W_{stiff}$$

$R_6$ = 280,552 lbs

$M_g > M_h$

$$M_7 = \left(\frac{w_{pack}\, l_7^2}{8} - \frac{M_g + M_h}{2}\right) + \frac{(M_g - M_h)^2}{2\, w_{pack}\, l_7^2} - \frac{W_{pload}\, a\, b}{l_6}$$

$M_7$ = 62,650 ft-lbs

$$R_7 = \left(\frac{w_{pack}\, l_6}{2} + \frac{W_{pload}\, a}{l_6} + \frac{M_f - M_g}{l_6}\right) + \left(\frac{w_{pack}\, l_7}{2} + \frac{M_g - M_h}{l_7}\right) + W_{stiff}$$

$R_7$ = 150,641 lbs

$M_h > M_i$

$$M_8 = \left(\frac{w_{pack}\, l_8^2}{8} - \frac{M_h + M_i}{2}\right) + \frac{(M_h - M_i)^2}{2\, w_{pack}\, l_8^2}$$

$M_8$ = 128,839 ft-lbs

$$R_8 = \left(\frac{w_{pack}\, l_7}{2} - \frac{M_g - M_h}{l_7}\right) + \left(\frac{w_{pack}\, l_8}{2} + \frac{M_h - M_i}{l_8}\right) + W_{stiff}$$

$R_8$ = 214,772 lbs

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$M_i<M_j$

$$M_9 = \left(\frac{w_{pack}\ l_9^2}{8} - \frac{M_h + M_i}{2}\right) + \frac{(M_i - M_j)^2}{2\ w_{pack}\ l_9^2}$$

$M_9$ = 48,653 ft-lbs

$$R_9 = \left(\frac{w_{pack}\ l_8}{2} + \frac{M_h - M_i}{l_8}\right) + \left(\frac{w_{pack}\ l_9}{2} + \frac{M_i - M_j}{l_9}\right) + W_{stif1}$$

$R_9$ = 114,846 lbs

$M_j<M_k$

$$M_{10} = \left(\frac{w_{pack}\ l_{10}^2}{8} - \frac{M_j + M_k}{2}\right) + \frac{(M_k - M_j)^2}{2\ w_{pack}\ l_{10}^2}$$

$M_{10}$ = 151,268 ft-lbs

$$R_{10} = \left(\frac{w_{pack}\ l_{10}}{2} + \frac{M_j - M_k}{l_{10}}\right) + \left(\frac{w_{pack}\ l_9}{2} + \frac{M_i - M_j}{l_9}\right) + W_{stif1}$$

$R_{10}$ = 122,373 lbs

$M_k>M_l$

$$M_{11} = \left(\frac{w_{pack}\ l_{11}^2}{8} - \frac{M_k + M_l}{2}\right) + \frac{(M_l - M_k)^2}{2\ w_{pack}\ l_{11}^2}$$

$M_{11}$ = 170,769 ft-lbs

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$$R_{11} = \left(\frac{w_{pack}\ l_{10}}{2} + \frac{M_j - M_k}{l_{10}}\right) + \left(\frac{w_{pack}\ l_{11}}{2} + \frac{M_k - M_l}{l_{11}}\right) + W_{stif1}$$

$R_{11}$ = 212,338 lbs

$M_l > M_m$

$$M_{12} = \left(\frac{w_{pack}\ l_2^2}{8} - \frac{M_l + M_m}{2}\right) + \frac{(M_m - M_l)^2}{2\ w_{pack}\ l_{12}^2}$$

$M_{12}$ = 169,926 ft-lbs

$$R_{12} = \left(\frac{w_{pack}\ l_{11}}{2} - \frac{M_k - M_l}{l_{11}}\right) + \left(\frac{w_{pack}\ l_{12}}{2} + \frac{M_l - M_m}{l_{12}}\right) + W_{stif1}$$

$R_{12}$ = 211,229 lbs

$M_m < M_n$

$$M_{13} = \left(\frac{w_{pack}\ l_{13}^2}{8} - \frac{M_m + M_n}{2}\right) + \frac{(M_n - M_m)^2}{2\ w_{pack}\ l_{13}^2}$$

$M_{13}$ = 172,128 ft-lbs

$$R_{13} = \left(\frac{w_{pack}\ l_{12}}{2} - \frac{M_l - M_m}{l_{12}}\right) + \left(\frac{w_{pack}\ l_{13}}{2} - \frac{M_m - M_n}{l_{13}}\right) + W_{stif1}$$

$R_{13}$ = 210,402 lbs

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$M_n > M_o$

$$M_{14} = \left(\frac{w_{pack}\,l_{14}^2}{8} - \frac{M_n + M_o}{2}\right) + \frac{(M_n - M_o)^2}{2\,w_{pack}\,l_{14}^2}$$

$M_{14}$ = 164,499 ft-lbs

$$R_{14} = \left(\frac{w_{pack}\,l_{13}}{2} + \frac{M_m - M_n}{l_{13}}\right) + \left(\frac{w_{pack}\,l_{14}}{2} + \frac{M_n - M_o}{l_{14}}\right) + W_{stif1}$$

$R_{14}$ = 207,606 lbs

$M_o < M_p$

$$M_{15} = \left(\frac{w_{pack}\,l_{15}^2}{8} - \frac{M_o + M_p}{2}\right) + \frac{(M_p - M_o)^2}{2\,w_{pack}\,l_{15}^2}$$

$M_{15}$ = 82,775 ft-lbs

$$R_{15} = \left(\frac{w_{pack}\,l_{14}}{2} - \frac{M_n - M_o}{l_{14}}\right) + \left(\frac{w_{pack}\,l_{15}}{2} - \frac{M_o - M_p}{l_{15}}\right) + W_{stif1}$$

$R_{15}$ = 94,645 lbs

$M_p > M_r$

$$M_{16} = \left(\frac{w_{pack}\,l_{16}^2}{8} - \frac{M_p + M_r}{2}\right) + \frac{(M_p - M_r)^2}{2\,w_{pack}\,l_{16}^2}$$

$M_{16}$ = 151,065 ft-lbs

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$$R_{16} = \left(\frac{w_{pack}\ l_{16}}{2} + \frac{M_p - M_r}{l_{16}}\right) + \left(\frac{w_{pack}\ l_{15}}{2} + \frac{M_o - M_p}{l_{15}}\right) + W_{stif1}$$

$R_{16}$ = 151,524 lbs

Weight of tapped stiffener: $w_{stif3}$ = 280.4 lbs

Weight of G loaded stiffener: $W_{stif3} = g_{load} \cdot w_{stif3}$ $W_{stif3}$ = 11,777 lbs

Reaction at Support 17:

$$R_{17} = w_{pack}\frac{l_{16}}{2} - \frac{M_p - M_r}{l_{16}} + W_{stif3}$$

$R_{17}$ = 127,374 lbs

Largest Moment and Reaction at Support 6, therefore evaluate for worst case stiffener ring and pipe loading:

$M_6$ = 336,257 ft-lbs $R_6$ = 280,552 lbs

**Determine highest stress on inner pipe section:**

Assume no strength contribution from outer skin.

Bending stress:

$$\sigma_{bpipe} = \frac{M_6\ R_{opipe}}{I_p}$$

$\sigma_{bpipe}$ = 5,551 psi

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Maximum shear stress:

$$\tau_{pipe} = 2\frac{R_6}{A_p}$$

$$\tau_{pipe} = 9{,}226 \text{ psi}$$

von Mises Stress:

$$\sigma_{ptot} = \sqrt{\sigma_{bpipe}^2 + 3\ \tau_{pipe}^2}$$

$$\sigma_{ptot} = 16{,}917 \text{ psi}$$

ASME Allowable (Reference 3, Table ACS-1, p.77):

$$\sigma_{asme} = 23{,}270 \text{ psi}$$

$$MS_{pipe} = \frac{\sigma_{asme}}{\sigma_{ptot}} - 1$$

$$MS_{pipe} = 0.38 \quad \textbf{OK}$$

**Stiffener Ring Parameters and Evaluation:**

Model ring loading as a combination of a ring loaded by a distributed load through the cross section, reacted against by a force causing a shear load through the ring. See Figures 2 and 3 below. (Reference 8, pages 176 and 178, Cases 20 and 25)

Poisson's Ratio for Carbon steel: $\nu = 0.3$
(Reference 3, page 516)

Bottom radius of ring: $R_{ring} = 29.25$ in

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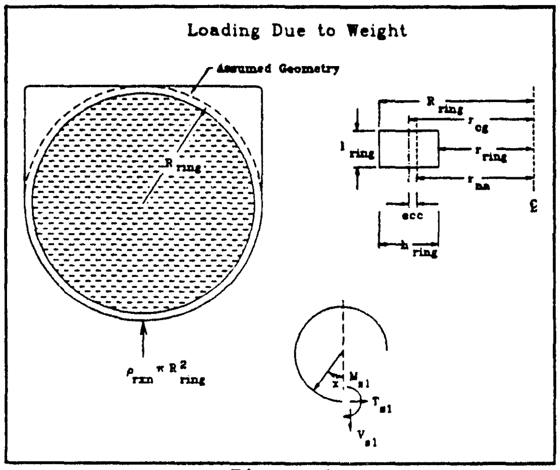


Figure 2

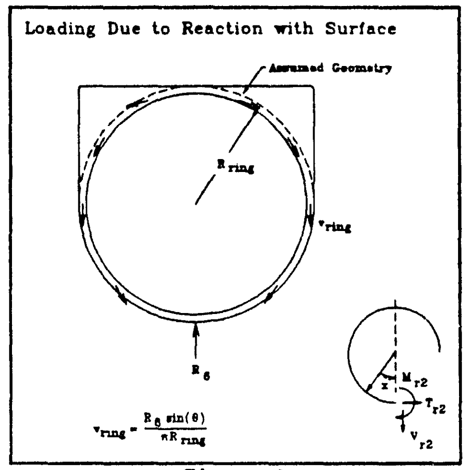


Figure 3

Width of ring: $l_{ring}$ = 1.0 inch

Angle for Case 25 is: $\theta$ = 0 deg

Angle of evaluation: x = 0 deg

a) Case 20, Loading due to Weight:

Assume load per ring smeared throughout cross section:

Load density:

$$\rho_{rxn} = \frac{R_6}{\pi\ R_{ring}^2\ l_{ring}}$$

$u = \cos(x)$ $z = \sin(x)$

From Figure 2, above:

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Moment due to weight:

$$M_{s1} = \rho_{rxn} R_{ring}^3 \left(\frac{1}{2} + \frac{1}{4} u - \frac{1}{2} \pi z + \frac{1}{2} x z\right)$$

$$M_{s1} = 2.13 \times 10^6 \text{ lbs-in/in}$$

Tangential load due to weight:

$$T_{s1} = \rho_{rxn} R_{ring}^2 \left(1 + \frac{1}{4} u - \frac{1}{2} \pi z + \frac{1}{2} x z\right)$$

$$T_{s1} = 121{,}447 \text{ lbs/in}$$

Radial Shear due to weight:

$$V_{s1} = \rho_{rxn} R_{ring}^2 \left[\left(\frac{1}{2} x u + \frac{1}{4} z\right) - \frac{1}{2} \pi u\right]$$

$$V_{s1} = -152{,}615 \text{ lbs/in}$$

b) Reaction load, Figure 3:

$s = \sin(\theta)$ $c = \cos(\theta)$ $u_{rxn} = \cos(x)$ $z_{rxn} = \sin(x)$

Moment due to reaction:

$$M_{s2} = R_6 R_{ring} \left[0.2386\ u_{rxn} - \frac{1}{2} s + 0.15915 \left(x z_{rxn} + \theta s + c - u_{rxn} c^2\right)\right]$$

$$M_{r2} = 177{,}518 \text{ ft-lbs}$$

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Tangential load due to reaction:

$$T_{r2} = R_6 \left[0.15915 \left(x\ z_{rxn} - u_{rxn}\ c^2\right) - 0.07958\ u_{rxn} - \frac{1}{2}\ z_{rxn}\right]$$

$$T_{r2} = -72{,}868\ \text{lbs}$$

Radial Shear due to reaction:

$$V_{r2} = R_6 \left[0.15915 \left(x\ u_{rxn} - \frac{1}{2}\ z_{rxn} + z_{rxn}\ c^2\right) - \frac{1}{2}\ u_{rxn}\right]$$

$$V_{r2} = -152{,}615\ \text{lbs}$$

c) Total Moments and Loads on Ring:

$M_{total} = M_{s1} \cdot l_{ring} - M_{r2}$ $M_{total} = 98.5$ ft-lbs

$T_{total} = T_{s1} \cdot l_{ring} + T_{r2}$ $T_{total} = 48{,}580$ lbs

$V_{total} = V_{s1} \cdot l_{ring} + V_{r2}$ $V_{total} = 0$ lbs

Since the ratio of the radius to thickness of the ring is slightly less than 10, treat as a curved beam:

Geometric Parameters of ring per Figure 2 above:

Inside radius:

$$r_{ring} = \frac{dp_{id}}{2}$$

Depth of ring: $h_{ring} = 3.25\ \text{in} + 0.375\ \text{in}$

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Neutral Axis radius:

$$r_{na} = \frac{h_{ring}}{\ln\left(\frac{R_{ring}}{r_{ring}}\right)}$$

Center of gravity of ring:

$$r_{cg} = r_{ring} + \frac{h_{ring}}{2}$$

Eccentricity:

$$ecc = r_{cg} - r_{na}$$

Cross sectional area of ring:

$$A_{ring} = h_{ring}\, l_{ring}$$

Stresses in ring:

Bending stress:

$$\sigma_{bottom} = \frac{M_{total}\,(r_{na} - r_{ring})}{A_{ring}\, ecc\, r_{ring}}$$

$$\sigma_{bottom} = 565 \text{ psi}$$

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Tangential stress:

$$\sigma_{ttop} = \frac{T_{total}}{A_{ring}}$$

$$\sigma_{ttop} = 13{,}401 \text{ psi}$$

Shear stress:

$$\tau_{ring} = 2\frac{V_{total}}{A_{ring}}$$

$$\tau_{ring} = 0 \text{ psi}$$

Total stress:

$$\sigma_T = \sigma_{bottom} + \sigma_{ttop} + \tau_{ring}$$
$$\sigma_T = 13{,}966 \text{ psi}$$

$$MS_{stiffen} = \frac{\sigma_{asme}}{\sigma_T} - 1$$

$$MS_{stiffen} = 0.67$$ **OK**

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**Connections:**

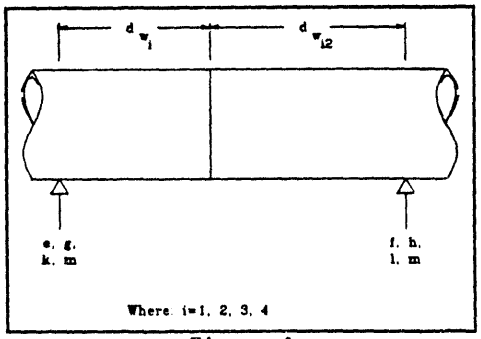


Figure 4

1) Stresses at pipe weld joints:

Largest moment at position h, largest reaction at Support 5.

Weldments at: between supports e (rxn load 5) and f (rxn load 6), g (rxn load 7) and h (rxn load 8), k (rxn load 11) and l (rxn load 12), m (rxn load 13) and n (rxn load 14).

Between support e and f:

$M_e < M_f$

Weld distances: $d_{w1} = 22.87$ in $d_{w12} = 25.13$ in

Moments on weld:

$$M_{w11} = \frac{w_{pack}\, d_{w1}}{2}(l_5 - d_{w1}) + \left(\frac{M_e - M_f}{l_5}\right) d_{w1} - M_e$$

$$M_{w11} = 177{,}856 \text{ ft-lbs}$$

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$$M_{w12} = \frac{w_{pack}\, d_{w12}}{2}(l_5 - d_{w12}) + \left(\frac{M_e - M_f}{l_5}\right) d_{w12} - M_f$$

$M_{w12}$ = 230,949 ft-lbs

Shear on weld:

$$V_{w1} = w_{pack}\left(\frac{l_5}{2} - d_{w1}\right) + \left(\frac{M_e - M_f}{d_{w1}}\right)$$

$V_{w1}$ = 33,101 lbs

Between support g and h:

$M_g > M_h$

Weld distances: $d_{w2}$ = 44.88 in $d_{w22}$ = 3.13 in

Moments on weld:

$$M_{w21} = \frac{w_{pack}\, d_{w2}}{2}(l_7 - d_{w2}) + \left(\frac{M_g - M_h}{l_7}\right) d_{w2} - M_g$$

$M_{w21}$ = 87,440 ft-lbs

$$M_{w22} = \frac{w_{pack}\, d_{w22}}{2}(l_7 - d_{w22}) + \left(\frac{M_g - M_h}{l_7}\right) d_{w22} - M_h$$

$M_{w22}$ = 70,851 ft-lbs

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Shear on weld:

$$V_{w2} = w_{pack}\left(\frac{l_7}{2} - d_{w2}\right) + \left(\frac{M_g - M_b}{d_{w2}}\right)$$

$$V_{w2} = -\ 100{,}579 \text{ lbs}$$

Between support k and l:

$M_k > M_l$

Weld distances: $d_{w3} = 17.13$ in $d_{w32} = 30.87$ in

Moments on weld:

$$M_{w31} = \frac{w_{pack}\, d_{w3}}{2}(l_{11} - d_{w3}) + \left(\frac{M_k - M_l}{l_{11}}\right) d_{w3} - M_k$$

$$M_{w31} = 161{,}568 \text{ ft-lbs}$$

$$M_{w32} = \frac{w_{pack}\, d_{w32}}{2}(l_{11} - d_{w32}) + \left(\frac{M_k - M_l}{l_{11}}\right) d_{w32} - M_k$$

$$M_{w32} = 163{,}811 \text{ ft-lbs}$$

Shear on weld:

$$V_{w1} = w_{pack}\left(\frac{l_{11}}{2} - d_{w32}\right) + \left(\frac{M_k - M_l}{d_{w3}}\right)$$

$$V_{w3} = 29{,}889 \text{ lbs}$$

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Between support m and n:

$M_m < M_n$

Weld distances: $d_{w4}$ = 39.13 in $d_{w42}$ = 14.87 in

Moments on weld:

$$M_{w41} = \frac{w_{pack}\, d_{w4}}{2}(l_{13} - d_{w4}) + \left(\frac{M_n - M_m}{l_{13}}\right) d_{w4} - M_m$$

$M_{w41}$ = 128,234 ft-lbs

$$M_{w42} = \frac{w_{pack}\, d_{w42}}{2}(l_{13} - d_{w42}) + \left(\frac{M_n - M_m}{l_{13}}\right) d_{w42} - M_n$$

$M_{w42}$ = 157,432 ft-lbs

Shear on weld:

$$V_{w4} = w_{pack}\left(\frac{l_{13}}{2} - d_{w4}\right) + \left(\frac{M_n - M_m}{d_{w4}}\right)$$

$V_{w4}$ = -61,567 lbs

Largest load is $M_{w12}$ between supports e and f:

Bending stress:

$$\sigma_w = \frac{M_{w12}\, R_{opipe}}{I_p}$$

$\sigma_w$ = 3,813 psi

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Shear stress:

$$\tau_w = 2\,\frac{V_{w2}}{A_p}$$

$$\tau_w = -3{,}307 \text{ psi}$$

von Mises Stress on weld:

$$\sigma_{totwel} = \sqrt{\sigma_w^2 + 3\,\tau_w^2}$$

$$\sigma_{totwel} = 6{,}881 \text{ psi}$$

$$MS_{pweld} = \frac{\sigma_{asme}}{\sigma_{totwel}} - 1$$

$$MS_{pweld} = 2.38 \quad \text{OK}$$

2) Lead slump on the outer skin (skin weldment):

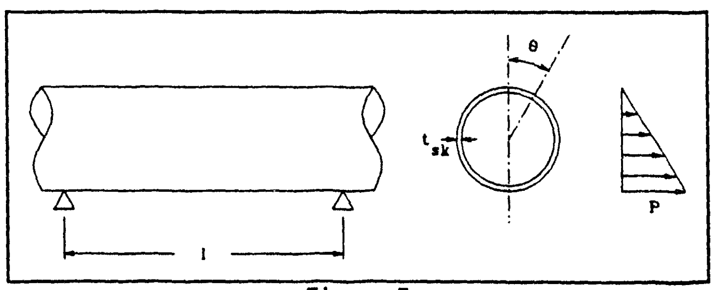


Figure 5

Model thinest section only.

Inside diameter of skin: $ip_{Pb} = 52$ in

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Thickness of skin: $t_{sk} = 0.1875$ in

Outside diameter of skin:

$$op_{Pb} = \left[\left(55 + \frac{3}{8}\right) - 2\ t_{sk}\right]$$

Cross sectional area of skin:

$$A_{Pb} = \frac{\pi}{4}\left(op_{Pb}^2 - ip_{Pb}^2\right)$$

$$A_{Pb} = 252\ \text{in}^2$$

Length between supports: $L_{Pb} = 48$ in

Mid-point of length:

$$z_{Pb} = \frac{L_{Pb}}{2}$$

Radius of lead:

$$r_{Pb} = \frac{ip_{Pb}}{2} + 1.50\,inches$$

Angle of evaluation: $\theta_{Pb} = 180$ deg

Poisson's ratio of carbon steel (Reference 3, page 516): $\nu = 0.3$

Density of lead (Reference 4, page 398): $\rho_{Pb} = 0.4096\ \text{lbs/in}^3$

Assume 62% density of shot: $\rho_{sh} = 0.62 \cdot \rho_{Pb}$

**ENGINEERING ANALYSIS**



Weight of lead between supports:

$$w_{sPb} = A_{Pb}\,\rho_{sh}\,L_{Pb}$$

$$w_{sPb} = 3{,}073 \text{ lbs}$$

Pb weight smeared over the cross sectional area:

Cross sectional area:

$$A_{smr} = \frac{\pi}{4}\,op_{Pb}^2$$

Smear density:

$$\rho_{smr} = \frac{w_{sPb}}{A_{smr}\,L_{Pb}}$$

Load between supports at angle of evaluation $\theta_{Pb}$, stress due to lead slump modeled using membrane theory of pipe filled between supports with material:

Tangential stress:

$$\sigma_t = \frac{g_{load}\,\rho_{smr}\,r_{Pb}^2}{t_{sk}}\,(1 - \cos(\theta_{Pb}))$$

$$\sigma_t = 9{,}130 \text{ psi}$$

Longitudinal stress:

$$\sigma_l = \frac{g_{load}\,\rho_{smr}}{t_{sk}}\left(\frac{z_{Pb}^2}{2}\right)\cos(\theta_{Pb}) + \nu\,\sigma_t$$

$$\sigma_l = 1{,}001 \text{ psi}$$

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Shear stress:

$$\sigma_{shr} = -\frac{g_{load}\,\rho_{smr}}{t_{sk}}\left(\frac{z_{Pb}^2}{2}\right)\sin(\theta_{Pb})$$

$$\sigma_{shr} = 0 \text{ psi}$$

Total stress at maximum deflection which is at the center:

$$\sigma_{tot} = \sigma_t + \sigma_l + \sigma_{shr} \qquad \sigma_{tot} = 10{,}131 \text{ psi}$$

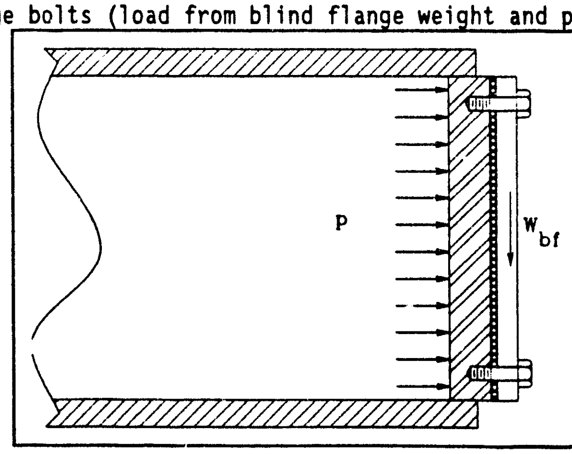
Margin of safety:

$$MS_{Pbslump} = \frac{\sigma_{asme}}{\sigma_{tot}} - 1$$

$$MS_{Pbslump} = 1.3 \quad \text{OK}$$

**Bolt and Guide Pin loads:**

a) Blind flange bolts (load from blind flange weight and pressure):



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Weight of blind flange: $w_{bfl}$ = 441 lbs

Bolt Parameters on blind flange (1-8 UN 2B X 2 1/4", ASTM A307, Gr. B) (Ref. 5):

Number of bolts: $n_{bfl} = 16$

Nominal diameter of bolts: $d_{bf}$ = 1 inch

Tensile stress area of bolt (ref. 4, 1278):

$$A_{bfl} = 0.7854\left(d_{bf} - \frac{0.9743\ inch}{8}\right)^2$$

$$A_{bfl} = 0.606\ in^2$$

Allowable tensile strength (Reference 3, page 276, Table UCS-23):

$$\sigma_{ten} = 55{,}000\ psi$$

Average shear stress on bolts due to weight of blind flange:

$$\sigma_{bolt} = \frac{g_{load}\ w_{bfl}}{A_{bfl}}$$

$$\sigma_{bolt} = 30{,}577\ psi$$

Data from ASME calculations verification:

Total pressure load on bolts: $W_{m1}$ = 28,096 lbs

Bolt stress from pressure:

$$\sigma_{bolpres} = \frac{W_{m1}}{16\ A_{bfl}}$$

$$\sigma_{bolpres} = 2{,}899\ psi$$

Preload torque on bolts (Reference 5): $T_{bf}$ = from 295 to 305 ft-lbs

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Stress on bolts due to preload:

$$\sigma_{bf} = \frac{T_{bf}}{0.2\ d_{bf}\ A_{bf1}}$$

$$\sigma_{bf} = 30{,}211 \text{ psi}$$

Total stress on bolts, if all 16 engaged in shear on drop:

$$\sigma_{f1bol} = \sigma_{bolpres} + \sigma_{bf} + \frac{\sigma_{bolt}}{16}$$

$$\sigma_{f1bol} = 35{,}021 \text{ psi}$$

Margin of Safety:

$$MS_{16bol} = \frac{\sigma_{ten}}{\sigma_{f1bol}} - 1$$

$$MS_{1bol} = 0.57 \quad \textbf{OK}$$

Total stress on bolt, if only 1 is engaged in shear on drop:

$$\sigma_{f1bol} = \sigma_{bolpres} + \sigma_{bf} + \sigma_{bolt}$$

$$\sigma_{f1bol} = 63{,}687 \text{ psi}$$

Margin of Safety:

$$MS_{1bol} = \frac{\sigma_{ten}}{\sigma_{f1bol}} - 1$$

$$MS_{1bol} = -0.14 \quad \textbf{NG}$$

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Minimum of engaged bolts in shear:

$$\frac{1}{\left[\frac{\sigma_{ten} - (\sigma_{bolpres} + \sigma_{bf})}{\sigma_{bolt}}\right]} = 1.4$$

*Therefore at minimum 2 bolts must be engaged in shear.*

Stress on bolts with only 2 engaged in shear:

$$\sigma_{flbol} = \sigma_{bolpress} + \sigma_{bf} + \frac{\sigma_{bolt}}{2}$$

$$\sigma_{flbol} = 48{,}398 \text{ psi}$$

Margin of Safety:

$$MS_{3bol} = \frac{\sigma_{ten}}{\sigma_{flbol}} - 1$$

$$M_{S3bol} = 0.14 \quad \textbf{OK}$$

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b) Guide pins, 2 each:

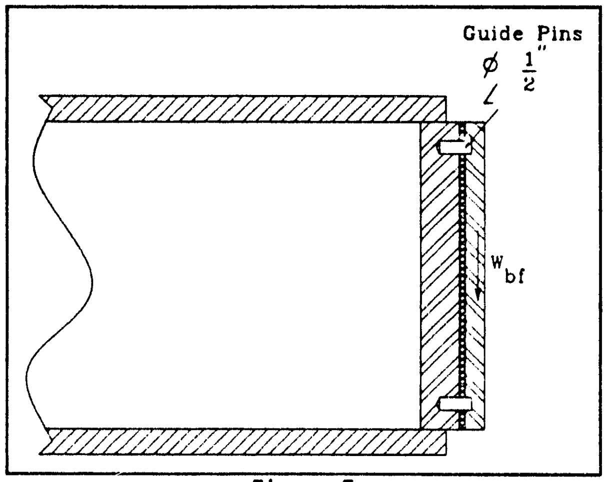


Figure 7

Guide pins, ASTM A-322, Grade 4130, 1/2" diameter (Reference 5)

Number of guide pins: $n_{gpin} = 2$

Guide pin diameter: $d_{gp} = 0.5$ inch

Yield allowable (Reference 11): $s_{shear} = 120{,}000$ psi

Tensile stress area of bolt (ref. 4, 1278):

$$A_{bf1} = 0.7854\left(d_{gp} - \frac{0.9743\ inch}{10}\right)^2$$

Short beam shear stress on pin:

$$\sigma_{gpin} = \frac{4 \cdot w_{bf1} \cdot g_{load}}{3 \cdot n_{gpin} \cdot A_{gp}}$$

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$$\sigma_{gpin} = 87{,}020 \text{ psi}$$

Bending stress:

$t_{bfl} = 0.75$ in $d_{bfl} = 51.25$ in
$t_{gas} = 0.125$ in

$$M_{gpbend} = \frac{t_{gas} \cdot w_{bfl} \cdot g_{load}}{2}$$

$$M_{gpbend} = 1{,}158 \text{ lbf·in}$$

$$I_{bfl} = \frac{\pi}{64} \cdot d_{gp}{}^4$$

$$\sigma_{gpbend} = \frac{M_{gpbend} \cdot \frac{d_{gp}}{2}}{2 \cdot I_{bfl}}$$

$$\sigma_{gpbend} = 47{,}166 \text{ psi}$$

Guide pin total stress:

$$s_{pin} = \frac{\sigma_{gpbend}}{2} + \sigma_{pin}$$

$$s_{pin} = 110{,}603 \text{ psi}$$

$$MS_{gpin} = \frac{s_{shear}}{s_{pin}} - 1$$

$$MS_{gpin} = 0.1 \qquad \textbf{OK}$$

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**Stress on the Internal Plate (Closed End):**

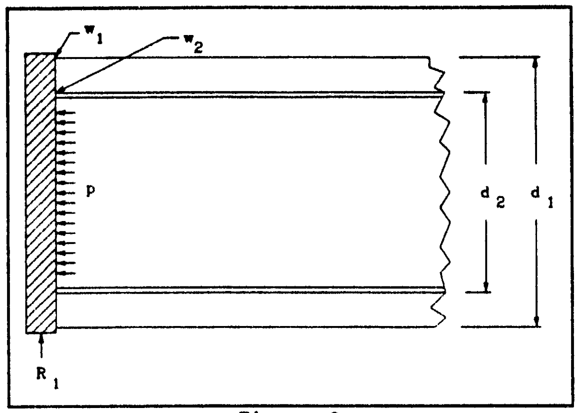


Figure 8

Determine loading on weld area:

Plate dimensions from (Reference 5):

Material of construction: Carbon Steel (ASTM A-516, GR 70)

Plate thickness 2 inch

For conservatism consider only inner pipe weld.

ASME allowable: $\sigma_{asme} = 23,270$ psi

Weld size: $w_w = 0.1875$ in.

Weld diameter: $d_w = 52$ in.

Circumference of weld: $c_w = \pi \cdot d_w$

Loading from pressure calculations for joint discontinuity:

$$s_{btot} = 5,478 \text{ psi}$$

Shear area of weld: $A_w = 0.707 \cdot w_w \cdot c_w$

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Maximum Shear on weld due to drop (loading from $R_1$):

$$\tau_{drop} = \frac{2\,R_1}{A_w}$$

$$\tau_{drop} = 3{,}158 \text{ psi}$$

Total stress on weld: $\sigma_{wtot} = \tau_{drop} + s_{btot}$

$$\sigma_{wtot} = 8{,}636 \text{ psi}$$

Margin of Safety:

$$MS_{weld} = \frac{\sigma_{asme}}{\sigma_{wtot}} - 1$$

$MS_{weld} = 1.69$ OK

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**Top cap bolt loads:**

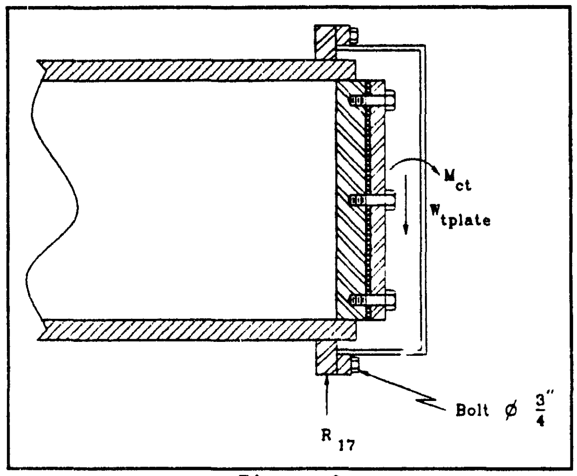


Figure 9

Loading from weight and reaction at support 17.

Weight of plate: $W_{tplate} = 1{,}039$ lbs

Bolts are 3/4 - 10 UN 2B X 2 1/4 inch, ASTM A-307, Gr. B.

Bolting parameters from Reference 5.

Diameter of bolts: $d_{tcbolt} = 0.750$ inch

Number of bolts: $n_{ctbolt} = 24$

Stress Area of bolts:

$$A_{tcbolt} = 0.7854\left(d_{tcbolt} - \frac{0.9743\ inch}{10}\right)^2$$

Bolt Tensile and allowable from Reference 3, page 276, Table UCS-23:

Tensile strength: $\sigma_{ten} = 55{,}000$ psi

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Bolt shear allowable: $\sigma_{shear} = 0.8\cdot(55{,}000\ \text{psi})$

Ratio of rxn between top cap and mating flange:

$$R_{ct} = R_{17}\left(\frac{1}{1+\frac{3}{4}}\right)$$

$$R_{ct} = 72{,}785\ \text{lbs}$$

Total shear load on top cap bolts:

$F_{shct} = R_{ct} - g_{load}\cdot W_{tplate}$ $\qquad F_{shct} = 29{,}165\ \text{lbs}$

Shear stress per bolt:

$$\tau_{ctsh} = \frac{4}{3}\,\frac{F_{shct}}{n_{ctbolt}\,A_{ctbolt}}$$

$$\tau_{ctsh} = 4{,}845\ \text{psi}$$

Moment of top cap:

CG of plate is at midplane: $CG_{tplate} = 2.476$ inch

Moment: $M_{ct} = g_{load}\cdot W_{tplate}\cdot CG_{tplate}$

$M_{ct} = 108{,}003$ in-lbs

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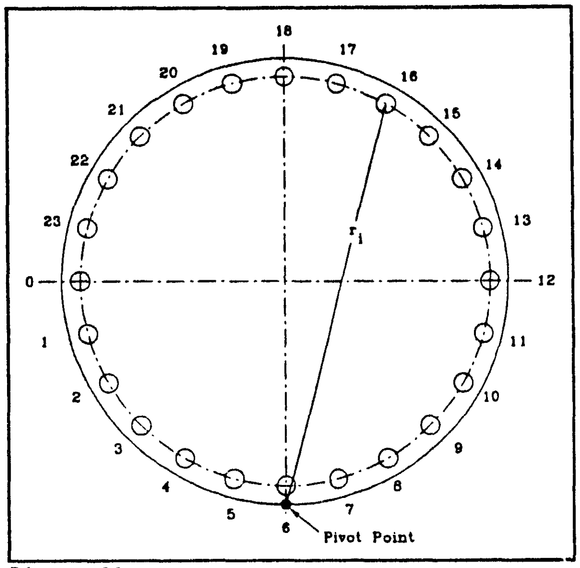


Figure 10

Bolts in circular pattern:

Largest radius about pivot about edge is: $r_{18}$ = 57.5 inches

Tensile load on bolts:

$$F_{ctbol} = \frac{r_{18}\, M_{ct}}{\sum_{i=0}^{23} (r_i)^2}$$

$F_{ctbol}$ = 156 lbs

Torque on bolts (Reference 5): $T_{tc}$ = from 118 to 128 ft-lbs

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Bolt preload stress:

$$\sigma_i = \frac{T_{tc}}{0.2\ d_{tcbolt}\ A_{tcbolt}}$$

$$\sigma_i = 35{,}161 \text{ psi}$$

Tensile stress on bolts:

$$\sigma_{ctbol} = \frac{F_{ctbol}}{A_{tcbol}}$$

$$\sigma_{ctbol} = 468 \text{ psi}$$

Total stress on top cap bolt (if only one engaged in shear of drop):

$$\sigma_{tctbol1} = \sigma_{ctbol} + \sigma_i + n_{ctbol} \cdot \tau_{ctsh}$$

$$\sigma_{tctbol1} = 151{,}897 \text{ psi}$$

Margin of Safety:

$$MS_{1tcbol} = \frac{\sigma_{ten}}{\sigma_{tctbol1}} - 1$$

$$M_{1tcbol} = -0.63 \quad \textbf{NG}$$

*Therefore more than one bolt needs to engaged in shear.*

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Determine minimum number of engaged bolts:

$$\frac{1}{\left[\dfrac{\sigma_{ten} - (\sigma_{ctbol} + \sigma_i)}{n_{ctbolt}\,\tau_{ctsh}}\right]} = 5.0$$

*Therefore at minimum 5 bolts are required to be engaged.*

Total stress on top cap bolts if all 24 bolts engaged:

$$\sigma_{tctbol24} = \sigma_{ctbol} + \sigma_i + \tau_{ctsh}$$

$$\sigma_{tctbol24} = 35{,}929 \text{ psi}$$

Margin of Safety:

$$MS_{24tcbol} = \frac{\sigma_{ten}}{\sigma_{tctbol24}} - 1$$

$$MS_{24tcbol} = 0.53 \quad \text{OK}$$

**Short Beam Shear:**

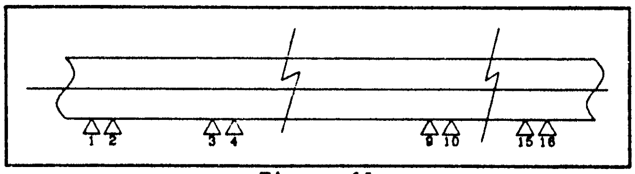

**Figure 11**

Short sections between supports 1 and 2, 3 and 4, 9 and 10 and, 15 and 16.

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Largest reaction loading at support 16 (thin outer skin):

Outside radius of pipe:

$$R_{sbeam} = \frac{od_{pipe}}{2}$$

$$R_{sbeam} = 27.88 \text{ in}$$

Reaction: $R_{16} = 151{,}574$ lbs

Shear stress in member:

$$\tau_{sbeam} = \frac{2\ R_{16}}{\frac{\pi}{4}\left(od_{pipe}^2 - id_{pipe}^2\right)}$$

$$\tau_{sbeam} = 5{,}077 \text{ psi}$$

Bending stress in member:

$$\sigma_{sbeam} = \frac{M_p\ R_{sbeam}}{I_{p1}}$$

$$\sigma_{sbeam} = 1{,}548 \text{ psi}$$

von Mises Stresses:

$$\sigma_{sbtot} = \sqrt{\sigma_{sbeam}^2 + (3\ \tau_{beam})^2}$$

$$\sigma_{sbtot} = 15{,}310 \text{ psi}$$

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Margin of safety:

$$MS_{shbeam} = \frac{\sigma_{asme}}{\sigma_{sbtot}} - 1$$

$$MS_{shbeam} = 0.52 \quad \text{OK}$$

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Subject Payload Impact to Flange Cover Due to Vibrational Shock Load
Originator P. M. Nguyen PM Nguyen Date 05/26/94
Checker S. S. Shiraga [signature] Date 06/13/94

## I. Objective:

The objective of this analysis is to determine the loading for the 106C-49 foot package top flange and bolts due to the payload (pump) impact which resulted from vibrational shock. This analysis is necessary since the payload is not restrained within the packaging (Reference 1).

## II. References:


1. WHC-SD-TP-PDC-015, Rev. 0-A, Packaging Design Criteria Transfer and Disposal of Equipment, Tank 241-C-106 Waste Sluicing System.

2. 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.

3. American Society of Mechanical Engineers, Boiler and Pressure Vessels, Section VIII, Division 2, 1989.

4. Industrial Press, Machinery's Handbook, 23 rd edition.

5. WHC Drawings, No. H-2-83722, H-2-83724, H-2-83725, H-2-83726 and H-2-83727.

6. Design Analysis, WO/Job No. ER4289, Kaiser Engineers Hanford, Nov. 11, 1993.

7. Roark, Formulas for Stress and Strain, 4th edition.

8. American Society of Mechanical Engineers, Boiler and Pressure Vessels, Section VIII, Division 1, 1989.


## III. Results and Conclusions:

The results show that the transporting shock load induced by the unrestrained payload striking in the inner flange will result in local buckling failure of the container inner flange (Margin of Safety of -0.047). Therefore, it is recommended that the payload be restrained inside the container. Although the bolts appear to be stressed beyond yield, there is sufficient preload and conservatism within the calculations to prevent unloading of the gasket. The calculational conservatism results from the bolt tightening calculations which do not take into account that the torsional stress disappears and the principle stresses are reduced after initial tightening of the bolts.

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Subject Payload Impact to Flange Cover Due to Vibrational Shock Load
Originator P. M. Nguyen PMN Date 05/26/94
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**IV. Engineering Evaluation:**

Load on Top Flange:

Model as a circular flat plate which is simply supported. Maximum moment is at center. Since contact area is unknown assume for conservation contact radius is less than ½ the flange thickness and use contact radius specified in ref. 7, Roark and Young, page 366.

Weight of Pump (Reference 6): $W_{pump} = 3{,}152$ lbs

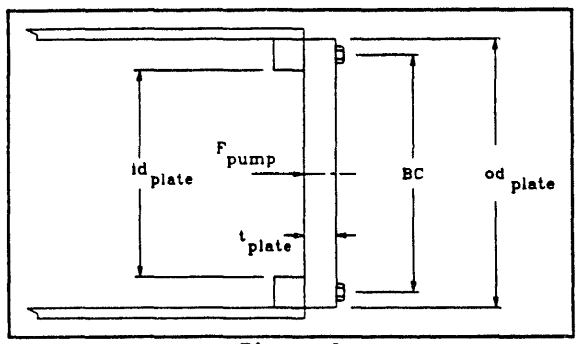


Figure 1

Dimensional Parameters of Flange:

Flange thickness:

$$t_{plate} = \frac{3}{4} \cdot in.$$

Bolt circle diameter:

$$BC = 49.250 \cdot in.$$

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OD of Flange:

$$od_{plate} = 51.25 \cdot in.$$

Inner contact Flange diameter:

$$id_{plate} = 47.250 \cdot in.$$

From Reference 2:

Shock induced vibration "G" factor: (Longitudinal direction)

$$g_1 = 2.3$$

Shock induced load:

$$F_{pump} = W_{pump} \cdot g_1$$

From Reference 7, page 366, define contact radius $r_0$:

$$r_{plate} = \frac{id_{plate}}{2}$$

$$r_{con} = \sqrt{1.6 \cdot r_{plate}^2 + t_{plate}^2} - 0.675 \cdot t_{plate}$$

$$r_{con} = 29.39 \cdot in.$$

Poisson's Ratio (Ref. 3):

$$\nu = 0.30$$

Maximum radial moment at center:

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$$M_r = \frac{F_{pump}}{4 \cdot \pi} \cdot \left[ (1 + \nu) \cdot \ln\left(\frac{r_{plate}}{r_{con}}\right) + 1 \right]$$

$$M_r = 415 \cdot lbs$$

Maximum tangential moment at center:

$$M_t = M_r$$

Maximum radial stress:

$$\sigma_r = \frac{6 \cdot M_r}{t_{plate}^{\ 2}} \qquad \sigma_r = 4{,}424 \cdot psi$$

Maximum tangential stress:

$$\sigma_t = \frac{6 \cdot M_t}{t_{plate}^{\ 2}} \qquad \sigma_t = 4{,}424 \cdot psi$$

Total stress at center:

$$\sigma_{tot} = \sigma_r + \sigma_t \qquad \sigma_{tot} = 8{,}848 \cdot psi$$

**Combine with load from reduced pressure calculations:**

Material allowable from Reference 3: $s_a$ = 23,270 psi

Flange loading from external pressure reduction calculations at 2 flange center:

$$\sigma_{press} = 15{,}615 \text{ psi}$$

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Total combined loading:

$$s_{ftot} = \sigma_{tot} + \sigma_{press}$$

$$s_{ftot} = 24{,}429\ psi$$

Margin of safety:

$$MS_f = \frac{s_a}{s_{ftot}} - 1$$

$$MS_f = -0.047 \qquad \text{NG}$$

**Load on bolts:**

Applied load on each bolt due to pump impact:

Number of bolts:

$$n_{bolt} = 16$$

$$F_{ba} = \frac{F_{pump}}{n_{bolt}} \qquad F_{ba} = 453 \cdot lbs$$

In this case to determine load generated by bending moments from the plate.

$$M_{rb} = F_{ba} \cdot r_{plate} \qquad M_{rb} = 893 \cdot ft \cdot lbs$$

Load per bolt:

Distance between bolt hole and edge of plate:

$$s = od_{plate} - BC$$

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Diameter of bolt hole: $d_{hbolt} = 1.125$ in

$$r_{hole} = \frac{d_{hbolt}}{2}$$

$$P_{bl} = 4 \cdot M_{rb} \cdot \left( \frac{3 \cdot od_{plate} \cdot s^2 - 4 \cdot r_{hole}^3}{8 \cdot od_{plate} \cdot s^3 - 3 \cdot \pi \cdot r_{hole}^4} \right)$$

$$P_{bl} = 8026 \cdot lbs$$

Total bolt load on one bolt:

$$F_{btot} = F_{ba} + P_{bl} \qquad F_{btot} = 8480 \cdot lbs$$

Tensile stress on bolt from shock induced vibration impact of pump:

Nominal diameter of bolt:

$$d_{bolt} = 1 \cdot in.$$

Number of threads per inch:

$$n_{th} = \frac{8}{in.}$$

Tensile stress and area:

$$A_{bt} = 0.7845 \cdot \left[ d_{bolt} - \left( \frac{0.9743}{n_{th}} \right) \right]^2$$

$$\sigma_{tb} = \frac{F_{btot}}{A_{bt}} \qquad \sigma_{tb} = 14015 \cdot psi$$

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Combine from ASME code verification calculation on bolt loading:

Bolting material allowable (Reference 8):

$$s_{ab} = 55{,}000 \text{ psi}$$

Bolt loading from ASME code verification calculations:

$$\sigma_{bolt} = 32{,}270 \text{ psi}$$

Total combined loading:

$$s_{btot} = \sigma_{tb} + \sigma_{bolt}$$

$$s_{btot} = 46{,}285 \text{ psi}$$

Margin of safety:

$$MS_{bolt} = \frac{s_{ab}}{s_{btot}} - 1$$

$$MS_{bolt} = 0.19 \quad \textbf{OK}$$

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Subject Temperature Brittle Fracture Evaluation
Originator P. M. Nguyen Date 06/06/94
Checker S. S. Shiraga Date 06/13/94

I. **Objectives:**

The objective of this evaluation is to verify that the containment materials used in the fabrication of the disposal packaging meet 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-015, Rev. 0-A, "Packaging Design Criteria Transfer and Disposal of Equipment, Tank 241-C-106 Waste Sluicing System".

2. American Society of Mechanical Engineers, Broiler and Pressure Vessels, Section VIII, Division 1, 1989.

3. WHC Drawing No., H-2-83722, H-2-83724, H-2-83725, H-2-83726 and H-2-83727.

III. **Results and Conclusions:**

This evaluation shows that some of the packaging containment materials used the packaging design do not meet all requirements for extreme low temperature service identified in References 1 and 2. Specifically the primary containment flanges have a nominal thickness of 1.25 to 2 inches which is greater than specified in Reference 2. The essential component of low temperature brittle fracture is load. When at rest horizontally and with no internal pressure, only the primary containment piping and flange bolts are under static load. This would allow the flanges to exceed the thickness limits specified in Reference 2, since they bear no significant loads. However, it is imperative that the Safety Evaluation 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 container must be vented to prevent pressurization at extreme low temperatures, in order to prevent loading of the flanges.

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Checker S. S. Shiraga Date 06/13/94

## IV. Engineering Evaluation:

Containment component materials of construction (Reference 3):

1) Inner flange 1 inch bolts: ASTM A 307, Grade B

2) Containment and shielding piping, 0.375 inch thick: ASTM 516, Grade 70

3) Inner Containment flange, 1.25 inch thick: ASTM 516

4) Inner Hub Flange, 1.75 inch thick: ASTM 516

5) 2" Thick outer flange: ASTM 516

Section UG-20 Design Temperatures (Reference 2, page 20), states that the requirements for exemptions from Impact Testing are:

Paragraph (1)(b): Nominal thickness for noted materials in Curves B, C or D of Figure UCS-66 limited to 1 inch.

Paragraph (2): Hydrostatic testing, since container primary containment is not under pressure, none required. Outer skin 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 loadings at low temperature extreme.

Paragraph (5): Since one way transport and no movement at extreme low temperatures, no cyclic loads.

Therefore, under extreme low temperature conditions (less than 0°F) no operations shall be allowed with the container.

Of these components, those under static load during extreme design temperatures are the bolts (item 1), containment and shielding piping (item 2).

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**Curve From UCS-66:**

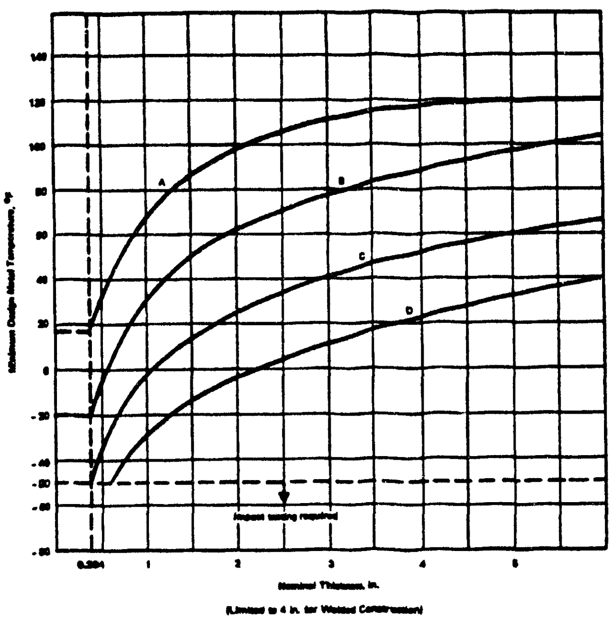

FIG. UCS-66 IMPACT TEST EXEMPTION CURVES (SEE UCS-66(a))

Figure 1

Containment piping all < 1/2 inch, from notes in Reference 2, page 172:

Use Curve B, at low extreme design temperature the thickness limit is greater 1/2 inch, neither component is thicker than 1/2 inch, therefore OK.

Inner flange 1 inch bolts:

Use notes on page 172 of Reference 2, Impact testing exemption temperature limit is -20 °F. This is below low extreme temperature specified in Reference 1, therefore OK.

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| Subject Lifting Calculations | | |
| Originator P. M. Nguyen PMNguyen | | Date 05/23/94 |
| Checker S. S. Shiraga [signature] | | Date 06/15/94 |

I. **Objective:**

The objective of this analysis is to evaluate the stress induced by lifting operations for the 106C-49 foot package.

II. **References:**


1. American Institute Steel Construction, Manual of Steel Construction, Ninth Edition.

2. American Society of Mechanical Engineers, Boiler Pressure and Vessels, Section VIII, Division 2, 1989.

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 Drawings, H-2-83722, H-2-83724, H-2-83725, H-2-83726 and H-2-83727.

5. Roark, Formulas for Stress and Strain, 4th edition.


III. **Results and Conclusions:**

The lifting evaluation is performed for the 106C 49 foot packaging system for four situations. For additional conservatism, the margins of safety for each analysis is based on Reference 1 allowables. Margins of safety based on Reference 2 are provided for information only. For conservatism the container is assumed to be lifted from the end rings which in practice it is not. The results are:

1. Shielded container being lifted horizontally (0 deg elevation). Margin of Safety for this analysis is 0.8, therefore the shielded package can withstand the stress induced by the operational horizontal lift.

2. Shielded container being lifted at an angle (10 deg elevation). Margin of Safety for bending and compressive within this evaluation are 0.42 and 11.9, hence the shielded package can withstand the angle lifting stress.

3. Non-shielded container being lifted horizontally (0 deg elevation). Margin of Safety for this analysis is 3.42, therefore the non-shielded package can withstand the stress induced by the operational horizontal lift.

4. Non-shielded container being lifted at an angle (10 deg elevation). Margin of Safety for bending and compressive within this evaluation are 2.35 and 29.1, hence the non-shielded package can withstand the angle lifting stress.

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Based upon this analysis, the container can be safely lifted at the specified orientations.

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IV. **Engineering Evaluation:**

Assume crane components are rigid.

1. **Container parameters:**

Pipe od: $dp_{od} = 52$ in Pipe thickness: $t_{pw} = 0.38$ in

Pipe id: $dp_{id} = dp_{od} - 2 \cdot t_{pw}$

Area:

$$A_p = \pi \cdot \frac{dp_{od}^2 - dp_{id}^2}{4}$$

Pipe moment of inertia:

$$I_p = \pi \cdot \frac{dp_{op}^4 - dp_{id}^4}{64}$$

Outer pipe cross section (thick portion):

$d_{gap} = 1.5$ in $t_{opipe} = 0.375$ in

$$R_{opipe} = 26 \text{ in} + 1.5 \text{ in} + t_{opipe}$$

$od_{opipe} = 2 \cdot R_{opipe}$ $id_{opipe} = 2\,(R_{opipe} - t_{opipe})$

Cross section area:

$$A_{op2} = \pi \cdot \left(\frac{od_{opipe}^2 - id_{opipe}^2}{4}\right)$$

Moment of inertia:

$$I_{p2} = \pi \cdot \left(\frac{od_{opipe}^2 - id_{opipe}^2}{4}\right)$$

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Outer pipe cross section (thin portion):

$d_{gp} = 1.5\ in$ $\quad t_{opthin} = 0.1875\ in$

$$R_{opthin} = 26\ in + 1.5\ in + t_{opthin}$$

$od_{opthin} = 2 \cdot R_{opthin}$ $\quad id_{opthin} = 2\ (R_{opthin} - t_{opthin})$

Cross section area:

$$A_{op1} = \pi \cdot \left( \frac{od_{opthin}^2 - id_{opthin}^2}{4} \right)$$

Moment of inertia:

$$I_{op1} = \pi \cdot \left( \frac{od_{opthin}^2 - id_{opthin}^2}{4} \right)$$

$$I_{p1} = I_p + I_{op1}$$

Length of container: $l_{con} = 49\ ft$

Weight of container with shielding: $W_{cg} = 65,884\ lbs$

Weight of container without shielding: $W_{con} = 28,238\ lbs$

Weight of shielding: $W_{sh} = 37,646\ lbs$

Elastic modulus at 115°F (Reference 2): $E_{cstl} = 29.258 \times 10^6\ psi$

ASME yield strength for ASTM A-516: $S_y = 38,000\ psi$

ASME allowables: $s_m = 23,270\ psi$

**AISC allowables (Reference 1):**

$$\frac{3300}{\left( \frac{S_y}{ksi} \right)} = 86.84$$

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$$\frac{od_{thin}}{t_{pw}} = 147.67$$

**Therefore a compact section.**

Bending allowable: $F_b = 0.66 \cdot S_y$ $F_b = 25{,}080$ psi

Compression allowable:

Define: $K_c = 1$

Radius of gyration:

$$r_{gyr} = 0.707 \cdot \frac{od_{opthin}}{2}$$

$$ratio = \frac{K_c \cdot l_{con}}{r_{gyr}}$$

ratio = 30.04

$$C_c = \sqrt{\frac{2 \cdot \pi^2 \cdot E_{cstl}}{S_y}}$$

$C_c = 123.28$

Since ratio << $C_c$ then compression allowable is:

$$F_a = \frac{\left(1 - \frac{ratio^2}{2 \cdot C_c^2}\right) \cdot S_y}{\left(\frac{5}{3}\right) + \frac{3 \cdot ratio}{8 \cdot C_c} - \frac{ratio^3}{8 \cdot C_c^3}}$$

$F_a = 20{,}995$ psi

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**2. Determine center of gravity of container with shielding:**

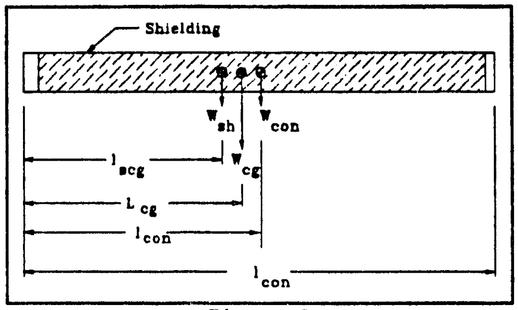


Figure 1

Length of shielding:

$$l_{sh} = \frac{49\ ft}{2}$$

Length from end to shielding:

$$l_s = 2\ in$$

cg of shielded section: $l_{scg} = l_{sh} + l_s$

$$l_{scg} = 24.67\ ft$$

cg of container (cg of entire pkg at thick skin):

$$l_{ccg} = 288.385\ in$$

$$L_{cg} = \frac{W_{con} \cdot l_{ccg} + W_{sh} \cdot l_{scg}}{W_{cg}}$$

$$L_{cg} = 293\ in$$

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3. **Determine loading with two pick point with shielding:**

Model as a simply supported beam with a concentrated load at the cg.

G loading of lift (Reference 3): $g_{lift} = 1.5$

Load due to lifting: $W_{lift} = g_{llift} \cdot W_{cg}$

$$M_{max} = \frac{W_{lift} \cdot L_{cg} \cdot (l_{con} - L_{cg})}{l_{con}}$$

$$M_{max} = 1.21 \text{ X } 10^6 \text{ ft} \cdot \text{lbs}$$

Bending at lift point (lift pts at thin skin):

$$\sigma_{b1} = \frac{M_{max} \cdot \frac{od_{opthin}}{2}}{I_{p1}}$$

$$\sigma_{b1} = 12{,}323 \text{ psi}$$

Vertical shear loading and maximum shear stress at lift point:

$$P_1 = \frac{W_{lift} \cdot (l_{con} - L_{cg})}{l_{con}}$$

$$P_1 = 49{,}625 \text{ psi}$$

$$\tau_{1s} = 2 \cdot \frac{P_1}{A_p}$$

$$\tau_{1s} = 1{,}632 \text{ psi}$$

Maximum total stress:

$$\sigma_{tot1} = \sigma_{b1} + \tau_{1s}$$

$$\sigma_{tot1} = 13{,}955 \text{ psi}$$

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$$MS_{1a} = \frac{S_a}{\sigma_{tot1}} - 1$$

ASME Allowable $MS_{1a} = 0.25$

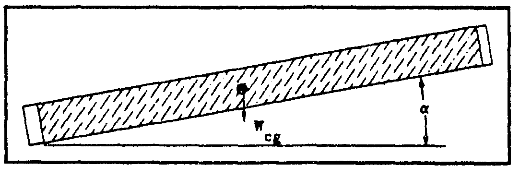
$$MS_{1b} = \frac{F_b}{\sigma_{tot1}} - 1$$

AISC Allowable $MS_{1b} = 0.8$ OK

**4. Determine loading at angle $\alpha$ with shielding:**

Evaluation angle: $\alpha = 10$ deg

Assume height of crane hook: $d_{crane} = 70$ ft




Equilibrium equations:

Forces:

$$F_v + T_v - W_{lift} = 0$$

$$F_b - T_h = 0$$

$$F_v = W_{lift} - T_v$$

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$$F_h = T_h$$

Moments:

Taking moments about point O.

$$F_v \cdot (l_{con} \cdot \cos(\alpha)) - F_h \cdot (l_{con} \cdot \sin(\alpha)) - W_{lift} \cdot [(l_{con} - l_{cg}) \cdot \cos(\alpha)] = 0$$

$$F_v = F_h \cdot \left(\frac{\sin(\alpha)}{\cos(\alpha)}\right) + W_{lift} \cdot \left[1 - \left(\frac{l_{cg}}{l_{con}}\right)\right]$$

$$T_v = T_h \cdot \tan(\beta)$$

$$\beta = atan\left(\frac{d_{crane} - l_{con} \cdot \sin(\alpha)}{l_{con} \cdot \cos(\alpha)}\right)$$

$$\beta = 51.88 \text{ deg}$$

$$F_v = W_{lift} - T_h \cdot \tan(\beta)$$

$$F_v = T_h \cdot \left(\frac{\sin(\alpha)}{\cos(\alpha)}\right) + W_{lift} \cdot \left[1 - \left(\frac{l_{cg}}{l_{con}}\right)\right]$$

Solve for $T_h$ then the rest:

$$W_{lift} - T_h \cdot \tan(\beta) = T_h \cdot \left(\frac{\sin(\alpha)}{\cos(\alpha)}\right) + W_{lift} \cdot \left[1 - \left(\frac{l_{cg}}{l_{con}}\right)\right]$$

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$$T_h = W_{lift} \cdot \frac{L_{cg}}{l_{con} \cdot [\tan(\beta) + \tan(\alpha)]}$$

$T_h$ = 33,917 lbs

$$F_h = W_{lift} \cdot \frac{L_{cg}}{l_{con} \cdot [\tan(\beta) + \tan(\alpha)]}$$

$F_h$ = 33,917 lbs

$$T_v = W_{lift} \cdot \frac{L_{cg}}{l_{con} \cdot [\tan(\beta) + \tan(\alpha)]} \cdot \tan\beta$$

$T_v$ = 43,220 lbs

$$F_v = W_{lift} \cdot \left[\frac{L_{cg} \cdot \tan(\alpha)}{[l_{con} \cdot (\tan(\beta)) + \tan(\alpha)]} + \left(1 - \frac{L_{cg}}{l_{con}}\right)\right]$$

$F_v$ = 55,606 lbs

$$F_{tot} = \sqrt{F_v^2 + F_h^2}$$

$F_{tot}$ = 65,134 lbs

$$T_{tot} = \sqrt{T_v^2 + T_h^2}$$

$T_{tot}$ = 54,940 lbs

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**Transform coordinates to container centerline:**

Total angle:

$$\theta = acos\left(\frac{F_h}{F_{tot}}\right)$$

$$\theta = 58.62 \text{ deg}$$

$F_{ch} = F_{tot} \cdot \cos(\theta-\alpha)$ $\quad F_{ch} = 43{,}058$ lbs

$F_{cv} = F_{tot} \cdot \sin(\theta-\alpha)$ $\quad F_{cv} = 48{,}871$ lbs

$T_{ch} = T_{tot} \cdot \cos(\beta+\alpha)$ $\quad T_{ch} = 25{,}897$ lbs

$T_{cv} = T_{tot} \cdot \sin(\beta+\alpha)$ $\quad T_{cv} = 48{,}453$ lbs

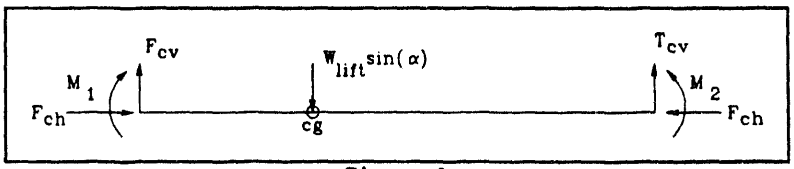


Figure 3

Conservatively model as a simply supported beam with concentrated load at the cg, end load of $F_{ch}$ and unequal moments due to vertical forces (case 8, p.150, Reference 5).

$$j_1 = \sqrt{\frac{E_{cstl} \cdot I_{p1}}{F_{ch}}}$$

$$U = \frac{j_1}{l_{con}}$$

Determine moments about the cg:

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Location of evaluation: $x = L_{cg}$

$$M_{lift} = \left(\frac{M_2 - M_1 \cdot \cos(U)}{\sin(U)}\right) \cdot \sin\left(\frac{x}{j_1}\right) + M_1 \cdot \cos\left(\frac{x}{j_1}\right)$$

$$M_{lift} = 1.43 \text{ X } 10^6 \text{ ft} \cdot \text{lbs}$$

$$M_{con} = W_{lift} \cdot \sin(\alpha) \cdot L_{cg}$$

$$M_{tot} = M_{lift} + M_{con}$$

$$M_{tot} = 1.85 \text{ X } 10^6 \text{ ft} \cdot \text{lbs}$$

Compressive stress:

$$\sigma_{comp} = \frac{W_{lift}}{A_p}$$

$$\sigma_{comp} = 1{,}625 \text{ psi}$$

Bending stress:

$$\sigma_{blift} = \frac{M_{tot} \cdot \frac{dp_{od}}{2}}{I_{p1}}$$

$$\sigma_{blift} = 17{,}709 \text{ psi}$$

AISC combined stress (Reference 1):

$$\frac{\sigma_{comp}}{F_a} + \frac{\sigma_{blift}}{F_b} = 0.78$$

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ASME allowable (Reference 2):

$$MS_{2a} = \frac{S_y}{\sigma_{blift}} - 1$$

ASME Allowable $MS_{2a} = 1.15$

AISC allowable (Reference 1):

$$MS_{2b} = \frac{F_b}{\sigma_{blift}} - 1$$

AISC Bending Allowable $MS_{2b} = 0.42$ OK

$$MS_{2c} = \frac{F_a}{\sigma_{comp}} - 1$$

AISC Compressive Allowable $MS_{2c} = 11.9$ OK

5. Container without shielding:

Model as a simply supported beam with a concentrated load at the cg.

g loading of lift (Reference 3): $g_{lift} = 1.5$

$$W_{lift} = g_{lift} \cdot W_{con}$$

$$M_{max} = \frac{W_{lift} \cdot l_{ccg} \cdot (l_{con} - l_{ccg})}{l_{con}}$$

$M_{max} = 518{,}684$ ft·lbs

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Bending at lift point:

$$\sigma_{b1} = \frac{M_{max} \cdot \frac{dp_{od}}{2}}{I_{p1}}$$

$$\sigma_{b1} = 4{,}958 \text{ psi}$$

Vertical shear loading and maximum shear stress at lift point:

$$P = \frac{W_{lift} \cdot (l_{con} - l_{ccg})}{l_{con}}$$

$$P_1 = 21{,}583 \text{ lbs}$$

$$\tau_1 s = 2 \cdot \frac{P_1}{A_p}$$

$$\tau_{1s} = 710 \text{ psi}$$

Maximum total stress:

$$\sigma_{tot1} = \sigma_{b1} + \tau_{1s}$$

$$\sigma_{tot1} = 5{,}668 \text{ psi}$$

$$MS_{3a} = \left(\frac{S_a}{\sigma_{tot1}}\right) - 1$$

ASME Allowable $MS_{3a} = 2.09$

$$MS_{3b} = \left(\frac{F_b}{\sigma_{tot1}}\right) - 1$$

AISC Allowable $MS_{3b} = 3.42$ OK

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6. **Determine loading at angle α without shielding:**

$$T_h = W_{lift} \cdot \frac{l_{ccg}}{l_{con} \cdot (\tan(\beta) + \tan(\alpha))}$$

$T_h$ = 14,321 lbs

$$F_h = W_{lift} \cdot \frac{l_{ccg}}{l_{con} \cdot (\tan(\beta) + \tan(\alpha))}$$

$F_h$ = 14,321 lbs

$$T_v = W_{lift} \cdot \frac{l_{ccg}}{[l_{con} \cdot (\tan(\beta) + \tan(\alpha))]} \cdot \tan(\beta)$$

$T_v$ = 18,249 lbs

$$F_v = W_{lift} \cdot \left[\frac{l_{ccg} \cdot \tan(\alpha)}{[l_{con} \cdot (\tan(\beta) + \tan(\alpha))]} + \left(1 - \frac{l_{ccg}}{l_{con}}\right)\right]$$

$F_v$ = 24,108 lbs

$$F_{tot} = \sqrt{F_v^2 + F_h^2}$$

$F_{tot}$ = 28,041 lbs

$$T_{tot} = \sqrt{T_v^2 + T_h^2}$$

$T_{tot}$ = 23,197 lbs

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**Transform coordinates to container centerline:**

Total angle:

$$\theta = acos\left(\frac{F_h}{F_{tot}}\right)$$

$$\theta = 59.29 \text{ deg}$$

$$F_{ch} = F_{tot} \cdot \cos(\theta - \alpha)$$

$$F_{ch} = 18{,}290 \text{ lbs}$$

$$F_{cv} = F_{tot} \cdot \sin(\theta - \alpha)$$

$$F_{cv} = 21{,}225 \text{ lbs}$$

$$T_{ch} = T_{tot} \cdot \cos(\theta - \alpha)$$

$$T_{ch} = 10{,}934 \text{ lbs}$$

$$T_{cv} = T_{tot} \cdot \sin(\theta - \alpha)$$

$$T_{cv} = 20{,}458 \text{ lbs}$$

Conservatively model as a simply supported beam with concentrated load at the cg, end load of $F_{ch}$ and unequal moments due to vertical forces (case 8, p. 150, Reference 5).

$$j_1 = \sqrt{\frac{E_{cst1} \cdot I_{p1}}{F_{ch}}}$$

$$U = \frac{j_1}{l_{con}}$$

Determine moments about the cg:

$$M_1 = F_v \cdot L_{cg}$$

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Location of evaluation: $x = l_{ccg}$

$$M_{lift} = \left(\frac{M_2 - M_1 \cdot \cos(U)}{\sin}(U)\right) \cdot \sin\left(\frac{x}{j_1}\right) + M_1 \cdot \cos\left(\frac{x}{j_1}\right)$$

$$M_{lift} = 604{,}617 \text{ ft} \cdot \text{lbs}$$

$$M_{con} = W_{lift} \cdot \sin(\alpha) \cdot L_{cg}$$

$$M_{tot} = M_{lift} + M_{con}$$

$$M_{tot} = 784{,}045 \text{ ft} \cdot \text{lbs}$$

Bending stress:

$$\sigma_{blift} = \frac{M_{tot} \cdot \frac{dp_{od}}{2}}{I_{p1}}$$

$$\sigma_{blift} = 7{,}495 \text{ psi}$$

Compressive stress:

$$\sigma_{comp} = \frac{W_{lift}}{A_p}$$

$$\sigma_{comp} = 696 \text{ psi}$$

AISC combined stress (Reference 1):

$$\frac{\sigma_{comp}}{F_a} + \frac{\sigma_{blift}}{F_b} = 0.33$$

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$$MS_{4a} = \frac{F_b}{\sigma_{blift}} - 1$$

AISC Allowable $MS_{4a} = 2.35$ OK

$$MS_{4b} = \frac{F_a}{\sigma_{comp}} - 1$$

AISC Allowable $MS_{4b} = 29.1$ OK

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Building Tank 241-C-106 (106C) Rev. 0 Job No.
Subject Pressure Increase and Decrease Evaluation
Originator P. M. Nguyen PMNguyen Date 05/24/94
Checker S. S. Shiraga [signature] Date 06/16/94

### I. Objective:

The objective of this analysis is to evaluate the pressurization of the 106C-49 foot package as required in Reference 5.

### II. References:

1. WHC-SD-TP-PDC-015, Rev. 0-A, "Packaging Design Criteria Transfer and Disposal of Equipment, Tank 241-C-106 Waste Sluicing System".

2. American Society of Mechanical Engineers, Boiler Pressure and Vessels, Section VIII, Division 2, 1989.

3. WHC Drawing No., H-2-83722, H-2-83724, H-2-83725, H-2-83726 and H-2-83727.

4. Roark, Formulas for Stress and Strain, 4th ed., R. J. Roark.

5. US-NRC, 10 CFR Part 71, "Packaging and Transportation of Radioactive Materials".

6. Memorandum, 84100-94-DBC-186, D. B. Calmus to S. S. Shiraga, "Container Barriers for 106-C Packaging", dated June 3, 1994.

### III. Results and Conclusions:

The analysis is performed for the increased external pressure of 20 psi and decreased external pressure of 3.5 psi, per Reference 1. Subsequently, the largest pressure differential results from decreased external pressure. Only the largest pressure differential of 11.2 psi which is internal was evaluated. The inner flange at the top and the 2" thick flange at the bottom end are considered the primary containment boundaries for transportation per Reference 6.

The results show that the package design is adequate to withstand the pressure differentials specified in Reference 5. Also the results are used in conjunction with the drop and pump impact evaluation, to determine performance under combined loading.

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IV. **Engineering Evaluation:**

**Pressure Change Evaluation Bottom End**

**Pipe and flange parameters:**

Modulus of Elasticity (Ref.2): $E_{cstl} = 29.258 \times 10^6$ psi

Poisson Ratio (Ref. 2): $\nu_{cstl} = 0.3$

Container diameter (Ref. 3): $od_p = 52$ inch

$$R_p = \frac{od_p}{2}$$

Wall thickness of pipe (Ref. 3): $t_p = 0.375$ inch

ASME allowable (Reference 2, Table ACS-1, p.77): $s_a = 23,270$ psi

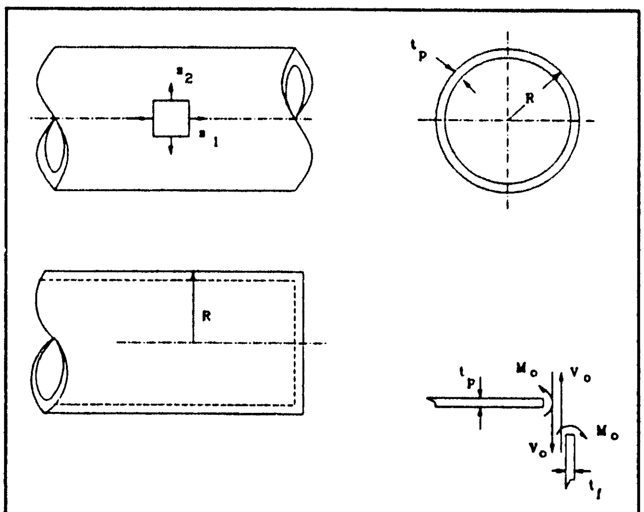


**Figure 1**

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Thickness of flange (Ref. 3): $t_f = 2.00$ inch

$$D_f = \frac{E_{cstl}\ t_f^3}{12\left(1 - \nu_{cstl}^2\right)}$$

$$D_p = \frac{E_{cstl}\ t_p^3}{12\left(1 - \nu_{cstl}^2\right)}$$

$$\lambda_p = \left(3\ \frac{\left(1 - \nu_{cstl}^2\right)}{R_p^2\ t_p^2}\right)^{\frac{1}{4}}$$

**Container Mid Sections Stress (Reference 4, page 298, Case 1):**

Evaluate package for reduction in external pressure (Ref. 1):

$P_{red} = 11.2$ psi

Meridional stress:

$$s_1 = \frac{P_{red} R_p}{2\ t_p}$$

$s_1 = 388$ psi

Hoop stress:

$$s_2 = \frac{P_{red} R_p}{2\ t_p}$$

$s_2 = 777$ psi

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**Container End Discontinuity Stress (Reference 4, page 307, Case 30):**

$$M_o = \frac{\dfrac{P_{red}\,R_p^3\,\lambda_p^2\,D_p}{4\,D_f\,(1+\nu_{cstl})} + \dfrac{2\,P_{red}\,R_p^2\,\lambda_p^3\,E_{cstl}\,t_f\,D_p}{E_{cstl}\,t_p\left(1-\frac{1}{2}\,\nu_{cstl}\right)\left[E_{cstl}\,t_f+2\,R_p\,D_p\,\lambda_p^3(1-\nu_{cstl})\right]}}{2\,\lambda_p + \dfrac{2\,R_p\,\lambda_p^2\,D_p}{D_f\,(1+\nu_{cstl})} - \dfrac{\lambda_p\,E_{cstl}\,t_f}{E_{cstl}\,t_f+2\,D_f\,\lambda_p^3\,R_p(1-\nu_{cstl})}}$$

$M_o$ = 124 lbs-in/in

$$V_o = M_o\left[2\,\lambda_p + \frac{2\,R_p\,\lambda_p^2\,D_p}{D_f\,(1+\nu_{cstl})}\right] - \frac{P_{red}\,R_p^3\,\lambda_p^2\,D_p}{4\,D_f\,(1+\nu_{cstl})}$$

$V_o$ = 784 $ft^{-1}$ lbs

Hoop stress:

$$s_{hbmax} = \frac{2\,M_o}{t_p}\,\lambda_p^2\,R_p$$

$s_{hbmax}$ = -2,913 psi

$$s_{hsmax} = \frac{2\,V_o}{t_p}\,\lambda_p\,R_p$$

$s_{hsmax}$ = -3,729 psi

$$s_{thmax} = s_{hbmax} + s_{hsmax} + s_2$$

$s_{thmax}$ = -5,866 psi

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Meridional stress:

$$S_{mbmax} = \frac{6\ M_o}{t_p^2}$$

$$S_{mbmax} = 186 \text{ psi}$$

$$S_{msmax} = \frac{1.932\ V_o}{\lambda_p\ t_p^2}$$

$$S_{msmax} = 2{,}180 \text{ psi}$$

$$S_{mtmax} = S_{mbmax} + S_{msmax} + S_1$$

$$S_{mtmax} = 2{,}755 \text{ psi}$$

Total stress:

$$S_{btot} = S_{mtmax} + S_{thmax}$$

$$S_{btot} = 5{,}478 \text{ psi}$$

Margin of Safety:

$$MS_1 = \frac{S_a}{S_{btot}} - 1$$

$MS_1 = 3.25$ OK

**Container bottom flange stress (Reference 4, page 307, Case 30):**

Flange pressure loading: $W_o = p_o \pi R_o^2$ $W_o = 23{,}786$ lbs

Flange thickness (Reference 3): $t_f = 1.75$ in

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Model as a simply supported plate.

Maximum stress from pressure at center of flange:

$$s_{fr} = \frac{3\ W_o}{8\ \pi\ m\ t_f^2} \cdot (3\ m + 1)$$

$$\text{Where:} \quad m = \frac{1}{\nu_{cstl}}$$

$$s_{fr} = 2{,}342 \text{ psi}$$

Maximum stress from moment at center of flange:

$$s_{fmr} = \frac{6\ M_o}{t_f^2}$$

$$s_{fmr} = 186 \text{ psi}$$

Shear stress:

$$s_s = \frac{V_o}{t_f}$$

$$s_s = 33 \text{ psi}$$

Total Flange stress:

$$s_{ftot} = s_{fr} + s_{fmr} + s_s$$

$$s_{ftot} = 2{,}561 \text{ psi}$$

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Margin of Safety:

$$MS_2 = \frac{s_a}{s_{ftot}} - 1$$

$$MS_2 = 8.09 \quad OK$$

**Pressure Change Evaluation Top End:**

Hub Flange thickness: $t_f = 1.75$ inches

Blind Flange thickness: $t_{bf} = 0.75$ inches

Evaluate package for reduction in external pressure.

$$M_o = \frac{\dfrac{P_{red}\, R_p^3\, \lambda_p^2\, D_p}{4\, D_f\,(1+\nu_{cstl})} + \dfrac{2\, P_{red}\, R_p^2\, \lambda_p^3\, E_{cstl}\, t_f\, D_p}{E_{cstl}\, t_p \left(1-\frac{1}{2}\nu_{cstl}\right)\left[E_{cstl}\, t_f + 2\, R_p\, D_p\, \lambda_p^3 (1-\nu_{cstl})\right]}}{2\,\lambda_p + \dfrac{2\, R_p\, \lambda_p^2\, D_p}{D_f\,(1+\nu_{cstl})} - \dfrac{\lambda_p\, E_{cstl}\, t_f}{E_{cstl}\, t_f + 2\, D_f\, \lambda_p^3\, R_p (1-\nu_{cstl})}}$$

$$M_o = 161 \text{ lbs}$$

$$V_o = M_o\left[2\,\lambda_p + \frac{2\, R_p\, \lambda_p^2\, D_p}{D_f\,(1+\nu_{cstl})}\right] - \frac{P_{inc}\, R_p^3\, \lambda_p^2\, D_p}{4\, D_f\,(1+\nu_{cstl})}$$

$$V_o = 960 \text{ ft}^{-1} \text{ lbf}$$

Hoop stress:

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$$s_{hbmax} = \frac{2\ M_o}{t_p} \lambda_p^2\ R_p$$

$$s_{hbmax} = -\ 3{,}779 \text{ psi}$$

$$s_{hsmax} = -\ \frac{2\ V_o}{t_p} \lambda_p\ R_p$$

$$s_{hsmax} = -\ 4{,}566 \text{ psi}$$

$$s_{thmax} = s_{hbmax} + s_{hsmax} + s_2$$

$$s_{thmax} = -\ 7{,}568 \text{ psi}$$

Meridional stress:

$$s_{mbmax} = \frac{6\ M_o}{t_p^2}$$

$$s_{mbmax} = 315 \text{ psi}$$

$$s_{msmax} = \frac{1.932\ V_o}{\lambda_p\ t_p^2}$$

$$s_{msmax} = 2{,}670 \text{ psi}$$

$$s_{mtmax} = s_{mbmax} + s_{msmax} + s_1$$

$$s_{mtmax} = 3{,}373 \text{ psi}$$

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Total stress: $S_{tot} = S_{mtmax} + S_{thmax}$

$S_{tot} = 4{,}510$ psi

Margin of Safety:

$$MS_3 = \frac{S_a}{S_{tot}} - 1$$

$MS_3 = 4.16$ OK

**Container top flange stress (Reference 4, page 307, Case 30):**

Stress in ¼ inch flange:

Diameter of flange assumed as inside radius of hub flange (Reference 2):

$d_f = 47\ ¼$ inch $R_f = 23.625$ inch

Flange pressure loading: $W_o = p_o \pi R_f^2$ $W_o = 19{,}639$ lbs

Model as a simply supported plate.

Maximum stress from pressure at center of flange:

$$s_{fr} = \frac{3\ W_o}{8\ \pi\ m\ t_{bf}^2} \cdot (3\ m + 1)$$

*Where*: $m = \frac{1}{\nu_{cstl}}$

$s_{fr} = 13{,}753$ psi

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Maximum stress from moment at center of flange:

$$s_{fmr} = \frac{6\ M_o}{t_{bf}^2}$$

$$s_{fmr} = 1{,}715 \text{ psi}$$

Shear stress:

$$s_s = \frac{V_o}{t_{bf}}$$

$$s_s = 107 \text{ psi}$$

Total Flange stress:

$$s_{ftot} = s_{fr} + s_{fmr} + s_s$$

$$s_{ftot} = 15{,}574 \text{ psi}$$

Margin of Safety:

$$MS_4 = \frac{s_a}{s_{ftot}} - 1$$

$$MS_4 = 0.49 \quad \text{OK}$$

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Building Tank 241-C-106 (106C) Rev. 0 Job No.
Subject Transportation Peak Shock Loading on 106-C (49ft)
Originator P. M. Nguyen Date 05/24/94
Checker S. S. Shiraga Date 06/15/94

## I. Objectives:

The objective of the vibrational analyses is to determine the stresses induced by peak shock loading during transportation of the 106C-49 foot 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 Vessel Code, Section VIII, Division 2, 1989.

3. Industrial Press, Machinery's Handbook, 23rd Edition.

4. WHC Drawings, H-2-83722, H-2-83724, H-2-83725, H-2-83726 and H-2-83727.

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 only cyclic stresses are not evaluated. The vertical and longitudinal shock loadings are modeled in three sections based on the method of tie-down. Due to the method of tie-down the container was modeled in two cases with a 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 ring. For this evaluation only the vertical and longitudinal directions were evaluated, since the container is radial symmetrical and the lateral direction loading is less than the vertical loading. Results of this evaluation were as follows:

1. The container section from the closed end to the strongback end was modeled as a clamped and fixed beam. The maximum total stress developed from vertical peak shock loading was 8,970 psi tensile and from longitudinal peak shock loading was -656 psi tensile.

2. The container section from the strongback to the trailer tie-down position was also modeled as a clamped and fixed beam. The maximum total stress developed from vertical peak shock loading was -7,252 psi compressive and -552 psi compressive from longitudinal peak shock loading.

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3. The container section from the trailer tie-down position to the container bolted end was modeled as a cantilevered section. The maximum total stress developed from vertical peak shock loading was 1,809 psi tensile and 127 psi from longitudinal peak shock loading.

All of these stresses are well under the allowable for the container material. Subsequently the package design and construction is adequate to withstand the peak shock loads induced by transport as characterized in Reference 1. Combining with external pressure reduction results will not alter the conclusion, since these stresses are also relatively minor.

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IV. Engineering Evaluation:

**Peak Vertical Shock Loading:**

Since the package is restrained by the saddles 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 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 defined as:

$$g_{ps} = 3.5 \quad at \quad \omega = \frac{4 \cdot \pi}{sec} \quad for\ a\ duration\ of \quad T_p = \frac{2 \cdot \pi}{\omega}$$

**Container Parameters:**

Material Modulus at 115 °F (Reference 2): $E_{cstl} = 29.258 \times 10^6$ psi

Pipe OD: 52 inches Pipe Thickness: $t_{pw} = 0.375$ inch

Pipe ID: $dp_{id} = dp_{od} - 2 \cdot t_{pw}$

Assume all
outer skin dimensions are the same:

Skin OD: $od_{sk} = 55.357$ inch

Skin Thickness: $t_{sl} = 0.1875$ inch

Skin ID: $id_{sk} = od_{sk} - 2 \cdot t_{sl}$

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Total Area:

$$A_p = \pi \cdot \frac{dp_{od}^2 - dp_{id}^2}{4} + \pi \cdot \frac{od_{sk}^2 - id_{sk}^2}{4}$$

Total Moment of Inertia:

$$I_p = \pi \cdot \frac{dp_{od}^4 - dp_{id}^4}{64} + \pi \cdot \frac{od_{sk}^4 - id_{sk}^4}{64}$$

Container Empty Weight: $W_{con}$ = 62,732 lbs

Payload Weight: $W_{pc}$ = 3,152 lbs

Length of Container without Top Hat: $L_{con}$ = 589.375 inches

Total Weight of Container: $W_{pack} = W_{con} + W_{pc}$ $W_{pack}$ = 65,884 lbs

Load per Unit Length:

$$w_{con} = \frac{W_{pack}}{L_{con}}$$

Pulsating Sinusoidal Force:

$$F_v = g_{ps} \cdot w_{con} \cdot l \cdot \sin(\omega \cdot t) \qquad (7)$$

Where l is defined as the length of the section.

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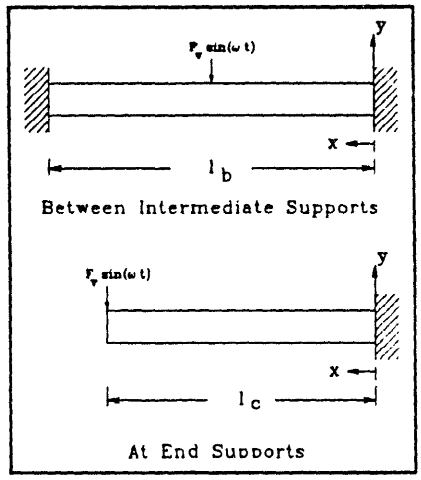


**Response equations for the clamped and fixed sections on strongback:**

Length of section between supports: $l_b = 24$ 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:

$$y = X \cdot (A \cdot \cos(\Omega \cdot t) + B \cdot \sin(\Omega \cdot t))$$

The general partial differential equation for free vibration then becomes:

$$\frac{d^4}{d x^4} X - (k)^4 \cdot X = 0$$

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The general solution for the normal function of deflection then becomes:

$$X = c_1 \cdot (\cos(k \cdot x) + (\cosh(k \cdot x)) + c_2 (\cos k \cdot x) - \cosh(k \cdot x)) \ldots$$
$$+ c_3 \cdot (\sin(k \cdot x) + \sinh(k \cdot x) + c_4 \cdot (\sin(k \cdot x) - \sinh(k \cdot x))$$

The boundary conditions for a clamped and fixed beam are:

$$At\ x = 0: \quad x = 0 \quad and \quad \frac{d}{dx} x = 0$$

$$At\ x = 1_b \quad x = 0 \quad and \quad \frac{d}{dx} x = 0$$

$$\frac{d}{dx} X = c_1 \cdot (-\sin(k \cdot x) \cdot k + \sinh(k \cdot x) \cdot k) + c_2 \cdot (-\sin(k \cdot x) \cdot k -$$
$$\sinh(k \cdot x) \cdot k) + c_3 \cdot (\cos(k \cdot x) \cdot k + \cosh(k \cdot x) \cdot k) +$$
$$c_4 \cdot (\cos(k \cdot x) \cdot k - \cosh(k \cdot x) \cdot k)$$

$$From\ x = 0 \qquad c_1 = c_3 = 0$$

So that:

$$X = c_2 \cdot (\cos(k \cdot x) - \cosh(k \cdot x)) + c_4 \cdot (\sin(k \cdot x) - \sinh(k \cdot x))$$

$$\frac{d}{dx} x = c_2 \cdot (-\sin(k \cdot x) \cdot k - \sinh(k \cdot x) \cdot k) +$$
$$c_4 \cdot (\cos(k \cdot x) \cdot k - \cosh(k \cdot x) \cdot k)$$

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*From* $x = l_b$:

$$c_2 \cdot (\cos(k \cdot l_b) - \cosh(k \cdot l_b)) + c_4 \cdot (\sin(k \cdot l_b) - \sinh(k \cdot l_b)) = 0$$

$$c_2 \cdot (\sin(k \cdot l_b) + \sinh(k \cdot l_b)) + c_4 \cdot (-\cos(k \cdot l_b) + \cosh(k \cdot l_b)) = 0$$

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:

$$\cos(k \cdot l_b) \cdot \cosh(k \cdot l_b) = 1$$

The non-zero roots of the above equation is approximated by:

$$k_i = \frac{\left(i + \frac{1}{2}\right) \cdot \pi}{l_b}$$

The normal function becomes:

$$X_i = \cosh(k_i \cdot x) - \cos(k_i \cdot x) - \alpha \cdot (\sinh(k_i \cdot x) - \sin(k_i \cdot x))$$

Where $\alpha_i$ is defined as:

$$\alpha_i = \frac{\cos(k_i \cdot l_b) - \cosh(k_i \cdot l_b)}{\sinh(k_i \cdot l_b) - (\sin k_i \cdot l_b)}$$

The response for a steady state forced vibration of a clamped and fixed beam is:

$$y = \frac{2 \cdot F_v \cdot}{E_{cstl}} \cdot \frac{l_b^3}{I_p} \cdot \sum_i \frac{X_i \cdot X_{load_i}}{(k_i \cdot l_b)} \cdot \beta_i \cdot \left(\sin(\omega \cdot t) - \frac{\omega}{\Omega_i} \cdot \sin(\Omega_i \cdot t)\right)$$

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Where $x_{load}$ is defined as the normal function at the load.

$$X_{load_i} = \cosh\left(k_i \cdot \frac{1_b}{2}\right) - \cos\left(k_i \cdot \frac{1_b}{2}\right) - \alpha_i \cdot \left(\sinh\left(k_i \cdot \frac{1_b}{1}\right) - \sin\left(k_i \cdot \frac{1_b}{2}\right)\right)$$

Since:

$$M = E_{cstl} \cdot I_p \cdot \frac{d^2}{d\,x^2}\,y$$

$$X_i = \cosh(k_i \cdot x) - \cos(k_i \cdot x) - \alpha_i \cdot (\sinh(k_i \cdot x) - \sin(k_i \cdot x))$$

$$\frac{d^2}{d\,x^2}\,X_i = X_i' = (k_i)^2 \cdot [\cosh(k_i \cdot x) + \cos(k_i \cdot x) - \alpha_i \cdot (\sinh(k_i \cdot x) + \sin(k_i \cdot x))]$$

$$\frac{d^3}{d\,x^3}\,X_i = X_i'' = (k_i)^3 \cdot (-\sinh(k_i \cdot x) + \sin(k_i \cdot x) + \alpha \cdot \cosh(K_i \cdot x) + \alpha_i \cdot \cos(K_i \cdot x))$$

$$\sigma_b = 2 \cdot F_v \cdot 1_b{}^3 \cdot \frac{dp_{od}}{2} \cdot \sum_i \frac{x_{load_i} \cdot X_i'}{(k_i \cdot 1_b)^4} \cdot \beta_i \cdot \left(\sin(\omega \cdot t) - \frac{\omega}{\Omega_i} \cdot \sin(\Omega_i \cdot t)\right)$$

$$V_b = 2 \cdot F_v \cdot 1_b{}^3 \cdot \sum_i \frac{x_{load_i} \cdot X_i''}{(k_i \cdot 1_b)^4} \cdot \beta_i \cdot \left(\sin(\omega \cdot t) - \frac{\omega}{\Omega_i} \cdot \sin(\Omega_i \cdot t)\right)$$

Determine stress, deflection, and shear load for the first five modes at $x = 1_b$ for one full period.

$$i = 1, \ldots, 5$$

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Natural Frequency:

$$\Omega_i = i^2 \cdot \pi^2 \cdot \sqrt{\frac{g \cdot E_{cstl} \cdot I_p}{w_{con} \cdot l_b^4}} \qquad k_i = \frac{\left(i + \frac{1}{2}\right) \cdot \pi}{l_b}$$

Frequency Ratio:

$$\beta_i = \frac{1}{\left[1 - \left(\frac{\omega}{\Omega_i}\right)^2\right]}$$

Normal Function Coefficient:

$$\alpha_i = \frac{\cosh(k_i \cdot l_b) - \cos(k_i \cdot l_b)}{\sinh(k_i \cdot l_b) - \sin(k_i \cdot l_b)}$$

Normal Function at Load:

$$X_{load_i} = \left(\cosh\left(k_i \cdot \frac{l_b}{2}\right) - \cos\left(k_i \cdot \frac{l_b}{2}\right)\right) - \alpha_i \cdot \left(\sinh\left(k_i \cdot \frac{l_b}{2}\right) - \sin\left(k_i \cdot \frac{l_b}{2}\right)\right)$$

Normal Function of the Section:

$$X_i = (\cosh(k_i \cdot x) - \cos(k_i \cdot x)) - \alpha_i \cdot (\sinh(k_i \cdot x) - \sin(k_i \cdot x))$$

Evaluation Time Intervals:

$$n = 0 \ldots 8 \qquad t_n = \frac{n}{8} \cdot T_p$$

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Pulsating Function Magnitude:

$$F_v = g_{ps} \cdot w_{con} \cdot l_b$$

Deflection:

$$y_n = \frac{2 \cdot F_v}{E_{cstl}} \cdot \frac{l_b^3}{I_p} \cdot \sum_i \frac{X_i \cdot X_{load_i}}{(k_i \cdot l_b)^4} \beta_i \left(\sin(\omega \cdot t_n) - \frac{\omega}{\Omega_i} \cdot \sin(\Omega_i \cdot t_n)\right)$$

Moment Normal Function:

$$X_i'' = (k_i)^2 \cdot [\cosh(k_i \cdot x) + \cos(k_i \cdot x) - \alpha_i \cdot (\sinh(k_i \cdot x) + \sin(k_i \cdot x))]$$

Bending Stress:

$$\sigma_{b_n} = \frac{2 \cdot F_v \cdot l_b^3 \cdot \frac{dp_{od}}{2}}{I_p} \cdot \sum_i \frac{X_{load_i} \cdot X_i''}{(k_i \cdot l_b)^4} \beta_i \cdot \left(\sin(\omega \cdot t_n) - \frac{\omega}{\Omega_i} \cdot \sin(\Omega_i \cdot t_n)\right)$$

Shear Normal Function:

$$X_i''' = -(k_i)^3 \cdot (-\sinh(k_i \cdot x) + \sin(k_i \cdot x) + \alpha_i \cdot \cosh(k_i \cdot x) + \alpha_i \cos(k_i \cdot x))$$

Shear Load:

$$V_{b_n} = 2 \cdot F_v \cdot l_b^3 \cdot \sum_i \frac{X_{load_i} \cdot X_i'''}{(k_i \cdot l_b)^4} \cdot \beta_i \cdot \left(\sin(\omega \cdot t_n) - \frac{\omega}{\Omega_i} \cdot \sin(\Omega_i \cdot t_n)\right)$$

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Maximum Shear Stress:

$$\tau_{sbmax_n} = 2 \cdot \frac{V_{b_n}}{A_p}$$

Total Stress:

$$\sigma_{btot_n} = \sigma_{b_n} + \tau_{sbmax_n}$$

| $t_n$ (sec) | $y_n$ (in) | $\sigma_b$ (psi) | $\tau_{sbmax}$ (psi) | $\sigma_{btot}$ (psi) |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0.063 | 0 | 4,317 | 1,813 | 6,130 |
| 0.125 | 0 | 6,167 | 2,579 | 8,747 |
| 0.188 | 0 | 4,518 | 1,896 | 6,414 |
| 0.250 | 0 | 251 | 114 | 365 |
| 0.313 | 0 | - 4,234 | - 1,775 | - 6,009 |
| 0.375 | 0 | - 6,321 | - 2,650 | - 8,970 |
| 0.438 | 0 | - 4,773 | - 2,007 | - 6,780 |
| 0.5 | 0 | - 407 | - 183 | - 591 |

Maximum total bending stress at stiffener rings:

$\sigma_{btot}$ = 8,970 psi

**Response Equations for the Clamped and Fixed Sections from Strongback:**

Length of Section Between Supports: $l_{1b}$ = 242.750 inches

Location Where Beam to be Evaluated: $x_1 = l_{1b}$

Determine loading using same methodology as above.

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Determine stress, deflection, and shear load for the first five modes at $xl = l_{1b}/2$ for one full period.

Natural Frequency:

$$\Omega l_i = i^2 \cdot \pi^2 \cdot \sqrt{\frac{g \cdot E_{cstl} \cdot I_p}{w_{con} \cdot l_{1b}^4}} \qquad kl_i = \frac{\left(i + \frac{1}{2}\right) \cdot \pi}{l_{1b}}$$

Frequency Ratio:

$$\beta l_i = \frac{1}{\left[1 - \left(\frac{\omega}{\Omega l_i}\right)^2\right]}$$

Normal Function Coefficient:

$$\alpha l_i = \frac{\cosh(kl_i \cdot l_{1b}) - \cos(kl_i \cdot l_{1b})}{\sinh(kl_i \cdot l_{1b}) - \sin(kl_i \cdot l_{1b})}$$

Normal Function at Load:

$$Xl_{load_i} = \left(\cosh\left(kl_i \cdot \frac{l_{1b}}{2}\right) - \cos\left(kl_i \cdot \frac{l_{1b}}{2}\right)\right) - \alpha l_i \cdot \left(\sinh\left(kl_i \cdot \frac{l_{1b}}{2}\right) - \sin\left(kl_i \cdot \frac{l_{1b}}{2}\right)\right)$$

Normal Function of the Section:

$$Xl_i = (\cosh(kl_i \cdot xl) - \cosh(kl_i \cdot xl)) - \alpha l_i \cdot (\sinh(kl_i \cdot xl) - \sin(kl_i \cdot xl))$$

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Pulsating Function Magnitude:

$$F1_v = g_{ps} \cdot w_{con} \cdot 1_{1b}$$

Deflection:

$$y1_n = \frac{2 \cdot F1_v}{E_{cst1}} \cdot \frac{1_{1b}^3}{I_p} \cdot \sum_i \frac{X1_i \cdot X1_{load_i}}{(k1_i \cdot 1_{1b})^4} \cdot \beta 1_i \cdot \left(\sin(\omega \cdot t_n) - \frac{\omega}{\Omega 1_i} \cdot \sin(\Omega 1_i \cdot t_n)\right)$$

Moment Normal Function:

$$X1_i'' = (k1_i)^2 \cdot [\cosh(k1_i \cdot x1) + \cos(k1_i \cdot x1) - \alpha 1_i \cdot (\sinh(k1_i \cdot x1) + \sin(k1_i \cdot x1))]$$

Bending Stress:

$$\sigma 1_{b_n} = \frac{2 \cdot F1_v \cdot 1_{1b}^3 \cdot \frac{dp_{od}}{2}}{I_p} \cdot \sum_i \frac{X1_{load_i} \cdot X1_i''}{(k1_i \cdot 1_{1b})^4} \cdot \beta 1_i \cdot \left(\sin(\omega \cdot t_n) - \frac{\omega}{\Omega 1_i} \cdot \sin(\Omega 1_i \cdot t_n)\right)$$

Shear Normal Function:

$$X1_i''' = -(k1_i)^3 \cdot (-\sinh(k1_i \cdot x1) + \sin(k1_i \cdot x1) + \alpha 1_i \cdot \cosh(k1_i \cdot x1) + \alpha 1_i \cdot \cos(k1_i \cdot x1))$$

Shear Load:

$$V1_{b_n} = 2 \cdot F1_v \cdot 1_{1b}^3 \cdot \sum_i \frac{X1_{load_i} \cdot X1_i'''}{(k1_i \cdot 1_{1b})^4} \cdot \beta 1_i \cdot \left(\sin(\omega \cdot t_n) - \frac{\omega}{\Omega 1_i} \cdot \sin(\Omega 1_i \cdot t_n)\right)$$

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**Maximum Shear Stress:**

$$\tau l_{sbmax_s} = 2 \cdot \frac{Vl_{b_s}}{A_p}$$

Total Stress:

$$\sigma l_{btot_s} = \sigma l_{b_s} + \tau l_{sbmax_s}$$

| $t_n$ (sec) | $y_n$ (in) | $\sigma_b$ (psi) | $\tau_{sbmax}$ (psi) | $\sigma_{btot}$ (psi) |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0.063 | 0 | 3,269 | 1,632 | 4,901 |
| 0.125 | 0 | 4,598 | 2,291 | 6,888 |
| 0.188 | 0 | 3,196 | 1,589 | 4,785 |
| 0.250 | 0 | - 130 | - 69 | - 199 |
| 0.313 | 0 | - 3,450 | - 1,722 | - 5,172 |
| 0.375 | 0 | - 4,838 | - 2,414 | - 7,252 |
| 0.438 | 0 | - 3,494 | - 1,749 | - 5,243 |
| 0.5 | 0 | - 209 | - 112 | - 321 |

Maximum total stress at stiffener rings:

$$\sigma_{btot} = -7,252 \text{ psi}$$

**Response Equations for the Cantilevered Sections:**

Using the same method as above, determine the response of the long cantilevered section.

Length of Section Between Supports: $l_c$ = 53.12 inches

Location where Beam to be Evaluated: $x_c$ = 0 inches

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Length of Top Cap: $l_{tcap} = 8.1875$ inches

Additional Weight Due to Top Cap: $W_{tcap} = 1{,}039$ lbs

$$w_{conl} = \frac{W_{con}}{L_{con}} + \frac{W_{tcap}}{l_{tcap}}$$

Determine stress and deflection for the first five modes at x = 0 and for one full period.

Natural Frequency:

$$\Omega_{c_i} = i^2 \cdot \pi^2 \cdot \sqrt{\frac{g \cdot E_{cstl} \cdot I_p}{w_{conl} \cdot l_c^4}} \qquad k_{c_i} = \frac{\left(i + \frac{1}{2}\right) \cdot \pi}{l_c}$$

Frequency Ratio:

$$\beta_{c_i} = \frac{1}{\left[1 - \left(\frac{\omega}{\Omega_{c_i}}\right)^2\right]}$$

Normal Function Coefficient:

$$\alpha_{c_i} = \frac{\cosh\left(k_{c_i} \cdot l_c\right) + \cos\left(k_{c_i} \cdot l_c\right)}{\sinh\left(k_{c_i} \cdot l_c\right) + \sin\left(k_{c_i} \cdot l_c\right)}$$

Normal Function at Load:

$$X_{cload_i} = \left(\cosh\left(k_{c_i} \cdot l_c\right) - \cos\left(k_{c_i} \cdot l_c\right)\right) - \alpha_{c_i} \cdot \left(\sinh\left(k_{c_i} \cdot l_c\right) - \sin\left(k_{c_i} \cdot l_c\right)\right)$$

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Normal Function at Section:

$$X_{c_i} = (\cosh(k_{c_i} \cdot x_c) - \cos(k_{c_i} \cdot x_c)) - \alpha_{c_i} \cdot (\sinh(k_{c_i} \cdot x_c) - \sin(k_{c_i} \cdot x_c))$$

Pulsating Function Magnitude:

$$F_{vc} = g_{ps} \cdot w_{conl} \cdot l_c$$

Deflection:

$$y_{c_n} = \frac{2 \cdot F_{vc}}{E_{cstl}} \cdot \frac{l_c^3}{I_p} \cdot \sum_i \frac{X_{c_i} \cdot X_{cload_i}}{(k_{c_i} \cdot l_c)^4} \cdot \beta_{c_i} \cdot \left(\sin(\omega \cdot t_n) - \frac{\omega}{\Omega_{c_i}} \cdot \sin(\Omega_{c_i} \cdot t_n)\right)$$

Normal Function of Bending Stress:

$$X_{c_i}' = (k_{c_i})^2 \cdot [\cosh(k_{c_i} \cdot x_c) + \cos(k_{c_i} \cdot x_c) - \alpha_{c_i} \cdot (\sinh(k_{c_i} \cdot x_c) + \sin(k_{c_i} \cdot x_c))]$$

Bending Stress:

$$\sigma_{cb_n} = \frac{2 \cdot F_{vc} \cdot l_c^3 \cdot \frac{dp_{od}}{2}}{I_p} \cdot \cdot \sum_i \frac{X_{cload_i} \cdot X_{c_i}'}{(k_{c_i} \cdot l_c)^4} \cdot \beta_{c_i} \cdot \left(\sin(\omega \cdot t_n) - \frac{\omega}{\Omega_{c_i}} \cdot \sin(\Omega_{c_i} \cdot t_n)\right)$$

Normal Function of Shear Load:

$$X_{c_i}'' = (k_{c_i})^3 \cdot [\sinh(k_{c_i} \cdot x_c) - \sin(k_{c_i} \cdot x_c) - \alpha_{c_i} \cdot (\cosh(k_{c_i} \cdot x_c) + \cos(k_{c_i} \cdot x_c))]$$

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Shear Load:

$$V_{cb_n} = 2 \cdot F_{vc} \cdot l_c^3 \cdot \sum_i \frac{X_{cload_i} \cdot X_{c_i}''}{(k_{c_i} \cdot l_c)^4} \cdot \beta_{c_i} \cdot \left(\sin(\omega \cdot t_n) - \frac{\omega}{\Omega_{c_i}} \cdot \sin(\Omega_{c_i} \cdot t_n)\right)$$

Maximum Shear Stress:

$$\tau_{cshmax_n} = 2 \cdot \frac{V_{cb_n}}{A_p}$$

Total Stress:

$$\sigma_{ctot_n} = \sigma_{cb_n} - \tau_{cshmax_n}$$

| $t_n$ (sec) | $y_n$ (in) | $\sigma_b$ (psi) | $\tau_{shmax}$ (psi) | $\sigma_{btot}$ (psi) |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0.063 | 0 | - 379 | 904 | - 1,283 |
| 0.125 | 0 | - 532 | 1,271 | -1,803 |
| 0.188 | 0 | - 375 | 895 | -1,270 |
| 0.250 | 0 | - 1 | 1 | - 2 |
| 0.313 | 0 | 375 | - 869 | 1,272 |
| 0.375 | 0 | 534 | - 1,275 | 1,809 |
| 0.438 | 0 | 378 | - 904 | 1,282 |
| 0.5 | 0 | - 1 | 4 | - 5 |

Maximum total stress at stiffener rings:

$$\sigma_{btot} = 1{,}809 \text{ psi}$$

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**Peak Longitudinal Shock Loading:**

Model as individual clamped and fixed beams between the supports and as a cantilever at the ends. Assume the load is pulsating sinusoidal force at mid span on the clamped and fixed beams and on the ends for the cantilever. For conservatism only the inner pipe is considered to resist the loading.

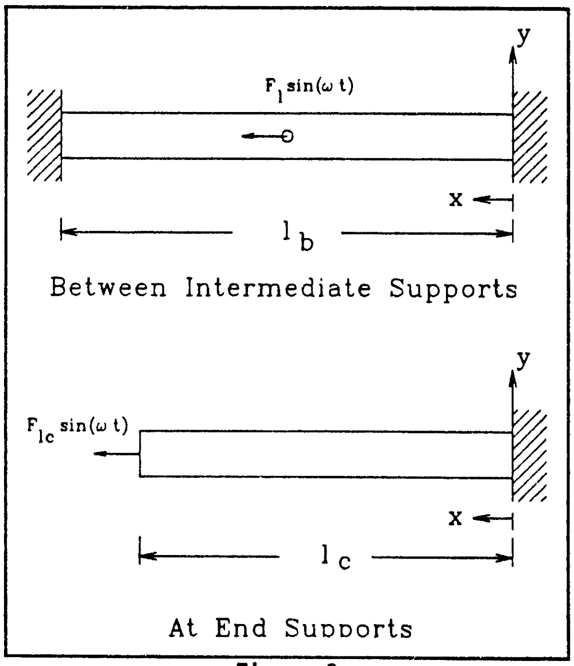


Figure 2

The peak shock load is taken from data developed in Reference 1, page 5. The peak longitudinal shock load parameters are defined as:

Peak Loading: $g_{psl}$ = 2.3 Frequency: $\omega = 4\pi$/sec

Duration: $T_p = 2\pi/\omega$

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**Container Parameters:**

Material modulus at 115°F (Reference 2): $E_{cstl} = 29.258 \times 10^6$ psi

Density of carbon steel (Reference 3, page 398):

$$\rho_{cstl} = 0.2835 \text{ lbs/in}^3$$

Acoustic velocity in carbon steel:

$$a_{cstl} = \sqrt{\frac{g\, E_{cstl}}{\rho_{cstl}}}$$

$$a_{cstl} = 16{,}634 \text{ ft/sec}$$

Pipe OD: $dp_{od} = 52$ in    Pipe thickness: $t_{pw} = 0.375$ in

Pipe ID: $dp_{id} = dp_{od} - 2 \cdot t_{pw}$

Cross sectional area of pipe:

$$A_p = \pi\, \frac{dp_{od}^2 - dp_{id}^2}{4}$$

Pipe cross sectional moment of inertia:

$$I_p = \pi\, \frac{dp_{od}^4 - dp_{id}^2}{64}$$

Container empty weight: $W_{con} = 62{,}732$ lbs

Container payload: $W_{pc} = 3{,}152$ lbs

Length of container: $L_{con} = 589.375$ in

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Total weight of container: $W_{pack} = W_{con} + W_{pc}$ $W_{pack} = 65,884$ lbs

Load per unit length:

$$w_{con} = \frac{W_{pack}}{L_{con}}$$

Pulsating sinusoidal force:

$$F_1 = g_{psl}\, w_{con}\, l \sin(\omega\, t)$$

Where l is defined as the length of the section.

**Differential Equations of Motion for Longitudinal Vibration:**

General form of equation:

$$\frac{d^2}{d\,t^2}\,u = a_{cstl}\,\frac{d^2}{dx^2}\,u$$

Where "u" is defined as the displacement of the cross section.

General solution is:

$$u(x,t) = \sum_{n}^{\infty}(A\cos(\Omega\,t) + B\sin(\Omega\,t))\left(C\cos\left(\frac{\Omega\,x}{a_{cstl}}\right) + D\sin\left(\frac{\Omega\,x}{a_{cstl}}\right)\right) = 0$$

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 homogeneous, isotropic and obeys Hooke's Law.

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**Derivation of normal function for clamped and fixed section:**

Since the beam is assumed to be clamped and fixed, displacement at the ends is equal to zero. The boundary conditions are: $u_{x=0}=u_{x=1}=0$.

Substituting these into the above equation:

$$u_{x=0} = \sum_{n}^{\infty} f(t)\left(C\cos\left(\frac{\Omega\, t}{a_{cstl}}\right) + D\sin\left(\frac{\Omega\, t}{a_{cstl}}\right)\right) = 0$$

Where f(t) is defined as a time dependent function.

Then C = 0 and:

$$u_{x=l} = \sum_{n}^{\infty} f(t)\, D\sin\left(\frac{\Omega\, t}{a_{cstl}}\right) = 0$$

Then:

$$\sin\left(\frac{\Omega\, t}{a_{cstl}}\right) = 0 \qquad \textit{Where:}\quad \Omega = \frac{n\,\pi\, a_{cstl}}{l}$$

Therefore the normal function then becomes:

$$X(x) = D\sin\left(\frac{n\,\pi\, x}{l}\right)$$

Clamped and fixed supported section between strongback:

Length of section between supports: $l_b = 24$ ft

Evaluation time intervals: $j = 0 .. 8$

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$$t_j = \frac{j}{8} T_p$$

Location of evaluation: $x_b = l_b$

Odd number of node locations: $n = 1 .. 5$ $i_n = 2 \cdot n - 1$

Magnitude of pulsating force: $F_l = g_{psl} \cdot w_{con} \cdot l_b$

$F_l = 74{,}047$ 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 disturbing force can be represented by a the series:

$$u = \sum_{n}^{\infty} \phi \; X(x)$$

Where $\phi$ is the unknown function of time.

By virtual work:

$$\delta\; u = X(x) = D \sin\left(\frac{n\,\pi\,x}{l}\right)$$

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:

$$\delta W_I = \int_0^l (-\rho\; A_p\; dx)\frac{d^2}{dx^2}\; u\; du = \rho\; A_p \int_0^l \left(\frac{d^2}{dx^2}\; u\right) D \sin\left(\frac{n\,\pi\,x}{l}\right) dx$$

Substituting for u with the series:

$$\delta W_I = \frac{-\rho A_p l}{2} D \frac{d^2}{dt^2} \phi$$

Virtual work produced by the elastic force is:

$$\delta W_E = \int_0^l \left( E_{cstl} A_p \frac{d^2}{dx^2} u \right) du$$

By substituting in for the above series:

$$\delta W_E = \frac{-n^2 \pi^2 E_{cstl} A_p}{8 l} D \phi$$

Virtual work of the disturbing force where: x = l/2

$$\delta W_F = F(t) D \sin\left(\frac{n \pi}{2}\right) = F(t) D (-1)^{\frac{i-1}{2}}$$

The second term is in a Fourier Series form.

Summing the above expression gives the total virtual work:

$$\frac{\rho A_p l}{2} \frac{d^2}{dt^2} \phi + \frac{n^2 \pi^2 E_{cstl} A_p}{8 l} \phi = F(t) (-1)^{\frac{i-1}{2}}$$

Rearranging terms:

$$\frac{d^2}{dt^2} \phi + [\Omega_{(i_n)}]^2 \phi = \frac{2}{\rho_{cstl} A_p l_b} (-1)^{\frac{i-1}{2}} F_i \sin(\omega t)$$

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The natural frequency is defined as:

$$\Omega_{(i_n)} = \frac{i_n \, \pi \, a_{cstl}}{l_b}$$

Using Duhamel's integral (Reference 5, page 43)

$$\phi = \frac{2\, F_l\, (-1)^{\frac{i_n - 1}{2}}}{A_p\, \rho_{cstl}\, l_b\, \Omega_i} \int_0^t \sin(\omega\, (t - z))\, \sin[\Omega_i\, (t - z)]\, dz$$

Solving for the integral:

$$\phi_{(i_n, j)} = \frac{2\, F_l\, (-1)^{\frac{i-1}{2}}}{A_p\, \frac{\rho_{cstl}}{g}\, l_b\, \Omega_{(i_n)}} \cdot \frac{[-\omega \cos(\omega\, t_j)\, \sin[\Omega_{(i_n)}\, t_j] + \Omega_{(i_n)} \sin(\omega\, t_j)\, \cos[\Omega_{(i_n)}]]}{[-\omega^2 + [\Omega_{(i_n)}]^2]}$$

Deflection:

$$u_j = \sum_n^{\infty} \phi_{(i_n, j)} \sin\left(\frac{i_n\, \pi\, x_b}{l_b}\right)$$

Axial Stress (by differentiation):

$$\sigma_{b_j} = E_{cstl}\left[\sum_n^{\infty} \phi_{(i_n, j)} \left(\cos\left(i_n\, \pi\, \frac{x_b}{l_b}\right) i_n\, \frac{\pi}{l_b}\right)\right]$$

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| Time $t_i$ (sec) | Displacement $u_i$ (in) | Axial Stress $\sigma_i$ (psi) |
|---|---|---|
| 0 | 0 | 0 |
| 0.063 | 0 | - 392 |
| 0.125 | 0 | - 656 |
| 0.188 | 0 | 435 |
| 0.25 | 0 | - 3 |
| 0.313 | 0 | 511 |
| 0.375 | 0 | - 572 |
| 0.438 | 0 | 449 |
| 0.5 | 0 | - 5 |

Maximum axial stress at stiffener rings:

$$\sigma_{bmax} = -656 \text{ psi}$$

**Clamped and fixed supported section outside of strongback:**

Length of section between supports: $11_b = 242.750$ in

Location of evaluation: $x1_b = 11_b$

Magnitude of pulsating force: $F1_t = g_{psl} \cdot w_{con} \cdot 11_b$

$F1_t = 62{,}413$ lbs

The natural frequency is defined as:

$$\Omega 1_{(i_n)} = \frac{i_n \pi a_{cstl}}{11_b}$$

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Using the same logic as above:

Deflection:

$$u1_j = \sum_n^{\infty} \phi 1_{(i_n, j)} \sin\left(\frac{i_n \pi x1_b}{l1_b}\right)$$

Axial Stress (by differentiation):

$$\sigma 1_{b_j} = E_{cstl} \left[\sum_n^{\infty} \phi 1_{(i_n, j)} \left(\cos\left(i_n \pi \frac{x1_b}{l1_b}\right) i_n \frac{\pi}{l1_b}\right)\right]$$

| Time $t_j$ (sec) | Displacement $u_j$ (in) | Axial Stress $\sigma_j$ (psi) |
|---|---|---|
| 0 | 0 | 0 |
| 0.063 | 0 | - 425 |
| 0.125 | 0 | - 550 |
| 0.188 | 0 | 387 |
| 0.25 | 0 | - 3 |
| 0.313 | 0 | 375 |
| 0.375 | 0 | - 552 |
| 0.438 | 0 | - 364 |
| 0.5 | 0 | 1 |

Maximum axial stress at stiffener rings:

$$\sigma 1_{bmax} = -552 \text{ psi}$$

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**Cantilevered Section:**

Length of cantilevered section:

$$l_c = [(589.375 - 540.375) + 4.125] \qquad l_c = 53.12 \text{ in}$$

Location of evaluation: $x_c = 0$ in

Add in additional length and weight of top hat:

Weight: $W_{chat} = 1{,}039$ lbs Length: $l_{tc} = 8.1875$ in

Assume additional weight distributed along the axis:

$$w_{con1} = w_{con} + \frac{W_{chat}}{l_{tc}}$$

Magnitude of pulsating force: $F_{lc} = g_{psl} \cdot w_{con1} \cdot l_c$

$F_{lc} = 29{,}159$ lbs

The natural frequency is defined as:

$$\Omega c_{(i_n)} = \frac{i_n \, \pi \, a_{cstl}}{l_c}$$

From the same logic as the above the response equation becomes:

$$\phi_{(i_n,j)} = \frac{2\,F_{lc}}{\frac{\rho_{cstl}}{g} A_p \, l_c} \left[ \frac{(-1)^{\frac{i_n - 1}{2}}}{\left[\left[\Omega_{c(i_n)}\right]^2 - \omega^2\right]} \sin(\omega \, t_j) \right]$$

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Deflection:

$$u_{c_j} = \sum_{n}^{\infty} \phi_{(i_n, j)} \sin\left(\frac{i_n \pi x_c}{l_c}\right)$$

Axial Stress (by differentiation):

$$\sigma_{c_j} = E_{cstl}\left[\sum_{n}^{\infty} \phi 1_{(i_n, j)} \left(\frac{1}{2}\cos\left(\frac{1}{2} i_n \pi \frac{x_c}{l_c}\right) i_n \frac{\pi}{l_c}\right)\right]$$

| Time $t_j$ (sec) | Displacement $u_j$ (in) | Axial Stress $\sigma_j$ (psi) |
|---|---|---|
| 0 | 0 | 0 |
| 0.063 | 0 | 90 |
| 0.125 | 0 | 127 |
| 0.188 | 0 | 90 |
| 0.25 | 0 | 0 |
| 0.313 | 0 | - 90 |
| 0.375 | 0 | - 127 |
| 0.438 | 0 | - 90 |
| 0.5 | 0 | 0 |

Maximum axial stress at stiffener rings:

$$\sigma 1_{tmax} = 127 \text{ psi}$$

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Originator P. M. Nguyen Date 05/26/94
Checker S. S. Shiraga Date 06/14/94

### I. Objective:

The objective of this analysis was to verify the 106-C 49 foot bolt and hub inner flange design loads in accordance with Reference 3, as an independent check of the design calculations which were performed to Reference 11. Also the thread engagement of the inner flange to insure proper strength of flange material. The top hat loading is not evaluated in this analysis, since it is not considered as a part of the containment boundary for transportation.

### II. References:


1. WHC-SD-TP-PDC-015, Rev. 0-A, "Packaging Design Criteria Transfer and Disposal of Equipment, Tank 241-C-106 Waste Sluicing System".
2. Engineering Change Notice 606658, dated May 02, 1994.
3. American Society of Mechanical Engineers, Boiler Pressure and Vessels, Section VIII, Division 2, 1989.
4. Industrial Press, Machinery's Handbook, 23 rd edition.
5. WHC Drawing No., H-2-83722, H-2-83724, H-2-83725, H-2-83726 and H-2-83727.
6. EPRI NP-4830 "The Effect of Target Hardness on the Structural Design of Concrete Storage Pads for Spent Fuel Casks".
7. Design Analysis, WO/Job No. ER4289, Kaiser Engineers Hanford, Nov. 11, 1993.
8. Roark, Formulas for Stress and Strain, 4th edition.
9. American Institute of Steel Construction, Manual of Steel Construction, 9th edition.
10. US-NRC, 10 CFR Part 71, "Packaging and Transportation of Radioactive Materials".
11. American Society of Mechanical Engineers, Boiler Pressure and Vessels, Section VIII, Division 1, 1989.
12. FlexiCarb Product Specification.
13. ASTM, American Society for Testing and Materials, ASTM A307, 1989, p.40.


### III. Results and Conclusions:

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The engineering evaluations independently verifies that the design is adequate to withstand the pressure loads specified in Reference 10 by meeting the requirements of Reference 3. 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 and blind flange stresses were also used in conjunction with the drop and payload impact analysis.

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IV. Engineering Evaluation:

1. **ASME SECTION VIII, DIV. 2 Allowables:**

Determination of pipe material allowable at temperature, (Ref. 3, Tbl. ACS-1, p.77):

$$S = \left[\frac{(23.1 - 23.3)\cdot 10^3}{(200 - 100)}\cdot(115 - 100) + 23.3\cdot 10^3\right]$$

$$S = 23{,}270 \text{ psi}$$

Modulus of Elasticity at temperature (Ref. 3, p.70):

$$E_{115} = \left[\frac{28.8 - 29.5}{200 - 70}\cdot(115 - 200) + 28.8\right]\cdot 10^6$$

$$E_{115} = 29.258 \times 10^6 \cdot \text{psi}$$

Poisson's ratio (Ref. 3, p.516):

Since no cyclic loading assumed:

$S_{y115} = 38{,}000$ psi $\quad S_{a115} = 38{,}000$ psi

$$\nu_{115} = 0.5 - 0.2\cdot\left(\frac{S_{y115}}{S_{a115}}\right)$$

$$\nu_{115} = 0.3$$

Design Pressure: $p = 11.2$ psi

Allowable tensile on bolting material (Reference 11, p.276):

$$s_{ab} = 55{,}000 \text{ psi}$$

2. **Bolt loads:** (Reference 3, Section 3-320, page 488)

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Gasket Factors from Reference 12:

$m = 2$ $y = 1{,}000$ psi

Gasket diameter:

$$N = \frac{(51.25 - 45.25)}{2}$$

Basic gasket seating width:

$$b_o = \frac{N}{2}$$

Effective gasket seating width:

Since $b_o > \frac{1}{4}$:

$$b = \frac{\sqrt{b_o}}{2}$$

Diameter at location of gasket reaction:

Since $b_o > \frac{1}{4}$:

$$G = (51.25 - 2b)$$

$$G = 50.025 \text{ in}$$

Total hydrostatic end force:

$$H = 0.785\, G^2\, p$$

$$H = 22{,}002 \text{ lbs}$$

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Total joint surface compression load:

$$H_p = 2\ b \cdot 3.14\ G\ m\ p$$

$$H_p = 6{,}094 \text{ lbs}$$

Required bolt load (internal pressure):

$$W_{m1} = H + H_p$$

$$W_{m1} = 28{,}096 \text{ lbs}$$

Total bolt load required for gasket sealing:

$$W_{m2} = 3.14\ b\ G\ y$$

$$W_{m2} = 136{,}030 \text{ lbs}$$

Since $W_{m1} < W_{m2}$ Gasket seating governs determine minimum bolt torque.

Bolt diameter: $d_{bolt} = 1$ inch Number of bolts: 16

Threads per inch: n = 8/in

Load per bolt for gasket seating:

$$w_{bolt} = \frac{W_{m2}}{16}$$

$$w_{bolt} = 8{,}502 \text{ lbs}$$

Assume a torquing coefficient of: $K_{coef} = 0.2$

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Required tightening torque to seat gasket:

$$T_{req} = K_{coef}\, w_{bolt}\, d_{bolt}$$

$$T_{req} = 142 \text{ ft-lbs}$$

Specified bolt torque (Reference 5): $T_{pre}$ = 295 to 305 ft-lbs

Assumed: $T_{pre}$ = 305 ft-lbs

Since $T_{pre} > T_{req}$ gasket seated and sealed.

**Bolt loading:**

Preload on bolts:

$$w_{act} = \frac{T_{pre}}{K_{coef}\, d_{bolt}}$$

$$w_{act} = 18{,}300 \text{ lbs}$$

Hydrostatic load per bolt:

$$h = \frac{H}{16}$$

$$h = 1{,}375 \text{ lbs}$$

Total load per bolt:

$$w_{btot} = w_{act} + h$$

$$w_{btot} = 19{,}675 \text{ lbs}$$

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Tensile stress area of bolts (Reference 13):

$$A_b = 0.7845\left(d_{bolt} - \frac{0.9473}{n}\right)^2$$

Total stress per bolt:

$$S_{bolt} = \frac{W_{btot}}{A_b}$$

$$S_{bolt} = 32{,}270 \text{ psi}$$

Margin of safety:

$$MS_{bolt} = \frac{S_{ab}}{S_{bolt}} - 1$$

$$MS_{bolt} = 0.7$$

**3. Flange bolt design loads:**

Internal pressure load:

$$W_{op} = W_{m1} = 28{,}096 \text{ lbs}$$

Required total bolt area:

$$A_{m2} = \frac{W_{m2}}{S_{ab}}$$

$$A_{m2} = 2.47 \text{ in}^2$$

**ENGINEERING ANALYSIS**

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Available bolt area:

$$A_{ab} = 0.7854 \left(1 - \frac{0.9743}{n}\right)^2 \cdot 16$$

$$A_{ab} = 9.69 \text{ in}^2$$

Margin of Safety:

$$MS_{ab} = \frac{A_{ab}}{A_{m2}} - 1$$

$$MS_{ab} = 2.91$$

Bolt yield strength (Reference 11): $S_a = 55{,}000$ psi

Gasket load:

$$W_{gsk} = \frac{(A_{m2} + A_b)\, S_a}{2}$$

$$W_{gsk} = 231{,}100 \text{ lbs}$$

Flange moments for internal pressure:

Inside diameter of flange (Reference 5): B = 47.25 in

Thickness of hub at back of flange (Reference 5): $g_1 = 0.75$ in

Bolt circle diameter (Reference 5): C = 49.25 in

Radial distance from bolt circle to point of intersection of hub and back of flange:

$$R = \frac{C - B}{2} - g_1$$

**ENGINEERING ANALYSIS**

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Hydrostatic end force on area inside of flange:

$$H_D = 0.785\ B^2\ p$$

$$H_D = 19{,}629 \text{ lbs}$$

Gasket Load:

$$H_G = W_{op} - H$$

$$H_G = 6{,}094 \text{ lbs}$$

Difference between total hydrostatic end force and the hydrostatic end force on area inside of flange:

$$H_T = H - H_D$$

$$H_T = 2{,}374 \text{ lbs}$$

Radial distance from the bolt circle to the circle on which $H_D$ acts:

$$h_D = R + 0.5\ g_1$$

Radial distance from gasket load reaction to the bolt circle:

$$h_G = \frac{C - G}{2}$$

$$h_G = -\ 0.388 \text{ in}$$

Radial distance from the bolt circle to the circle on which $H_T$ acts:

$$h_T = \frac{R + g_1 + h_G}{2}$$

Component of moment due to $H_D$:

$$M_D = H_D \cdot h_D$$

$$M_D = 12{,}268 \text{ in-lbs}$$

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$$M_D = H_D \cdot h_D$$

$$M_D = 12{,}268 \text{ in-lbs}$$

Component of moment due to $H_G$:

$$M_G = H_G \cdot h_G$$

$$M_G = -\ 2{,}362 \text{ in-lbs}$$

Component of moment due to $H_T$:

$$M_T = H_T \cdot h_T$$

$$M_T = 727 \text{ in-lbs}$$

Total moments from internal pressure:

$$M_{opres} = M_D + M_G + M_T$$

$$M_{opres} = 10{,}632 \text{ in-lbs}$$

Moment from gasket seating:

$$M_{ogas} = \frac{W_{gsk} \cdot (C - G_1)}{2}$$

$$M_{ogas} = -\ 89{,}600 \text{ in-lbs}$$

**4. Hub flange stresses (integral type flange):**

Flange thickness: $t_{fb} = 1.75$ in

Hub length: $h = 0.375$ in

Thickness of hub at small end: $g_o = 0.375$ in

Hub Factor:

**ENGINEERING ANALYSIS**

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$$h_o = \sqrt{B\, g_o}$$

$$h_o = 4.21 \text{ in}$$

Ratio of thicknesses:

$$\frac{g_1}{g_o} = 2$$

Ratio of hub lengths:

$$\frac{h}{h_o} = 0.0891$$

From Reference 3, page 497:

Factors for integral type flange: F = 0.909 V = 0.46

From Reference 3, page 499:

Hub correction factor for integral type flange: f = 3.4

Flange outside diameter: A = 51.25 in

Ratio of outside diameter to inside diameter of flange:

$$K = \frac{A}{B}$$

$$K = 1.085$$

From Reference 3, page 496: K Factors: U = 29 T = 1.95

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$$d = \frac{U}{V} h_o g_o^2$$

d = 37.32 $in^3$

$$e = \frac{F}{h_o}$$

e = 0.216 $in^{-1}$

$$L = \frac{t_{fb} e + 1}{T} + \frac{t_{fb}^3}{d}$$

L = 0.850

$$Z = \frac{K^2 + 1}{K^2 - 1}$$

Z = 12.33

$$Y = \frac{1}{K - 1}\left(0.66845 + 5.71690\frac{K^2 \log(K)}{K^2 - 1}\right)$$

Y = 23.78

Longitudinal hub stress:

Gasket seating:

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$$S_H = \frac{f \cdot M_{ogas}}{L \cdot g_1^2 \cdot B}$$

$S_H$ = - 13,480 psi

Operation:

$$s_h = \frac{f\ M_{opres}}{L\ g_1^2\ B}$$

$s_H$ = 1,600 psi

Combined total: $H_t = S_H + s_H$ $H_t$ = - 11,880 psi

Radial flange stress:

Gasket seating:

$$S_R = \frac{(1.33\ t_{fb}\ e + 1)\ M_{ogas}}{L\ t_{fb}^2\ B}$$

$S_R$ = - 1,094 psi

Operation:

$$s_R = \frac{(1.33\ t_{fb}\ e + 1)\ M_{opres}}{L\ t_{fb}^2\ B}$$

$s_R$ = 130 psi

Combined total: $R_t = S_R + s_R$ $R_t$ = - 964 psi

Tangential flange stress:

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Gasket seating:

$$S_T = \frac{Y \cdot M_{ogas}}{t_{fb}^2 \cdot B} - Z \cdot S_R$$

$$S_T = -16{,}328 \text{ psi}$$

Operation:

$$s_T = \frac{Y \cdot M_{opres}}{t_{fb}^2 \cdot B} - Z \cdot S_R$$

$$s_T = 146 \text{ psi}$$

Combined total: $T_t = S_T + s_T$ $T_t = -16{,}180$ psi

**5. Allowable flange design stresses**

ASTM A-516, gr. 55 since no grade was specified on drawing, use lowest grade (Ref. 3, p. 75), at 115°F, yield:

$$S_f = 18{,}300 \text{ psi}$$

$$1.5 \cdot S_f = 27{,}450 \text{ psi}$$

For conservatism base on combined stresses:

Paragraph (a)(1): $H_t < 1.5 \cdot S_f$ **OK**

Paragraph (b): $R_t < S_f$ **OK**

Paragraph (c): $T_t < S_f$ **OK**

Paragraph (d):

$$\frac{H_t + R_t}{2} < S_f$$

**OK**

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Paragraph (e):

Weld size: $w_w = 0.375$ in

Weld area:

$$A_w = 0.707\, w_w\, \pi\, B$$

$$A_w = 78.71 \text{ in}^2$$

Stress on weld:

$$\tau_w = \frac{W_{m2}}{A_w}$$

$$\tau_w = 1{,}728 \text{ psi}$$

ASME allowable: $S_w = 0.8 \cdot S_f$ $S_w = 14{,}640$ psi

Margin of safety:

$$MS_w = \frac{S_w}{\tau_w} - 1$$

$MS_w = 7.47$ **OK**

6. **Check Length of Thread Engagement for 1-8UN x 2 1/4 Bolt:**

Reference 4, page 1278.

**ENGINEERING ANALYSIS**

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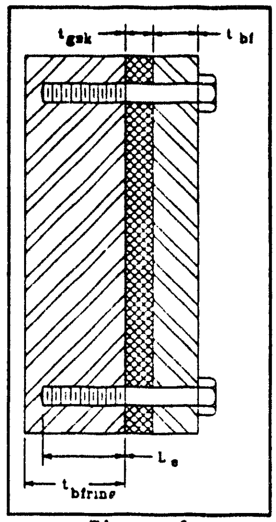


Figure 1

$K_{nmax}$ = 0.86 in $E_{smin}$ = 0.92 in

$$A_t = 0.7854 \cdot \left(1 - 0.\frac{97438}{8}\right)^2$$

$$A_t = 0.61\ in^2$$

$$L_e = \frac{2 \cdot A_t}{(3.1416 \cdot K_{nmax}) \cdot \left[\frac{1}{2} + 0.57735 \cdot 8 \cdot (E_{smin} - K_{nmax})\right]}$$

$L_e$ = 0.5947 in $l_{bolt}$ = 2.25 in $t_{gask}$ = 0.25 in $t_{bflan}$ = 0.75 in

Length of engagement: $L_{act} = l_{bolt} - t_{gask} - t_{bflan}$

## ENGINEERING ANALYSIS

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$$MS_{eng} = \frac{L_{act}}{L_e} - 1$$

$MS_{eng} = 1.102$ OK

## 6.5 TIEDOWN ANALYSIS

**DON'T SAY IT** — *Write It!*

DATE: 5/26/94

TO: Donald B. Calmus G2-02

FROM: Harold E. Adkins, Jr. G2-03

Telephone: 376-9703

cc: J. W. Thornton G2-03
S. R. Crow G2-03
S. S. Shiraga N1-40
J. R. Bellomy III S6-12
T. C. Mackey S2-03
J. V. Egger S2-03

SUBJECT: 106-C TRANSPORT PACKAGING TIE-DOWN ANALYSIS

For the 106-C project, two separate transport systems designs were chosen. These two systems will be referred to in this document as the main and optional transport systems. These two transport systems consist of four tie-down configurations. The main and optional transport systems, equipped to handle both the 49 foot and 62 foot containers, are shown in Figure 1 and 2 respectively. These systems consist of a tilt-trailer/transport mechanism and a specially modified extendable transport trailer respectively. The four tie-down configurations for these two particular transport systems were designed and analyzed around the following assumptions.

1) Containers are loaded with their payload and are fully shielded as mentioned in earlier portions of this SEP.

2) Tilt-trailer pivot pins are able to withstand the remaining portion of the longitudinal load that the tie-down system is incapable of handling. This only applies to the main transport system. Analysis to support this assumption can be supplied by T. C. Mackey.

3) Support saddles and their attachment fixtures are able to withstand the entire longitudinal loading condition and can be considered as blocking for the lateral loading condition. This only applies to the optional transport system. Analysis to support this assumption was performed and can be supplied by J. V. Egger.

4) The tie-down points on the trailer are capable of withstanding the forces exerted by the tie-down cables (wire rope).

For the main transport system (Figure 1), the results of the analysis indicate that the cables for the two possible tie-down configurations must have a minimum Nominal Breaking Strength (NBS) of 14,474 lbs for each of the twelve (12) cables. To remain consistent with the analysis performed, 34,000 lb shackles with a pin diameter of 1-5/8 inches and 10,000 lb safety hoist rings (D-rings) should be used for both of these tie-down configurations.

For the optional transport system (Figure 2), the results of the analysis indicate that the cables for the two possible tie-down configurations must have a minimum Nominal Breaking Strength (NBS) of 9,160 lbs for each of the

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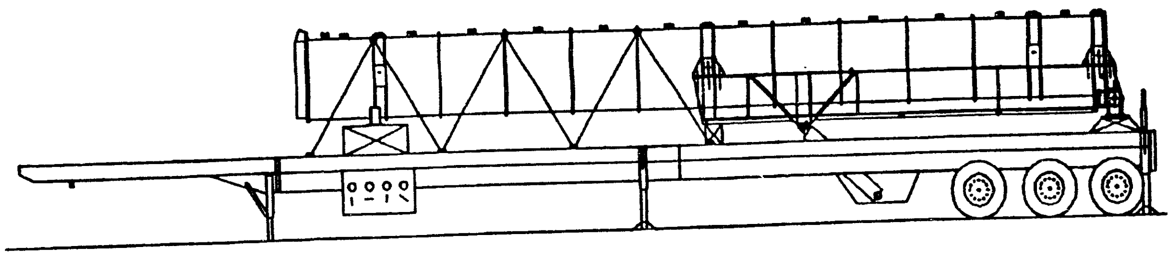
sixteen (16) cables. To remain consistent with the analysis performed, 34,000 lb shackles with a pin diameter of 1-5/8 inches and 10,000 lb safety hoist rings (D-rings) should also be used for both of these tie-down configurations.

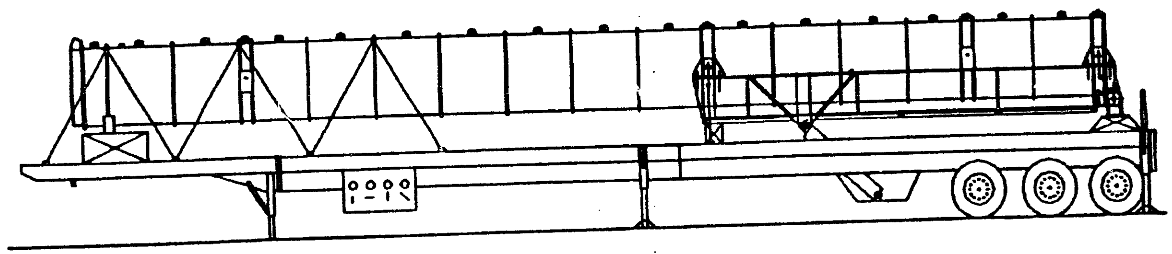
It is suggested by the analyst to implement a ratchet-action load binding type of device to minimize exposure time and to aid in pre-tensioning the tie-downs. These such devices must meet or exceed the working load limit of the cables they are being used with. It is important for interested parties to note that all of the tie-down components mentioned above are available through McMaster-Carr supply company (ratchet-action load binder - Ref. No. 5249). Pre-tensioning is left to the discretion of the riggers responsible.

An important note that should be brought to the readers attention is as follows. In figure 2, support saddle location is not the same for the 49 and 62 foot containers. At the trailing end of the trailer, support is applied to different stiffening rings. Even with this in mind, the tie-down combination at this particular location will be the same, the cable placement will merely be reversed in the longitudinal direction. This will save on cost by minimizing tie-down fabrication need. I.E., only one set of tie-downs will be needed for the optional transport system.

The analysis, consisting of hand calculations, were checked by S. R. Crow and are attached.

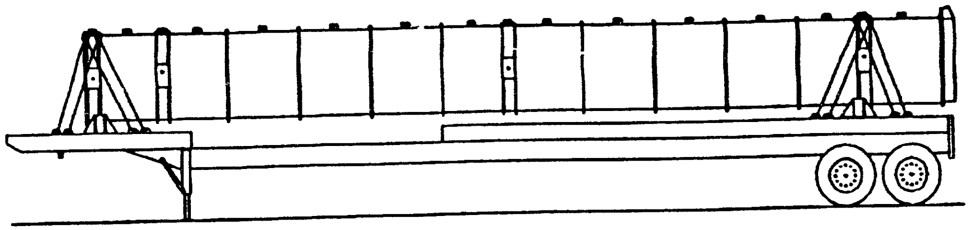


49' Container Transport Configuration

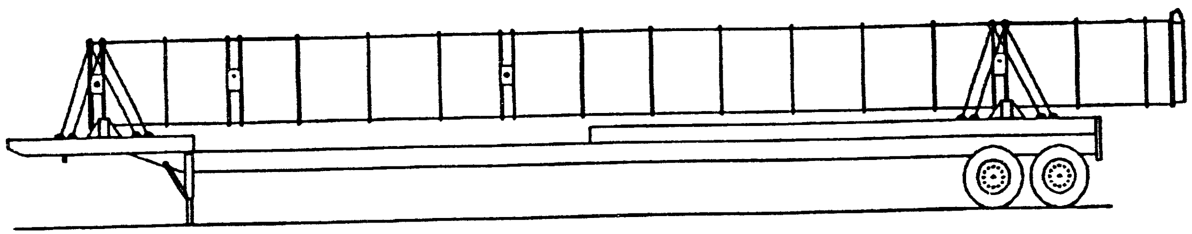


62' Container Transport Configuration

Figure 1. Main Transport System



49' Container Transport Configuration



62' Container Transport Configuration

Figure 2. Optional Transport System

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(7) Subject 106-C Tilt-trailer Tie-downs (short container)
(8) Originator Harold E. Adkins Jr. Date 5-3-94
(9) Checker S.R. Crowl S.R. Crowl Date 5-17-94

(10) Phase I of bearing load analysis - Determine the maximum load that the tie-down points will withstand.

Assumptions:

- To meet the requirements of 10CFR 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 ~~or chains~~ that attach directly to the trailer.

$$\frac{F_{br}}{F_y} = \frac{l_e}{d} \quad \text{(C-J3-1 AISC - Steel Construction)}$$

Longitudinal

- $l_e = 3.84$ in (Distance from free edge)
- $d = 1.5$ in (Diameter of fastener)
- $F_y = 36{,}000$ psi (ASTM A-36 yield strength)
- $F_{br} = ?$ (Critical bearing stress)

$$F_{br} = \frac{F_y \cdot l_e}{d} = \frac{(36{,}000)(3.84)}{1.5} = \underline{92{,}160 \text{ psi}} \checkmark$$

projected Area = (material thickness)(hardware diam.)

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(7) Subject 106-C Tilt-trailer Tie-downs (short container)
(8) Originator Harold E. Adkins Jr. [signature] Date 5-3-94
(9) Checker S.R. Crow [signature] Date 5-17-94

(10)
{ material thickness = 1.5"
{ hardware diam. = 1.5"

$Load_{max} = F_{Pcr} \cdot$ (projected area)

$Load_{max} = (92,160)(1.5)(1.5) = \underline{207,360\ lb_f}$ ✓

– From 10 CFR 71.45(b)(1), the attachment points on the container must be capable of withstanding w/o exceeding

{ 10 × weight Longitudinal
{ 5 × weight Lateral
{ 2 × weight Vertical

– Weight of package max = $\underline{66,000\ lb_f}$
# of points effective = 4

$\frac{10 \times 66,000}{4} = 165,000\ lb_f$ ✓

Longitudinal Safety margin $= \left(\frac{207,360}{165,000} - 1\right)$
$\therefore SM_{long.} = \underline{0.26}$ ✓

Vertical

{ $l_e = 5.72''$
{ $d = 1.5''$
{ $F_y = 36,000\ psi$
{ $F_{Pcr} = ?$

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(7) Subject 106-C Tilt-trailer Tie-downs (short container)
(8) Originator Harold E. Adkins Jr., [signature] Date 5-3-94
(9) Checker S.R. Crow [signature] Date 5-17-94

(10)
$$P_{cr} = \frac{(36{,}000)(5.72)}{(1.5)} = 137{,}280 \checkmark$$

$$Load_{max} = (137{,}280)(1.5)(1.5) = \underline{308{,}880\ lb_f} \checkmark$$

$$\frac{2 \times 66{,}000}{4} = 33{,}000\ lb_f$$

Vertical Safety margin $= \left(\frac{308{,}880}{33{,}000} - 1\right)$

$\therefore$ $\underline{S.M._{Vert}} = \underline{8.36} \checkmark$

Lateral

– For the lateral case, in light of the fact that the container is fixed in the strongback, only a tensile load on 2 of the hard points will be considered. This load will be applied to the welds connecting the mounting plates to the stiffening rings.

Weld area $= (2)\times(2)(2'' \times 13'') = \underline{52\ in^2}$

$$5 \times 66{,}000\ lb_f = 330{,}000\ lb_f$$

$$\sigma = \frac{P}{a} = \frac{330{,}000}{52} = 6346\ psi$$

$$\sigma_{max} = 36{,}000\ psi$$

$\therefore$ $\underline{S.M._{Lat.}} = \left(\frac{36{,}000}{6{,}346} - 1\right) = \underline{4.67} \checkmark$

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(1) Drawing ______ (2) Doc. No. ______ (3) Page 4 of 15
(4) Building ______ (5) Rev. ______ (6) Job No. D2M9J
(7) Subject 106-C T/H trailer tie-downs (short container)
(8) Originator Harold E. Adkins, Jr. HEA Jr. Date 5-3-94
(9) Checker S.R. Crow SRCrow Date 5-17-94

(10) phase II of bearing load analysis -
Now, selecting an alternate set of tie-down points to analize the bearing loads.

Assumptions:

- To meet the requirements of 10CFR 71.45(b)(1), only points at which the cables attach to the container will be analized using moment combinations taking into account the weight of the strongback. The pivot point will be the pivot pins on the strongback.
- 3 attachment points per side will be used. (6 cables per side in a "V" configuration)

$\frac{F_{Pcr}}{F_Y} = \frac{l_e}{d}$ (C-J3-1 AISC - Steel Construction)

$l_e = 2.469$ in
$d = 1.5/8"$
$F_Y = 36,000$ psi

$F_{Pcr} = F_Y \frac{l_e}{d} = \frac{(36000)(2.469)}{(1.625)} = 54,698$ psi ✓

projected area $= (1)(1.625) = 1.625$
$Load_{max} = (54,698)(1.625) = \underline{88,884\text{ lbs}}$ ✓

- From 10CFR 71.45(b)(1), the tie-down system must be capable of withstanding w/o exceeding yield:

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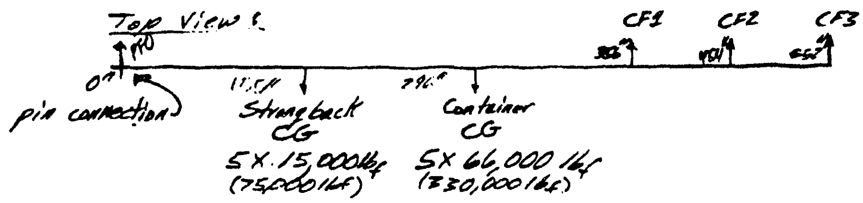
(7) Subject 106-C Tilt-trailer Tie-downs (short container)
(8) Originator Harold E. Adkins, Jr. [signature] Date 5-3-94
(9) Checker S.R. Crow (S.R. Crow) Date 5-17-94

(10)
{ 2× Weight Vertical
{ 10× weight Longitudinal
{ 5× weight Lateral

Longitudinal will be ignored because of the fact that the pins connecting the strongback are capable of a 100,000 lbf load before ripping free and if they fail, the tie-down system (Cables) will be designed to fail under the container-strongback load before subjecting maximum loading to container-cable tie-down points. (To be proved later in calculations)

Lateral Load Case - (5×G)

$$\sum M_0 = \sum F = 0$$




$$\sum F = 0 = CF1 + CF2 + CF3 + PFO_{lat} - 5\times 15{,}000 - 5\times 66{,}000$$

$$PFO_{lat} = 405{,}000\ lb_f - CF1 - CF2 - CF3$$

**DESIGN CALCULATION**

(1) Drawing ______ (2) Doc. No. ______ (3) Page 6 of 15
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(7) Subject 106-C Tilt-trailer Tie-downs (Short Container)
(8) Originator Harold E. Adkins Jr. Date 5-4-94
(9) Checker S.R. Crow Date 5-17-94

(10) $\Sigma M_o = -155 \cdot 75{,}000 - 296 \cdot 330{,}000 + 356 \cdot CF1 + 454 \cdot CF2 + 552 \cdot CF3 = 0$

But,

$CF3 \cdot 552 = CF2 \cdot 454$

$CF3 \cdot 552 = CF1 \cdot 356$

Solving - we find that

$PFO_{ut} = 156{,}396\ lb_f$
$CF1 = 102{,}346\ lb_f$
$CF2 = 80{,}253\ lb_f$
$CF3 = 66{,}005\ lb_f$

- This says that the highest rip-out force is 102,346 $lb_f$. This exceeds the $Load_{max}$ of 87,884 $lb_f$ which is allowable.
- It is time to take a frictional force or two into account.
- First we need to assume that the trailer is rigid. At the points where the strongback and the container rest on the trailer supports, we apply a friction force. Even if the trailer is not rigid, Frictional forces that are relieved at one point would be distributed @ the other point creating a reasonable balance. Proved Below.

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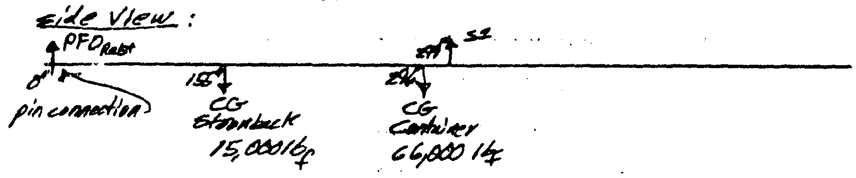
(7) Subject 106-C Tilt-trailer Tie-downs (Short Container)
(8) Originator Harold E Adkins, Jr. Date 5-4-94
(9) Checker S.R. Crow Date 5-17-94

(10) - First, only assume the strongback support comes into contact.

Side View :




$\Sigma F = 0 = PFO_{Rest} + S1 - 15{,}000\,lb_f - 66{,}000\,lb_f$

* $PFO_{Rest} = 81{,}000\,lb_f - S1$

$\Sigma M_{CG_{SB}} = 0 = -PFO_{Rest} \cdot 155 - 66{,}000 \cdot (296-155) + S1 \cdot (299-155)$

* $(155)PFO_{Rest} = S1 \cdot 144 - 9{,}306{,}000$

$PFO_{Rest} = 7786\ lb_f$

$S1 = 73{,}114\ lb_f$

$C_{f\,static} > C_{f\,sliding} = 0.57$ (mild steel on mild steel) Table 3.2.1 of Marks Handbook for Mechanical Engineers 9th ed.

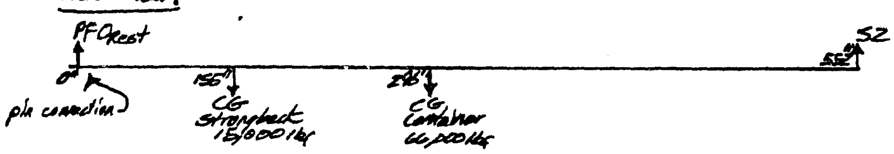
$F_f = (0.57)(73{,}114)$

$= 41{,}675\ lb_f$

$M_{f_0} = (41{,}675)(299) = 12{,}460{,}819\ in\text{-}lb_f$

- Next, assume only the container support comes into contact.

Side View:

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**DESIGN CALCULATION**

(1) Drawing ______ (2) Doc. No. ______ (3) Page 8 of 15
(4) Building ______ (5) Rev. ______ (6) Job No. 02M9J
(7) Subject 106-C Tilt-trailer Tie-downs (Short Container)
(8) Originator Harold E. Adkins Jr., HEA Jr. Date 5-4-94
(9) Checker S.R. Crow SRCrow Date 5-17-94

(10) $\Sigma F = 0 = PFO_{Rest} + S2 - 81{,}000\ lb_f$

$\Sigma M_{CG} = 0 = -PFO_{Rest}\cdot(155) - 66{,}000(296-155) + S2(552-155)$

$PFO_{Rest} + S2 = 81{,}000$

$PFO_{Rest}(155) - S2(397) = -9{,}306{,}000$

$PFO_{Rest} = 41{,}397\ lb_f$

$S2 = 39{,}603\ lb_f$

$F_f = (0.57)(39{,}484) = 22{,}574\ lb_f$

$M_{f_o} = (22{,}506)(552) = 12{,}460{,}770\ in\text{-}lb_f$

- Now, with both supports coming into contact →

$\Sigma F = 0 = PFO_{Rest} + S1 + S2 - 81{,}000\ lb_f$

$\Sigma M_o = 0 = -(15{,}000)(155) - (66{,}000)(296) + S1(299) + S2(552)$

$S2\cdot 552 = S1\cdot 299$

$PFO_{Rest} = 24{,}642\ lb_f$

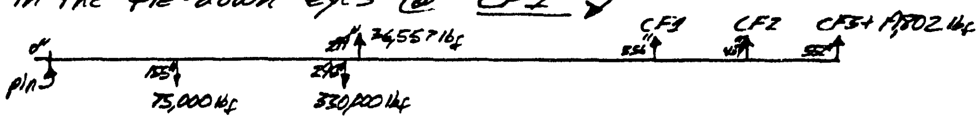
$S1 = 36{,}557\ lb_f$

$S2 = 19{,}802\ lb_f$

$M_{f_o} = (36{,}557)(0.57)(299) + (19{,}802)(0.57)(552)$

$M_{f_o} = 12{,}460{,}911\ in\text{-}lb_f$

- Going back to our original Free-body for the lateral loading case to verify that adequate strength in the tie-down eyes @ CF1 →



**DESIGN CALCULATION**

(1) Drawing ______ (2) Doc. No. ______ (3) Page 9 of 15
(4) Building ______ (5) Rev. ______ (6) Job No. D2M9I
(7) Subject 106-C TH-trailer Tie-downs (Short Container)
(8) Originator Harald E. Adkins Jr. [signature] Date 5-4-94
(9) Checker S. R. Crow [signature] Date 5-17-94

(10) $\sum F = 0 = PFO_{lat.} + CF1 + CF2 + CF3 + 19{,}802 + 36{,}557 - 75{,}000 - 330{,}000$

$\sum M_o = 0 = -155 \cdot 75{,}000 - 296 \cdot 330{,}000 + 291 \cdot 36{,}557 + 356 \cdot CF1 + 454 \cdot CF2 + 552 \cdot (CF3 + 19{,}802)$

But, $CF3 \cdot 552 = CF2 \cdot 454$
$CF3 \cdot 552 = CF1 \cdot 356$

$PFO_{lat.} = 149{,}758\ lb_f$
$CF1 = 81{,}876\ lb_f$
$CF2 = 64{,}202\ lb_f$
$CF3 = 52{,}804\ lb_f$

CF1 = Cable force 1 being subjected to the tie-down eye on the stiffening ring @ 356" from the bottom of the container.

- This is the highest bearing load due to the configuration.

$CF1 = 81{,}876\ lb_f < 88{,}884\ lb_f = Load_{max}$ ✓
(on eye of stiffening ring)

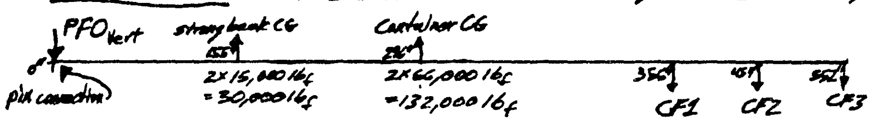
$SM = \left(\frac{88{,}884}{81{,}876} - 1\right) = 0.086$

Now for the vertical case

Vertical: → (2×G)

$\sum M_o = \sum F = 0$

Side View: → 2 effective tie-down points @ CF1, 2, 3




$\sum F = 0 = -PFO_{vert.} - 2CF1 - 2CF2 - 2CF3 + 162{,}000\ lb_f$

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**DESIGN CALCULATION**

(1) Drawing ______ (2) Doc. No. ______ (3) Page 10 of 15
(4) Building ______ (5) Rev. ______ (6) Job No. 02M9J
(7) Subject 106-C Tilt Trailer Tie-downs (Short Container)
(8) Originator Harold E. Adkins Jr., [signature] Date 5-4-94
(9) Checker S.R. Crow [signature] Date 5-17-94

(10) $\Sigma M_o = +(155)(30{,}000) + (296)(132{,}000) - (356)(2 \cdot CF1) - (454)(2 \cdot CF2) - (552)(2 \cdot CF3) = 0$

But, $CF3 \cdot 552 = CF2 \cdot 454$

& $CF3 \cdot 552 = CF1 \cdot 356$

$PFO_{vert} = 62{,}558$ lbf
$CF1 = 20{,}469$ lbf
$CF2 = 16{,}051$ lbf
$CF3 = 13{,}201$ lbf

$CF1 = 20{,}469$ lbf $< 88{,}884$ lbf $= Load_{max}$ ✓

$S.M. = \left(\frac{88{,}884}{20{,}469} - 1\right) = 3.34$

Now, to check container welds

- Determine stiffening-ring weld allowable loads. The rings were welded to the 52" O.D. pipe using 0.3125" welds both sides. As per ASME Boiler and Pressure Vessel Code, Section VIII, Div. 2, UW-18(d). 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 tension of the material being welded and a joint efficiency of 55%.

Weld dimension = 0.3125"

- Allowable stress for API spec. 5L Grade B = 35,000 psi. min.

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**DESIGN CALCULATION**

(1) Drawing ______ (2) Doc. No. ______ (3) Page 11 of 15
(4) Building ______ (5) Rev. ______ (6) Job No. D2M9J
(7) Subject 106-C Tilt-Trailer Tie-Downs (Short Container)
(8) Originator Harold E. Adkins Jr. Date 5-5-94
(9) Checker S.E. Crow Date 5-17-94

(10) Weld area = $(2)(\pi)(52.625^2 - 52^2) = 102.7\ in^2$
Load allow $= 35{,}000 \times 102.7 \times 0.55 = \underline{1.977 \times 10^6\ lb_f}$

$L_{max}/ring = 10 \cdot 66{,}000 / 4\ rings = 165{,}000\ lb_f$ (page 2) (for strongback connection to two rings on container)

– But w/ Longitudinal loading distributed to the cable connections only ∴

$L_{max}/ring = \frac{10 \cdot 66{,}000}{3\ rings} = 220{,}000\ lb_f$

$222{,}000 > 165{,}000$ so ∴

∴ SM = Safety margin = $\left(\frac{1.977 \times 10^6}{220{,}000} - 1\right) = \underline{\underline{7.99}}$

– Now to determine the cable sizes and identify the cabling configuration.

Assumptions:

– The pins connecting the strongback to the trailer provide a fixed rotation point and are at the same elevation as the resting center of the container support. (@ the open end)
– The pins provide no rotational restraint.
– The strongback and container are solely restrained by the cable force and pivot around the resting center of the container support.

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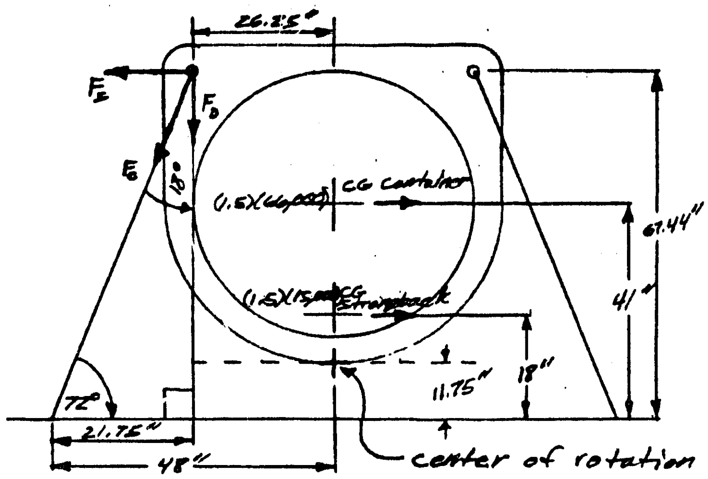
**DESIGN CALCULATION**

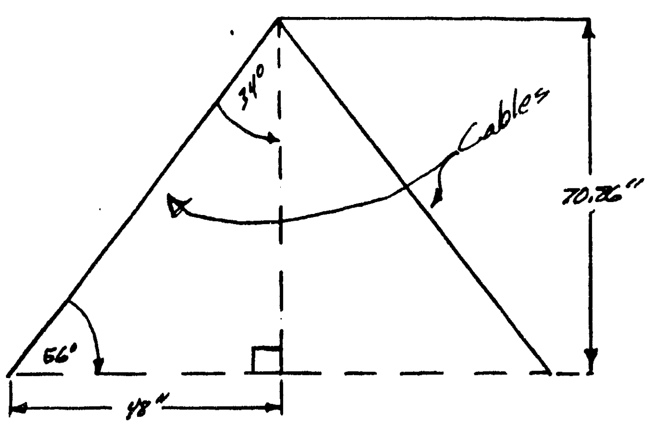
(1) Drawing ______ (2) Doc. No. ______ (3) Page 12 of 15
(4) Building ______ (5) Rev. ______ (6) Job No. D2M9J
(7) Subject 106-C Tilt trailer Tie-downs (short Container)
(8) Originator Harold E. Adkins, Jr. Date 5-5-94
(9) Checker S.R. Crow Date 5-17-94

(10) End View:




-3 Sets of 2 cables per side

- Cable Plane -

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**DESIGN CALCULATION**

(1) Drawing ______ (2) Doc. No. ______ (3) Page 13 of 15
(4) Building ______ (5) Rev. ______ (6) Job No. 02M9J
(7) Subject 106-C Tilt-trailer Tie-downs (short container)
(8) Originator Harold E. Adkins Jr. Date 5-5-94
(9) Checker S.R. Crow Date 5-17-94

(10) Lateral Loading of cables (1.5 G load)
- 6 effective cables -

$\Sigma M = 0$ ---- (Around center of Rotation)

$-(1.5)(66{,}000)(41-11.75) - (1.5)(15{,}000)(18-11.75)$
$+(6 \cdot F_{C_L} \cdot \cos(34°) \cdot \cos(72°) \cdot (67.44-11.75))$ ~$F_3$
$+(6 \cdot F_{C_L} \cdot \cos(34°) \cdot \sin(72°) \cdot (26.25)) = 0$ ~$F_D$

$$F_{C_L} = \frac{(1.5)[(66{,}000)(41-11.75)+(15{,}000)(18-11.75)]}{(6\cos(34°))(\cos(72°)(67.44-11.75)+\sin(72°)(26.25))}$$

$F_{C_L} = 14{,}474 \text{ lb}_f$ ✓

Vertical Loading of Cables (1.5 G load)
- 12 effective Cables -

$\Sigma F = 0$

$+(1.5)(66{,}000) + (1.5)(15{,}000) - 12 \cdot F_{C_V} \cdot \cos(34°) \cdot \sin(72°)$
$= 0$

$$F_{C_V} = \frac{(1.5)(66{,}000+15{,}000)}{12\cos(34°)\sin(72°)}$$

$F_{C_V} = 12{,}841 \text{ lb}_f$ ✓

Longitudinal Loading of Cables (1.5 G Load)
- 6 effective Cables

Assume that the container can slide along it's axis and is only restrained by the

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**DESIGN CALCULATION**

(1) Drawing ______ (2) Doc. No. ______ (3) Page 14 of 15
(4) Building ______ (5) Rev. ______ (6) Job No. D2M9I
(7) Subject 106-C Tilt-trailer Tie downs (Short container)
(8) Originator Harold E. Adkins Jr. Date 5-5-94
(9) Checker S.R. Crow Date 5-17-94

(10) pins and the cables acting along the axis of the container ⇒
- conservative assumption to say the least.

If $F_{C_{max}} = F_{C_L} = 14,474 \text{ lb}_f$ ⇒

$\Sigma F = 0$

$$(1.5)(66,000 + 15,000) - 6 \cdot F_{C_{max}} \cdot \sin(34°) - 2(F_{pin}) = 0$$

$$F_{pin} = \frac{(1.5)(66,000+15,000) - 6(14,474)\sin(34°)}{2}$$

$$F_{pin} = 36,469 \text{ lb}_f$$

- If we assume a yield strength of 108,000 psi for the AISI 4340 steel pins (which is highly conservative), the minimum cross-sectional area that the pin must display is ⇒

$$\frac{36,469 \text{ lb}_f}{108,000 \text{ psi}} = 0.338 \text{ in}^2$$

But, our pin cross-sectional area is ⇒

$$\frac{\pi (3'' \text{diam})^2}{4} = 7.069 \text{ in}^2$$

- We have 20 times the cross-sectional area we

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**DESIGN CALCULATION**

(1) Drawing ______ (2) Doc. No. ______ (3) Page 15 of 15
(4) Building ______ (5) Rev. ______ (6) Job No. D2M9J
(7) Subject 106-C Tilt-trailer Tie downs (short container)
(8) Originator Harold E. Adkins Jr. Date 5-6-94
(9) Checker S.R. Crow Date 5-17-94

(10) need. + The pins will survive.

- It is recommended by ANSI 14.2, Appendix C, to "Pre-load" the cables
  - Drawn from Table C-2 are the pretention percentages for the cables.

  The pretention loads are as follows.

- If Improved Plow steel (IPS) wire rope is being used –

  Pre-load = (17%)(Max load capability of wire rope)

  $= (0.17)(Load_{max}\ capability)$

- If Galvanized Iron Wire (GIW) wire rope is being used –

  Pre-load = (39%)(Load$_{max}$ Capability)

  $= (0.39)(Load_{max}\ Capability)$

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**DESIGN CALCULATION**

(1) Drawing ________ (2) Doc. No. ________ (3) Page 1 of 12
(4) Building ________ (5) Rev. ________ (6) Job No. 02M9J
(7) Subject 10G-C Tilt-trailer Tie-downs (Long Container)
(8) Originator Harold E. Adkins, Jr. HEA Date 5-6-94
(9) Checker S.R. Crow S.R. Crow Date 5-17-94

(10) Phase I of bearing load analysis -
Determine the maximum load that the tie-down points will withstand.

Assumptions:

- To meet the requirements of 10CFR 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 attach directly to the trailer.

$$\frac{F_{Pcr}}{F_y} = \frac{l_e}{d} \quad \text{(C-J3-4 AISC - Steel construction)}$$

Longitudinal

- $l_e = 3.84$ in (Distance from free edge)
- $d = 1.5$ in (Diameter of fastener)
- $F_y = 36{,}000$ psi (ASTM A-36 yield strength)
- $F_{Pcr} = ?$ (Critical bearing stress)

$$F_{Pcr} = \frac{F_y \cdot l_e}{d} = \frac{(36{,}000)(3.84)}{(1.5)} = \underline{92{,}160 \text{ psi}}$$

projected area = (material thickness)(hardware diam)

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**DESIGN CALCULATION**

(1) Drawing ______ (2) Doc. No. ______ (3) Page 2 of 12
(4) Building ______ (5) Rev. ______ (6) Job No. 02M9J
(7) Subject 106-C Tilt-trailer Tie-downs (Large Container)
(8) Originator Harold E. Adkins, Jr. [signature] Date 5-6-94
(9) Checker S.R. Crow [signature] Date 5-17-94

(10)

{ material thickness = 1.5"
{ hardware diameter = 1.5"

$Load_{max} = F_{Pcr} \cdot$ (Projected Area)

$Load_{max} = (92,160)(1.5)(1.5) = \underline{207,360\ lb_f}$

– From 10CFR 71.45(b)(1), the attachment points on the container must be capable of withstanding w/o exceeding

{ 10× weight Longitudinal
{ 5× weight Lateral
{ 2× weight Vertical

– weight of package max = 61,500 lbf
\# of points effective = 4

$$\frac{10 \times 61{,}500}{4} = 153{,}750\ lb_f$$

Longitudinal Safety Margin $= \left(\frac{207{,}360}{153{,}750} - 1\right)$

$\therefore\ \underline{S.M._{long} = 0.35}$ ✓

Vertical

{ $L_e = 5.72''$
{ $d = 1.5''$
{ $F_y = 36{,}000$ psi
{ $F_{Pcr} = ?$

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**DESIGN CALCULATION**

(1) Drawing ______ (2) Doc. No. ______ (3) Page 3 of 12
(4) Building ______ (5) Rev. ______ (6) Job No. 02M9J
(7) Subject 106-C Tilt-trailer Tie-downs (Long container)
(8) Originator Arnold E. Adkins, Jr. Date 5-3-94
(9) Checker S.R. Crow Date 5-17-94

(10)

$$P_{cr} = \frac{(36,000)(5.72)}{(1.5)} = 137,280$$

$$Load_{max} = (137,280)(1.5)(1.5) = \underline{308,880\ lb_f}$$

$$\frac{2 \times 61,500}{4} = \underline{30,750\ lb_f}$$

Vertical Safety margin $= \left(\frac{308,880}{30,750} - 1\right)$

$\therefore$ $S.M._{vert} = 9.04$

Lateral

-For the lateral case, in light of the fact that the container is fixed in the Strongback, only a tensile load on 2 of the hardpoints will be considered. This load will be applied to the welds connecting the mounting plates to the stiffening rings.

$$\text{Weld area} = (2)(2)(1'' \times 13'') = \underline{52\ in^2}$$

$$5 \times 61,500\ lb_f = 307,500\ lb_f$$

$$\sigma = \frac{P}{A} = \frac{307,500}{52} = 5913\ psi$$

$$\sigma_{max} = 36,000\ psi$$

$$\therefore\ S.M._{Lat.} = \left(\frac{36,000}{5913} - 1\right) = \underline{5.09}$$

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**DESIGN CALCULATION**

(1) Drawing ______ (2) Doc. No. ______ (3) Page 4 of 12
(4) Building ______ (5) Rev. ______ (6) Job No. D2M9I
(7) Subject 106-C Tilt-trailer Tie-downs (Long Container)
(8) Originator Harold E. Adkins, Jr. Date 5-6-94
(9) Checker S.R. Crow Date 5-17-94

(10) Phase II of bearing load analysis –
Now, selecting an alternative set of tie-down points to analize the bearing loads.

Assumptions:

– To meet the requirements of 10CFR 71.45(b)(1), only points @ which the cables attach to the container will be analyzed using moment combinations taking into account the weight of the strongback. The pivot point will be the pivot pins on the strongback.

–3 attachment points per side will be used. (6 cables per side in a "V" configuration)

$$\frac{F_{Pcr}}{F_Y} = \frac{l_e}{d} \quad \text{(C-J3-2 AISC - steel Construction)}$$

$l_e = 2.469$ in
$d = 1\tfrac{5}{8}''$
$F_y = 36{,}000$ psi

$$F_{Pcr} = F_y \frac{l_e}{d} = \frac{(36{,}000)(2.469)}{(1.625)} = 54{,}698 \text{ psi}$$

projected area $= (1)(1.625) = \underline{1.625}$

$Load_{max} = (54{,}698)(1.625) = \underline{88{,}884 \text{ lbs}}$

– From 10 CFR 71.45 (b)(1), the tie-down system must be capable of withstanding w/o exceeding yield:

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**DESIGN CALCULATION**

(1) Drawing ______ (2) Doc. No. ______ (3) Page 5 of 12
(4) Building ______ (5) Rev. ______ (6) Job No. 02M9J
(7) Subject 106-C Tilt-Trailer Tie-downs (Long Container)
(8) Originator Harold E. Adkins Jr. Date 5-9-94
(9) Checker S.R. Crow [signature] Date 5-17-94

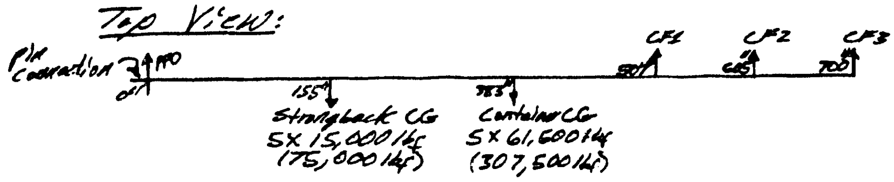
(10) 2X Weight Vertical
10X Weight Longitudinal
5X Weight Lateral

Longitudinal will be ignored because of the fact that the pins connecting the strongback are capable of a 100,000 lb load before ripping free and if they fail, the tie-down system (cables) will be designed to fail under the container-strongback load before subjecting maximum loading to container-cable tie-down points. (To be proved later in calculations)

<u>Lateral Load Case</u> – (5xG)

$\Sigma M_o = \Sigma F = 0$

<u>Top View:</u>




$\Sigma F = 0 = CF1 + CF2 + CF3 + PFO - 75{,}000 - 307{,}500$

$PFO_{lat.} = 382{,}500 - CF1 - CF2 - CF3$

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**DESIGN CALCULATION**

(1) Drawing ____ (2) Doc. No. ____ (3) Page 6 of 12
(4) Building ____ (5) Rev. ____ (6) Job No. D2M9I
(7) Subject 106-C Tilt-Trailer Tie-downs (Long Container)
(8) Originator Harold E. Adkins Jr. Date 5-9-94
(9) Checker S.R. Crow Date 5-17-94

(10) $\Sigma M_o = 0 = -155(75{,}000) - 383(307{,}500) + 507 \cdot CF1 + 605 \cdot CF2 + 700 \cdot CF3$

But, $CF3 \cdot 700 = CF2 \cdot 605$
$CF3 \cdot 700 = CF1 \cdot 507$

Solving - we find that:

$PFO_{Lat.} = 164{,}515$ lbf
$CF1 = 85{,}074$ lbf
$CF2 = 71{,}293$ lbf
$CF3 = 61{,}618$ lbf

CF1 = Cable force 1 being subjected to the tie-down eye on the stiffening ring @ 507" from the bottom of the container.

- This is the highest bearing load due to the configuration.

$CF1 = 85{,}074$ lbf $< 88{,}884$ lbf $= Load_{max}$ (on eye of stiffening ring)

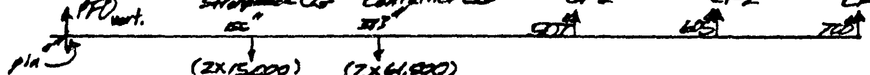
$S.M._{Lat} = \left(\frac{88{,}884}{85{,}074} - 1\right) = 0.045$

Now, for the Vertical Case -

Vertical: + (2xG)

$\Sigma M_o = \Sigma F = 0$

Side View: → 2 effective tie-down points @ CF1,2,3




$\Sigma F = 0 = PFO_{vert} + 2 \cdot CF1 + 2 \cdot CF2 + 2 \cdot CF3 - 30{,}000 - 123{,}000$

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**DESIGN CALCULATION**

(1) Drawing ______ (2) Doc. No. ______ (3) Page 7 of 12
(4) Building ______ (5) Rev. ______ (6) Job No. DZM9F
(7) Subject 106-C Tilt-Trailer Tie-downs (Long Container)
(8) Originator Harold E. Adkins, Jr., HEA Jr. Date 5-9-94
(9) Checker S.R. Crow S R Crow Date 5-17-94

(10) $\Sigma M_0 = -(155)(30{,}000) - (383)(123{,}000) + (507)(2 \times CF1) + (605)(2 \times CF2) + (700)(2 \times CF3) = 0$

But, $CF3 \cdot 700 = CF2 \cdot 605$
$CF3 \cdot 700 = CF1 \cdot 507$

$PFO_{vert.} = 65{,}806$ lbf
$CF1 = 17{,}015$ lbf
$CF2 = 14{,}259$ lbf
$CF3 = 12{,}324$ lbf

$CF1 = 17{,}015$ lbf $< 88{,}884$ lbf $= Load_{max.}$

$S.M. = \left(\frac{88{,}884}{17{,}015} - 1\right) = 4.22$

Now, to check container welds

- Determine stiffening-ring weld allowable loads. The rings were welded to the 52" O.D. pipe using 0.3125" welds both sides. As per ASME Boiler and pressure vessel code, Section VIII, Div. 1, UW-18(d). The allowable load on the fillet welds shall be equal to the product of the weld area (based on min. leg dimension), the allowable stress value in tension of the material being welded and a joint efficiency of 55%.

  Weld dimension = 0.3125"

- Allowable stress for API spec. 5L Grade B = 35,000 psi min.

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**DESIGN CALCULATION**

(1) Drawing ______ (2) Doc. No. ______ (3) Page 8 of 12
(4) Building ______ (5) Rev. ______ (6) Job No. 02M9I
(7) Subject 106-C Tilt-trailer Tie-downs (Long Container)
(8) Originator Harold E. Adkins, Jr. Date 5-9-94
(9) Checker S R Crow Date 5-17-94

(10) Weld area $= (2)(\pi)(52.625^2 - 52^2) = 102.7\ in^2$

$Load_{allow} = 35{,}000 \times 102.7 \times 0.55 = 1.977 \times 10^6\ lb_f$

$L_{max}/ring = 10 \cdot 61{,}500 / 4\ rings = 153{,}750\ lb_f$

(for strongback connection to two rings on container)

- But w/ longitudinal loading distributed to the cable connections only ⇒

$L_{max}/ring = \frac{10 \times 61{,}500}{3\ rings} = 205{,}000\ lb_f$

$205{,}000 > 165{,}000$ so ⇒

$\therefore S.M. = \left(\frac{1.977 \times 10^6}{205{,}000} - 1\right) = 8.64$

- Now, to determine the cable sizes and identify the cabling configuration.

Assumptions:

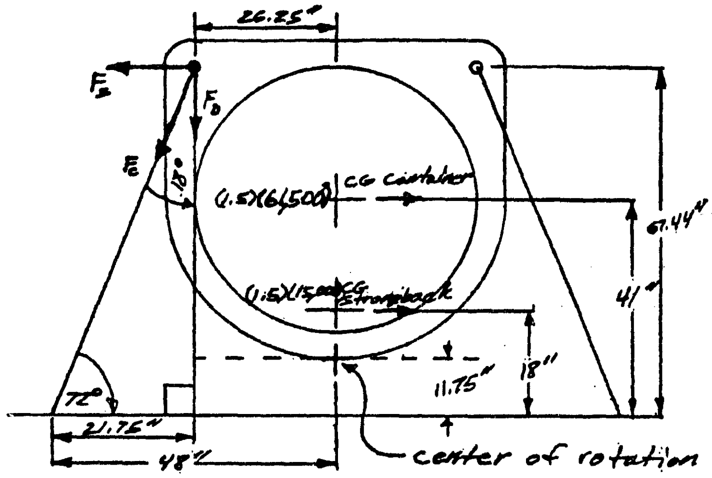
- The pins connecting the strongback to the trailer provide a fixed rotation point and are at the same elevation as the resting center of the container support. (@ the open end)
- The pins provide no rotational restraint
- The strongback and container are solely restrained by the cable force and pivot around the resting center of the container support.

BD-6400-060.1 (12/87)

**DESIGN CALCULATION**

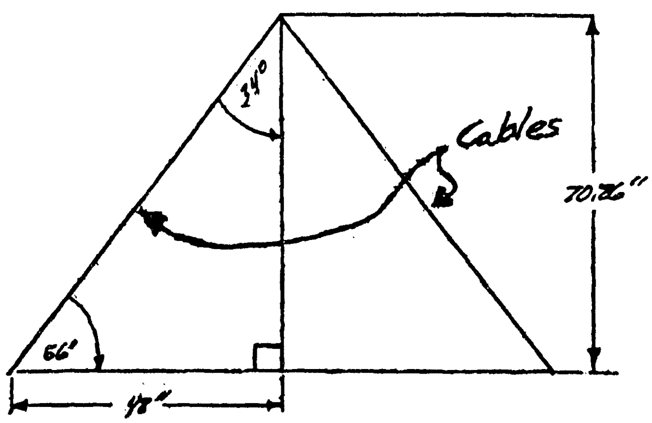
(1) Drawing ______ (2) Doc. No. ______ (3) Page 9 of 12
(4) Building ______ (5) Rev. ______ (6) Job No. D2M9J
(7) Subject 106-C Tilt trailer Tie-Downs (Long Container)
(8) Originator Harold E. Adkins, Jr. Date 5-9-94
(9) Checker S.R. Crow Date 5-17-94

(10) End View:




-3 sets of 2 cables per side

- Cable Plane -




BD-6400-060.1 (12/87)

**DESIGN CALCULATION**

(1) Drawing ______ (2) Doc. No. ______ (3) Page 10 of 12
(4) Building ______ (5) Rev. ______ (6) Job No. 02M9J
(7) Subject 106-C Tilt-Trailer Tie-downs (Long Container)
(8) Originator Harold E. Adkins, Jr. Date 5-9-94
(9) Checker S. R. Crow [signature] Date 5-17-94

(10) Lateral loading of cables (1.5 G load)

- 6 effective cables -

$\Sigma M = 0$ (Around center of Rotation)

$-(1.5)(61,500)(41-11.75)-(1.5)(15,000)(18-11.75)$

$+(6 \cdot F_{c_L} \cdot \cos(34°) \cdot \cos(72°) \cdot (67.44-11.75))$ ~$F_s$

$+(6 \cdot F_{c_L} \cdot \cos(34°) \cdot \sin(72°) \cdot (26.25)) = 0$ ~$F_D$

$$F_{c_L} = \frac{(1.5)[(61,500)(41-11.75)+(15,000)(18-11.75)]}{(6\cos(34°))(\cos(72°)(67.44-11.75)+\sin(72°)(26.25))}$$

$F_{c_L} = 13,533$ lbf

Vertical loading case (1.5 G load)

- 12 effective cables -

$\Sigma F = 0$

$+(1.5)(61,500)+(1.5)(15,000)-12F_{c_V} \cdot \cos(34°)\sin(72°) = 0$

$$F_{c_V} = \frac{(1.5)(61,500+15,000)}{12\cos(34°)\sin(72°)}$$

$F_{c_V} = 12,128$ lbf

Longitudinal Loading of Cables (1.5 G load)

- 6 effective cables -

Assume that the container can slide along its axis and is only restrained by the

BD-6400-060 1 (12/87)

**DESIGN CALCULATION**

(1) Drawing ______ (2) Doc. No. ______ (3) Page 11 of 12
(4) Building ______ (5) Rev. ______ (6) Job No. 02M9I
(7) Subject 106-C Tilt-trailer Tie-downs (Long container)
(8) Originator Harold E. Adkins, Jr. Date 5-9-94
(9) Checker S.R. Crow Date 5-17-94

(10) pins and the cables acting along the axis of the container ⇒

- Conservative assumption to say the least.

If $F_{c\text{-}max} = F_{c_4} = 13{,}533\ lb_f$ ⇒

$\underline{\Sigma F = 0}$

$(1.5)(61{,}500 + 15{,}000) - 6 \cdot F_{max} \cdot \sin(34°) - 2(F_{pin}) = 0$

$$F_{pin} = \frac{(1.5)(61{,}500 + 15{,}000) - 6(13{,}553)\sin(34°)}{2}$$

$F_{pin} = \underline{34{,}672\ lb_f}$

- If we assume a yield strength of 108,000 psi (which is highly conservative), the minimum cross-sectional area that the pin must display is ⇒

$$\frac{34{,}672\ lb_f}{108{,}000\ psi} = \underline{0.321\ in^2}$$

But our pin cross-sectional area is ⇒

$$\frac{\pi(3''\text{diam})^2}{4} = \underline{7.069\ in^2}$$

- We have 22 times the cross-sectional area we need. The pins will survive. ✓

BD-6400-060.1 (12/87)

**DESIGN CALCULATION**

(1) Drawing ______ (2) Doc. No. ______ (3) Page 12 of 12
(4) Building ______ (5) Rev. ______ (6) Job No. 02M19I
(7) Subject 106-C Tilt-Trailer Tie-downs (Long Container)
(8) Originator Harold E. Adkins Jr., HEA Jr. Date 5-9-94
(9) Checker S.R. Crow [signature] Date 5-17-94

(10)

- It is recommended by ANSI 14.2, Appendix C, to "Pre-load" the cables
- Drawn from Table C-1 are the pretention percentages for the cables.

The pretention loads are as follows.

- If Improved Plow steel (IPS) wire rope is being used -

Pre-load = (17%)·(Max load capability)
(0.17)(11)

- If Galvanized Iron wire (GIW) rope is being used -

Pre-load = (39%)·(Max load capability)
(0.39)·(11)

BD-6400-060.1 (12/87)

V .. ..

**DESIGN CALCULATION**

(1) Drawing H-2-85724 (2) Doc. No. ______ (3) Page 1 of 9
(4) Building ______ (5) Rev. 0 (6) Job No. D2M9I
(7) Subject 106-C Package Tie-downs (short container)
(8) Originator Harold E. Adkins Jr., [signature] Date 3-30-94
(9) Checker [signature] S.R. Crow Date 5-17-94

(10) Determine the maximum load that the tie-down points will withstand.

$\frac{F_{Pcr}}{F_y} = \frac{l_e}{d}$ (C-J3-1 AISC-steel Construction)

$l_e = 2.469$ in. (Distance to free edge)
$d = 1\ 5/8"$ (Diameter of fastener)
$F_y = 36{,}000$ psi (ASTM A36 yield strength)
$F_{Pcr} = ?$ (Critical Bearing Stress)

$F_{Pcr} = F_y \frac{l_e}{d} = \frac{(36{,}000)(2.469)}{(1.625)} = 54{,}698$ psi ✓

projected area = (width)(hardware diam.)
width = 1 in.
hardware diam = 1.625 in.

$Load_{max} = F_{Pcr} \cdot$ (projected area)

$Load_{max} = (54{,}698)(1)(1.625) = \underline{88{,}884\ lb_f}$ ✓

- From 10 CFR 71.45(b)(1), the tie-down system must be capable of withstanding w/o exceeding yield:

2X Weight Vertical
10X Weight Longitudinal
5X Weight Lateral

- Weight of package max = $\underline{66{,}000\ lb_f}$ ✓

BD-6400-060 1 (12/87)

**DESIGN CALCULATION**

(1) Drawing H-2-85724 (2) Doc. No. ____ (3) Page 2 of 9
(4) Building ____ (5) Rev. 0 (6) Job No. D2M9I
(7) Subject 106-C Package Tie-downs (short container)
(8) Originator A.E. Adkins Jr., [signature] Date 3-30-94
(9) Checker [signature] S.R. Crow Date 5-17-94

(10) # of tie-down points = 8

$$\frac{2 \cdot 66,000}{8} = 16,500\ lb_f \checkmark$$

$\therefore$ Safety margin $= \left(\frac{88,884}{16,500} - 1\right) = \underline{4.39}$ ✓

$$\frac{10 \cdot 66,000}{8} = 82,500\ lb_f \checkmark$$

$\therefore$ Safety margin $= \left(\frac{88,884}{82,500} - 1\right) = \underline{0.077}$ ✓

$$\frac{5 \cdot 66,000}{4} = 82,500\ lb_f \checkmark$$

$\therefore$ Safety margin $= \left(\frac{88,884}{82,500} - 1\right) = \underline{0.077}$ ✓

- Determine stiffener-ring weld allowable loads. The rings were welded to the 52" O.D. pipe using 0.3125" welds both sides. As per ASME Boiler and Pressure Vessel Code, Section VIII, Div. 1, UW-18(d). 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 tension of the material being welded and a joint efficiency of 55%.

Weld dimension = 0.3125"

- Allowable stress for API spec. 5L Grade B = 35,000 psi min.

BD-6400-060.1 (12/87)

**DESIGN CALCULATION**

(1) Drawing H-2-83724 (2) Doc. No. ______ (3) Page 3 of 9
(4) Building ______ (5) Rev. 0 (6) Job No. PZ M9J
(7) Subject 106-C Package Tie-downs (Short Container)
(8) Originator H.E. Adkins Jr., [signature] Date 3-30-94
(9) Checker [signature] S.R. Crow Date 5-17-94

(10) Weld area $= (2)(\pi)\frac{(52.625^2 - 52^2)}{4} = 102.7\ in^2$

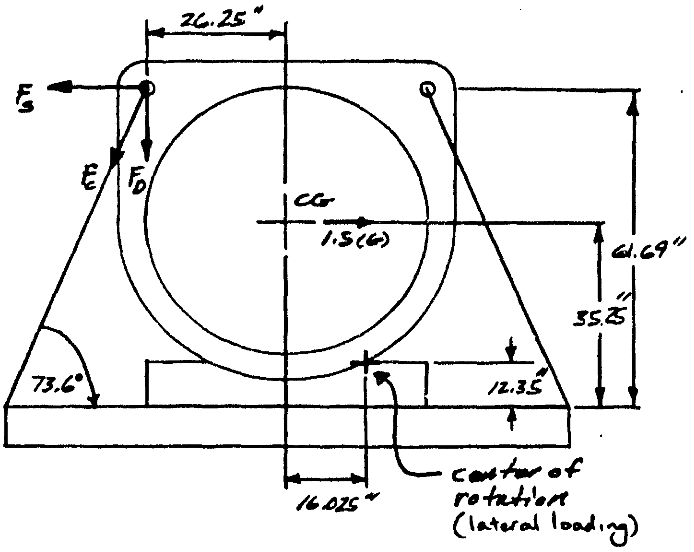
$L_{all} = 35{,}000 \times 102.7 \times 0.55 = \underline{1.977 \times 10^6\ lb_f}$

$L_{max}/ring = \frac{10 \cdot 66{,}000}{4} = \underline{165{,}000\ lb_f}$

$\therefore$ Safety Margin $= \left(\frac{1.977 \times 10^6}{165{,}000} - 1\right) = \underline{\underline{10.98}}$

- Determine cable sizes for the tie-down locations as shown on following sketchs.

End View

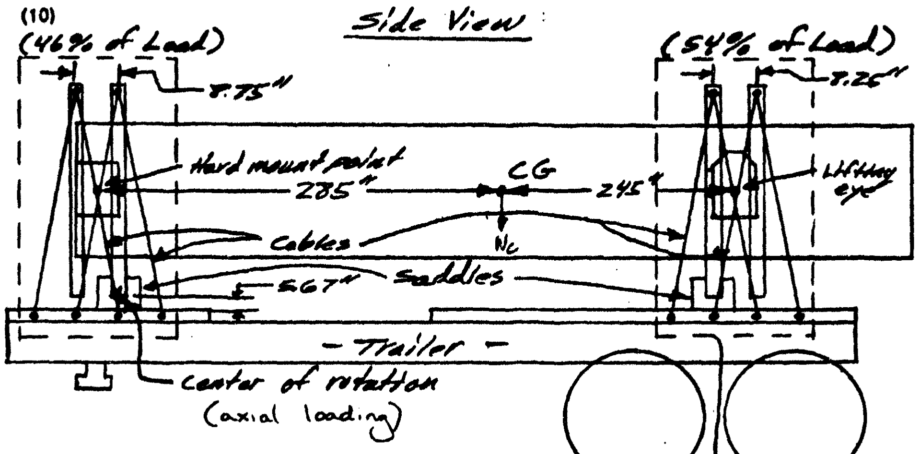


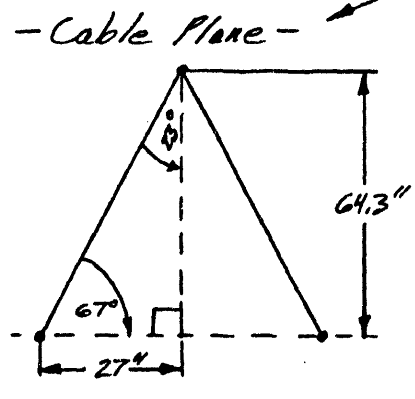

BD-6400-060.1 (12/87)

**DESIGN CALCULATION**

(1) Drawing H-2-83724 (2) Doc. No. ______ (3) Page 4 of 9
(4) Building ______ (5) Rev. 0 (6) Job No. D2M9J
(7) Subject 106-C Package Tie-downs (Sheet Container)
(8) Originator H. E. Adkins Jr. [signature] Date 3-31-94
(9) Checker S. R. Crow [signature] Date 5-17-94

(10)




BD-6400-060 1 (12/87)

## DESIGN CALCULATION

(1) Drawing H-2-73724 (2) Doc. No. ______ (3) Page 5 of 9
(4) Building ______ (5) Rev. 0 (6) Job No. D2M9F
(7) Subject 106-C Package Tie-downs (Short Container)
(8) Originator H.E. Adkins, Jr. [signature] Date 5-31-94
(9) Checker S.R. Crow [signature] Date 5-17-94

(10) Assumptions:

1. Saddles are adequatly secured to trailer to hold container in place and provide a center of rotation as indicated.
2. Saddles will survive the axial loading condition.
3. CG is located @ the axial and radial center of the container.

- Vertical loading -
  - 16 cables - effective
  - max. weight of container w/ payload & shielding = $W_c$ = 66,000 $lb_f$
  - 1.5 G Loading (upward)

$\Sigma F = 0$

$$(1.5G)(W_c) - 16(\cos 23°)(\sin 73.6°)F_{c_V} - W_c = 0$$

$$F_{c_V} = \frac{W_c(1.5-1)}{16 \cos 23° \sin 73.6°} = \frac{(66{,}000)(1.5-1)}{16 \cos 23° \sin 73.6°}$$

$$F_{c_V} = 2336\ lb_f$$ ✓

BD-6400-060 1 (12/87)

**DESIGN CALCULATION**

(1) Drawing H-2-83724 (2) Doc. No. ____ (3) Page 6 of 9
(4) Building ____ (5) Rev. 0 (6) Job No. D2M9J
(7) Subject 106-C Package Tie-downs (short Container)
(8) Originator H.E. Adkins Jr. [signature] Date 5-31-94
(9) Checker S.R Crow [signature] Date 5-17-94

(10)

– Lateral Loading –

* Limiting case for tie-down system is the lateral load on the tail end of the trailer where the top end of the container will be placed as shown on the above drawing.

-@ this point, 54% of the load provided by the package is being applied to that local portion of the tie-down system. This was selected as the worst possible case.

$\Sigma M = 0$ (Around center of rotation)

$$-((1.56)\cdot W_c\cdot(35.25''-12.35''))\cdot\overset{(54\%)}{(0.54)} + (W_c\cdot 16.025'')\cdot\overset{(54\%)}{(0.54)}$$

$$+(4\cdot F_{c_L}\cdot \cos(23°)\cdot \cos(73.6°)\cdot(61.69''-12.35'')) \quad \sim F_z$$

$$+(4\cdot F_{c_L}\cdot \cos(23°)\cdot \sin(73.6°)\cdot(26.25''+16.025'')) \quad \sim F_D$$

$$=0$$

$$F_{c_L} = \frac{(1.5\cdot(35.25-12.35)-16.025)\cdot(0.54)\cdot(66{,}000)}{4\cdot\cos(23°)[\cos(73.6)\cdot(61.69-12.35)+\sin(73.6)\cdot(26.25+16.025)]}$$

$$F_{c_L} = \underline{\underline{3255\ lb_f}}$$ ✓

BD-6400-060 1 (12/87)

**DESIGN CALCULATION**

(1) Drawing H-2-85724 (2) Doc. No. ______ (3) Page 7 of 9
(4) Building ______ (5) Rev. 0 (6) Job No. 02M9I
(7) Subject 106-C Package Tie-downs (short Container)
(8) Originator H.E. Adkins Jr. Date 3-31-94
(9) Checker S.R. Crow Date 5-17-94

(10)

– Axial Loading – (8 cables – effective)

$\Sigma M = 0$ (Around center of rotation)

$$(1.5G \cdot W_c \cdot (35.25'' - 5.67'')) - (W_c \cdot (275'' - \tfrac{7.75''}{2}))$$
$$- 8F_{cA} \cdot (\cos(23°) \cdot \sin(73.6°) \cdot (275'' + 245'' - \tfrac{7.75''}{2})) = 0$$

$$F_{cA} = \frac{(1.5 \cdot (35.25 - 5.67) - (275 - \frac{7.75}{2})) \cdot 66{,}000}{8 \cdot (\cos(23°) \cdot \sin(73.6°) \cdot (275 + 245 - \frac{7.75}{2}))}$$

$$F_{cA} = -4199 \text{ lb}_f$$

* The negative sign indicates that no tensile load will be applied to the cables. → All forces in the axial case will be applied to the saddles.

– Size of cables needed: (As per Ansi 14.2)

$F_{cA} < F_{cV} < F_{cL} = 3{,}255 \text{ lb}_f$

N.B.S. = Nominal Breaking Strength

$T_{eff}$ = terminal efficiency = 0.8

$S_{fac}$ = safety factor = 0.46

$Load_{max} = 3{,}255 \text{ lb}_f = F_{cL}$

$$N.B.S. = \frac{Load_{max}}{T_{eff} \cdot S_{fac}} = \frac{3255}{(0.8)(0.46)} = 8{,}845 \text{ lb}_f$$ ✓

BD-6400-060 1 (12/87)

**DESIGN CALCULATION**

(1) Drawing H-2-83724 (2) Doc. No. ______ (3) Page 8 of 9
(4) Building ______ (5) Rev. 0 (6) Job No. 02M0I
(7) Subject 10G-C Package Tie-downs (short container)
(8) Originator H. E. Adkins Jr., HEA Jr. Date 3-31-94
(9) Checker S. R. Crow S R Crow Date 5-17-94

(10)

- Possible D-rings, shackles, Turnbuckles, and cable selections through McMaster-Carr.

* It is important to note that all spectrum analysis on the containers must be repeated because of this change in the tie-down system.

HEA Jr. 3-31-94

* A protection fixture will need to be placed @ locations where cables cross and remain in contact w/ each other in order to prevent cable wear. Because of the given cable configuration, 4 fixtures will be required.

BD-6400-060 1 (12/87)

**DESIGN CALCULATION**

(1) Drawing H-2-83724 (2) Doc. No. ______ (3) Page 9 of 9
(4) Building ______ (5) Rev. 0 (6) Job No. D2M9I
(7) Subject 106-C Package Tie-downs (short container)
(8) Originator H. E. Adkins Jr. Date 5-31-94
(9) Checker S. R. Crow Date 5-17-94

(10) It is recommended by ANSI 14.2, Appendix C, to "Pre-load" the cables. Drawn from Table C-I are the pretention percentages for the cables.

The pretention loads are as follows.

- If Improved Plow steel (IPS) wire rope is being used-

Pre-load = (17%)·(Nominal breaking strength)
= (0.17)·(N.B.S.)

- If Galvanized Iron Wire (GIW) wire rope is being used-

Pre-load = (39%)·(N.B.S.)
= (0.39)·(N.B.S)

BD-6400-060.1 (12/87)

**DESIGN CALCULATION**

(1) Drawing H-2-93728 (2) Doc. No. ______ (3) Page 1 of 9
(4) Building ______ (5) Rev. 0 (6) Job No. D2M9F
(7) Subject 10G-C Package Tie-downs (Long Container)
(8) Originator H.F. Adkins Jr. Date 3-2-94
(9) Checker S.R. Crow Date 5-17-94

(10) Determine the maximum load that the tie-down points will withstand.

$$\frac{F_{Pcr}}{F_y} = \frac{l_e}{d} \quad \text{(C-J3-1 AISC-Steel Construction)}$$

- $l_e = 2.469$ in (Distance to free edge)
- $d = 1\frac{5}{8}''$ (Diameter of fastener)
- $F_y = 36{,}000$ psi (ASTM A36 yield strength)
- $F_{Pcr} = ?$ (Critical bearing stress)

$$F_{Pcr} = F_y \frac{l_e}{d} = \frac{(36{,}000)(2.469)}{(1.625)} = 54{,}698 \text{ psi} ✓$$

projected area = (width)(hardware diam.)

- width = 1 in.
- hardware diam = 1.625 in

$$Load_{max} = F_{Pcr} \cdot (\text{projected area})$$

$$Load_{max} = (54{,}698)(1)(1.625) = \underline{88{,}884 \text{ lb}_f} ✓$$

- From 10 CFR 71.45(b)(1), the tie-down system must be capable of withstanding w/o exceeding yield:
  - 2X Weight Vertical
  - 10X Weight Longitudinal
  - 5X Weight Lateral.
- Weight of package max = $\underline{61{,}500 \text{ lb}_f}$

BD-6400-060.1 (12/87)

**DESIGN CALCULATION**

(1) Drawing H-2-83728 (2) Doc. No. ______ (3) Page 2 of 9
(4) Building ______ (5) Rev. 0 (6) Job No. D2M9I
(7) Subject 106-C Package Tie-downs (Long Container)
(8) Originator H.E. Adkins Jr. Date 3-2-94
(9) Checker S.R. Crow Date 5-17-94

(10) # of tie-down points = 8

$$\frac{2 \cdot 61{,}500}{8} = 15{,}375 \text{ lbf} \checkmark$$

$$\therefore \text{ safety margin} = \left(\frac{88{,}884}{15{,}375} - 1\right) = \underline{4.78} \checkmark$$

$$\frac{10 \cdot 61{,}500}{8} = 76875 \text{ lbf}$$

$$\therefore \text{ Safety margin} = \left(\frac{88{,}884}{76{,}875} - 1\right) = \underline{0.16} \checkmark$$

$$\frac{5 \cdot 61{,}500}{4} = 76875 \text{ lbf}$$

$$\therefore \text{ Safety margin} = \left(\frac{88{,}884}{76{,}875} - 1\right) = \underline{0.16} \checkmark$$

- Determine Stiffener-ring weld allowable Loads.

The rings were welded to the 52" O.D. pipe using 0.3125" welds both sides As per ASME Boiler and Pressure Vessel Code, Section VIII, Div. 1, UW-18(d). 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 ~~tension~~ of the material being welded and a joint efficiency of 55%.

BD-6400-060.1 (12/87)

**DESIGN CALCULATION**

(1) Drawing H-2-83728 (2) Doc. No. ______ (3) Page 5 of 9
(4) Building ______ (5) Rev. 0 (6) Job No. 02M9J
(7) Subject 106-C Package Tie-downs (Long Container)
(8) Originator H.E. Adkins Jr. [signature] Date 3-2-94
(9) Checker S.R. Crow [signature] Date 5-17-94

(10) Weld dimension = 0.3125"

- Allowable stress for API spec. 5L Grade B = 35,000 psi min

Weld area $= (2)(\pi)\frac{(52.625^2 - 52^2)}{4} = 102.7\,in^2$

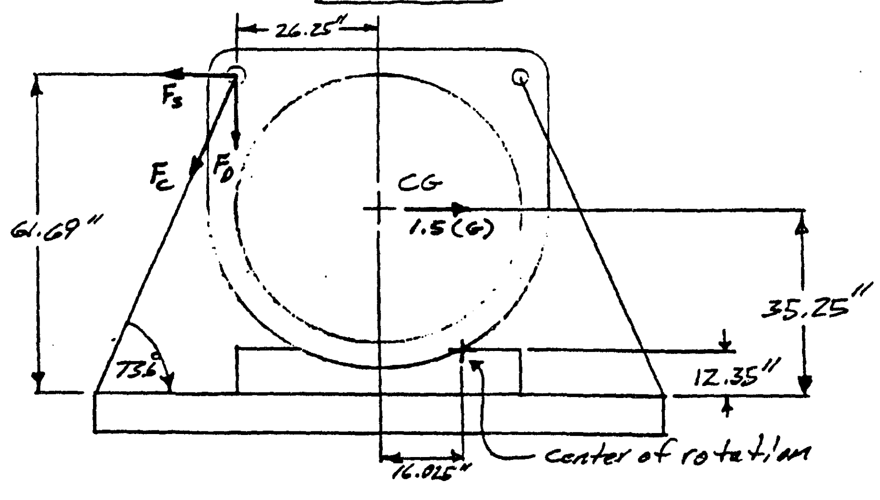
$L_{all} = 35{,}000 \times 102.7 \times 0.55 = 1.977 \times 10^6\ lb_f$

$L_{max}/ring = \frac{10 \cdot 61{,}500}{4} = 153{,}750\ lb_f$

$\therefore$ Safety Margin $= \left(\frac{1.977 \times 10^6}{153{,}750} - 1\right) = 11.75$

- Determine cable sizes for the tie-down locations as shown on following sketches.

End View

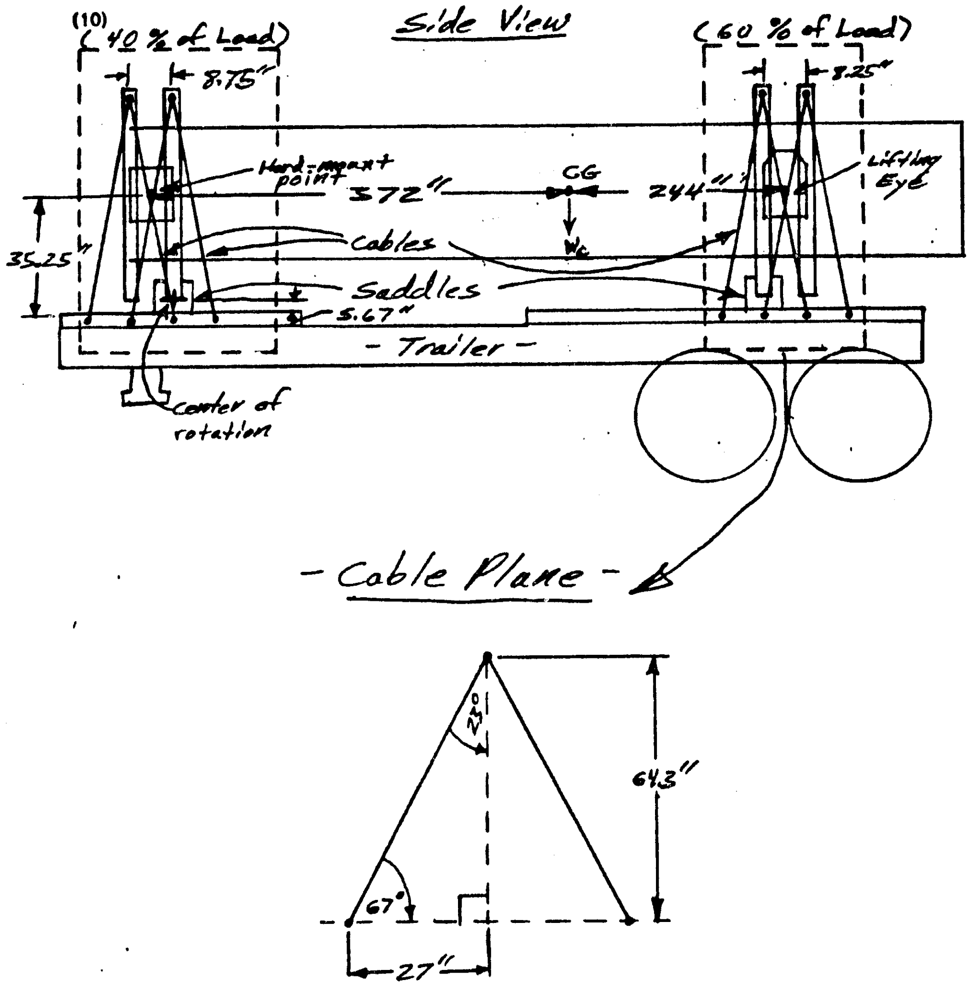



BD-6400-060.1 (12/87)

**DESIGN CALCULATION**

(1) Drawing H-2-83728 (2) Doc. No. ______ (3) Page 4 of 9
(4) Building ______ (5) Rev. ______ (6) Job No. 02M9J
(7) Subject 106-C Package Tie-downs (Long container)
(8) Originator H.E. Adkins Jr. Date 5-2-94
(9) Checker S.R. Crow Date 5-17-94

(10)




BD-6400-060.1 (12/87)

**DESIGN CALCULATION**

(1) Drawing H-2-83728 (2) Doc. No. ________ (3) Page 5 of 9
(4) Building ________ (5) Rev. 0 (6) Job No. D2M9J
(7) Subject 106-C Package Tie-downs (Long Container)
(8) Originator H.E. Adkins Jr. [signature] Date 3-2-94
(9) Checker S.R. Crow [signature] Date 5-17-94

(10) Assumptions:

① Saddles are adequatly secured to trailer to hold container in place and provide a center of rotation as indicated.

② Saddles will survive the axial loading condition.

③ CG is located @ the axial and radial center of the container.

- Vertical Loading -
- 16 cables - effective -
- max. weight of container w/ payload & shielding $= W_c = 61{,}500\ lb_f$
- 1.5 G Loading (upward)

$\Sigma F = 0$

$$(1.5\,G)(W_c) - 16(\cos 23^\circ)(\sin 73.6^\circ)\,F_{cv} - (W_c) = 0$$

$$F_{cv} = \frac{W_c\,(1.5-1)}{16\cos 23^\circ \cdot \sin 73.6^\circ} = \frac{(61{,}500)(1.5-1)}{16\cos 23^\circ \cdot \sin 73.6^\circ}$$

$$F_{cv} = 2176\ lb_f$$

BD-6400-060.1 (12/87)

**DESIGN CALCULATION**

(1) Drawing H-2-93728 (2) Doc. No. ______ (3) Page 6 of 9
(4) Building ______ (5) Rev. ______ (6) Job No. D2M9F
(7) Subject 106-C Package Tie-downs (Long Container)
(8) Originator N.E. Adkins Jr. [initials] Date 3-2-94
(9) Checker S.R Crow S.R. Crow Date 5-17-94

(10)

— *Lateral Loading* —

* Limiting case for tie-down system is the lateral load on the tail end of the trailer where the top end of the container will be placed as shown on the above drawing.

- @ this point, 60% of the load provided by the package is being applied to that local portion of the tie-down system. This was selected as the worst possible case.

$\Sigma M = 0$ (Around center of rotation)

$$-((1.5G)\cdot W_c \cdot (35.25'' - 12.35''))\cdot \underset{(60\%)}{(0.60)} + (W_c \cdot 16.025'')\cdot \underset{(60\%)}{(0.60)}$$
$$+(4 \cdot F_{c_L} \cdot \cos(23°) \cdot \cos(73.6°) \cdot (61.69'' - 12.35'')) \quad \sim F_s$$
$$+(4 \cdot F_{c_L} \cdot \cos(23°) \cdot \sin(73.6°) \cdot (26.25'' + 16.025'')) \quad \sim F_p$$
$$= 0$$

$$F_{c_L} = \frac{(1.5\cdot(35.25-12.35) - 16.025)\cdot(0.60)\cdot(61{,}500)}{4\cdot\cos(23°)\cdot[\cos(73.6°)\cdot(61.69-12.35) + \sin(73.6°)\cdot(26.25+16.025)]}$$

$$F_{c_L} = \underline{\underline{3371\ lb_f}} \checkmark$$

BD-6400-060.1 (12/87)

**DESIGN CALCULATION**

(1) Drawing H-2-83728 (2) Doc. No. ______ (3) Page 7 of 9
(4) Building ______ (5) Rev. 0 (6) Job No. D2M9I
(7) Subject 106-C Package Tie-downs (Long Container)
(8) Originator H.E. Adkins Jr. Date 3-2-94
(9) Checker S.R. Crow Date 5-17-94

(10)

– Axial Loading – (8 cables – effective):

$\Sigma M = 0$ (Around center of rotation)

$(1.5G \cdot W_c \cdot (35.25'' - 5.67'')) - (W_c \cdot (372'' - \frac{8.75''}{2}))$

$- 8 F_{cA} \cdot (\cos(23°) \cdot \sin(73.6°) \cdot (372'' + 244'' - \frac{8.75''}{2})) = 0$

$$F_{cA} = \frac{(1.5 \cdot (35.25 - 5.67) - (372 - \frac{8.75}{2})) \cdot 61{,}500}{8 \cdot (\cos(23°) \cdot \sin(73.6°) \cdot (372 + 244 - \frac{8.75}{2}))}$$

$F_{cA} = -4601\ lb_f$ ✓

* The negative sign indicates that no tensile load will be applied to the cables.

→ All forces in the axial case will be applied to the saddles.

– Size of cables needed: (As per ANSI 14.2)

$F_{cA} < F_{cV} < F_{cL} = 3{,}371\ lb_f$ ✓

N.B.S. = Nominal Breaking Strength

$T_{eff}$ = terminal efficiency = 0.8

$S_{fac}$ = safety factor = 0.46

$Load_{max} = 3371\ lb_f = F_{cL}$

BD-6400-060.1 (12/87)

**DESIGN CALCULATION**

(1) Drawing H-2-83728 (2) Doc. No. ______ (3) Page 8 of 9
(4) Building ______ (5) Rev. 0 (6) Job No. D2M9I
(7) Subject 106-C Package Tie-downs (Long container)
(8) Originator H. E. Adkins Jr. Date 3-2-94
(9) Checker S.R.Crow Date 5-17-94

(10) $$N.B.S. = \frac{Load_{max}}{T_{eff} \cdot S_{fac.}} = \frac{3371}{(0.8)(0.46)} = 9160\ lb_f$$

- Possible D-rings, shackles, Turnbuckles and cable selections through McMaster-Carr.

* It is important to note that all spectrum analysis on the containers must be repeated because of this change in the tie-down system.

HEA Jr. 3-30-94

* A protection fixture will need to be placed @ locations where cables cross and remain in contact w/ each other in order to prevent cable wear. Because of the given cable configuration, 4 fixtures will be required.

BD-6400-060 1 (12/87)

**DESIGN CALCULATION**

(1) Drawing H-2-93728 (2) Doc. No. ______ (3) Page 9 of 9
(4) Building ______ (5) Rev. 0 (6) Job No. 02M9J
(7) Subject 106-C Package Tie-downs (Long Container)
(8) Originator H.E. Adkins Jr. Date 5-24-94
(9) Checker S.R. Crow Date 5-17-94

(10) It is recommended by ANSI 14.2, Appendix C, to "Pre-Load" the cables. Drawn from Table C-1 are the pretention percentages for the cables.

The pretention Loads are as follows.

- If Improved Plow Steel (IPS) wire rope is being used -

  Pre-load = (17%)·(Nominal breaking strength)
  = (0.17)·(Nominal breaking strength)

- If Galvanized Iron Wire (GIW) wire rope is being used -

  Pre-load = (39%)·(Cable breaking strength)
  = (0.39)(Cable breaking strength)

BD-6400-060 1 (12/87)

## 6.6 BRITTLE FRACTURE ANALYSIS

BRITTLE FRACTURE ANALYSIS
106-C PACKAGING PROJECT
D.B. CALMUS

**PACKAGING CATEGORY**: Determine the Packaging Category from Table 1 in Regulatory Guide 7.11. Since the contents are in excess of 30 $A_2$, the Packaging Category is II.

**REQUIREMENTS FOR NDT**: Use Category II information requirements listed in Table 5 of NUREG 1815 to determine the NDT for brittle fracture. As noted, for thickness between 0.19 to 0.625, selection of material made to "fine grain practice" is sufficient to meet brittle fracture requirements without testing. For thickness greater than 0.625, two options are available. One option is with full dynamic loading, and one option is for reduced loading rates. If the reduced loading is considered, Figure 7 can be used to determine the NDT or Table 6 (derived from Figure 7) can be used. Table 5 subscript "b" allows the use of material without testing if the NDT can be met by selecting the maximum NDT temperature given if Figure 1 or Table 3.

**PACKAGE LOADING**: Either full dynamic loading at yield stresses or reduced temperatures based on lower yields can be used to determine NDT as shown in Figure 6 of NUREG 1815. Curve 1 is for dynamic loading at yield stresses, curve 2 is material loaded to less than 100*g* and with yields strengths between 60 kips and 100 kips and curve 3 is for steels loaded to less than 100*g* and with yield strengths less than 60 kips.

For 106-C package transfers, hypothetical accidents are not considered credible and stresses during normal conditions of transfer are estimated to be well below yield stress and below 100*g* during transfer indicating that the dynamic load rates reduced by 30 °F or 70 °F (curve 2 or 3, Figure 6, NUREG 1815) may be considered. For this evaluation, the 70 °F reduction (curve 3) can be used since the A516 yield strength is below 60 kips (38 kips).

**CALCULATE NDT**: To determine the NDT for 2 in. thick material, use Table 6, curve 3 with Lowest Service Temperature (LST) specified to be -10 °F. The formula for determining NDT is NDT = LST-A. The A value is found in Table 6 to be -17 °F for 2 in. thick material. The calculated NDT = -10 °F -(-17 °F) or NDT = 7 °F.

**SELECT MATERIAL**: Use Table 3 to find the NDT ranges for various ASTM specifications of steel and select the material based on the calculated 7 °F NDT. A516 normalized steel has a NDT range of -50 °F to 10 °F and should be acceptable for this project. In addition, if the calculated NDT is equal to or greater than the maximum (10 °F) NDT range of the material, the material can be used without specific NDT testing. Under these conditions, 7 °F is considered close enough to the 10 °F maximum that A516 normalized steel is considered acceptable without specific NDT testing.

The above analysis is for the worst case (2 in. thick) brittle fracture material of the packaging containment flanges and indicates that the 1¼ in. thick blind flanges for the containment assembly are also considered acceptable.

# 7.0 THERMAL EVALUATION

## 7.1 INTRODUCTION

Internal heat generation of the contents should not prevent the container 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 HEAT TRANSFER EVALUATION AND CONCLUSION

Based on results of a gas generation study (Part B, Section 8.3), the maximum thermal loading of the package is estimated to be 6.23 Btu/h for the 102-AY agitator pump, 4.27 Btu/h for the 106-C heel pump and 0.614 Btu/h for the 106-C transfer pump. These minimal heat loads will be transferred passively to the environment and will not affect the integrity of the package during transfer or storage.

# 8.0 GAS GENERATION EVALUATION

## 8.1 GENERAL INFORMATION

Packages of radioactive waste with the potential for gas generation or 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 packages. 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 package due to waste contents.

## 8.2 GAS GENERATION EVALUATION AND CONCLUSIONS

Results of the gas generation study indicated that hydrogen gas build-up will exceed acceptable Westinghouse Hanford Company (WHC) limits of 5% within 8 years for the heel pump package and 6.9 years for the agitator pump package. To assure that hydrogen build-up will not exceed the acceptable limits during the 20 year service life of the package, both the primary and secondary containment barriers of the package are vented. The study also indicated that the estimated maximum internal pressure build-up in the package at the 5% hydrogen rate would be 0.77 psi. Considering this low rate (0.77 psi) of pressure build-up combined with the requirement that the package is vented, indicates that packaging design pressure ratings and extensive pressure leak testing analysis is not required for packages described in this SEP.

## 8.3 GAS GENERATION ANALYSIS

Westinghouse Hanford Company

**ANALYSIS**

Page 1 of 2
Job No. 106-C SEP
Date 01/08/94
By R. P. Genoni
Checked By L.E. [signature] 3/7/94

For: Packaging Safety Engineering
Location: 1100/MO-404/Room 4
Subject: Gas Generation for Pump Packages

**Problem:** Determine the hydrogen gas generation rates and potential operating pressures for two packaging variations (106-C equipment and 102-Y equipment), and 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) DOE/TIO-11026, D. C. Kocker, "Radioactive Decay Tables," April 1991

(3) WHC-SD-TP-PDC-015, "Packaging Design Criteria, Transfer and Disposal Equipment, Tank 241-C-106 Waste Sluicing System"

Determination:

The calculation technique described in Reference 1 was used to predict the radiolytic gas generation for two variations of transfer and disposal packagings containing equipment (pumps) from Tanks 106-C and 102-AY. The Lotus 1-2-3® spreadsheet provided with Reference 1 was the analytical tool used in this calculation. This methodology has been approved by the U. S. Nuclear Regulatory Commission as a means for determining hydrogen gas generation rates.

The following table contains data extracted from Reference 3, Appendix A, which was used for input into the spreadsheet

| Input | 102-AY Agitator | 106-C Heal Pump | 106-C Transfer Pump |
|---|---|---|---|
| Package ID | 51.25 in (4.27 ft) | 51.25 in (4.27 ft) | 51.25 in (4.27 ft) |
| Package Interior Length | 744 in (62 ft) | 588 in (49 ft) | 588 in (49 ft) |
| Package Volume | 888.2 $ft^3$ | 702.0 $ft^3$ | 702.0 $ft^3$ |
| Est. Pump Volume (non void) | 4.09 $ft^3$ | 3.54 $ft^3$ | 2.05 $ft^3$ |
| Est. Container Void Volume w/o waste | 884.11 $ft^3$ | 698.46 $ft^3$ | 699.95 $ft^3$ |
| Waste Weight | 146 lbs | 590 lbs | 85 lbs |
| Waste Volume | 2.024 $ft^3$ | 6.1 $ft^3$ | .878 $ft^3$ |
| Waste Density | 72.1 lbs/$ft^3$ | 96.7 lbs/$ft^3$ | 96.8 lbs/$ft^3$ |

54-7400-276 (2/88)

Westinghouse Hanford Company

**ANALYSIS**

Page 2 of 2
Job No. ~~106-C SEP~~
Date 01/08/94
By R. P. Genoni
Checked By J. E. Mercado 2/4/94

For Packaging Safety Engineering
Location 1100/MO-404/Room 4
Subject Gas Generation for Pump Packages

The following table contains results obtained from the spreadsheet calculations.

| Results | 102-AY Agitator | 106-C Heal Pump | 106-C Transfer Pump |
|---|---|---|---|
| Initial Gas Generation Rate | 2.340E+01 cc/hr | 1.577E+01 cc/hr | 2.270E+00 cc/hr |
| Gas Generation Rate @ 5% Hydrogen Concentration | 2.153E+01 cc/hr | 1.430E+01 cc/hr | 8.692E-01 cc/hr |
| Days (years) to 5% Concentration | 2544 (6.97) | 3004 (8.23) | At 100 years the concentration is 3.71%. |
| Pressure at 5% Concentration | .77 psi | .77 psi | .57 psi at 100 years |
| Max Decay Heat Watts (BTU/hr) | 6.231 (21.267) | 4.268 (14.566) | .614 (2.096) |

See spreadsheets and data library attached.

54-7400-276 (2/88)

PROGRAM to CLASSIFY RADIOACTIVE WASTE CONTAINERS for TRANSPORTATION and DISPOSAL
OP Defaults ..Analytical Resources, Inc., 3/85 & 8/90
Modified for DOE Radionuclides and Thermal Wattage
RP Summit[illegible] Field, Westinghouse–Hanford Co ... 8/90
Originally Published by the Electric Power Research Institute in NP-4888 and NP-4797

FILE REF: 100-AY Agitator Pump (WHC-SD-TP-PDC-[illegible])
DATE: 1/10/94 Revised
BY: R.P. General
CHECKED: [illegible]

*** 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")——> | Solid | >> 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=[illegible] liner, 3=[illegible] liner, 4=[illegible] liner)——> | 4 | >> Reqd input for H2 calculations |
| 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——> | [illegible] | |
| Enter date last sealed——> | [illegible] | >> |
| Enter date to be shipped——> | [illegible] | >> Must be later than CI date |
| Enter date of shipment receipt——> | [illegible] | |
| 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——> | [illegible] Ft3 | |
| Enter waste volume——> | 2.024 Ft3 | |
| CALCULATED Container void volume | [illegible] Ft3 | |
| Enter estimated waste void volume——> | Ft3 | |
| ** OR ** | | |
| Enter waste true density (vendor data)——> | 72.1 Lbs/Ft3 | |
| CALCULATED Waste void fraction = | -0.001 | |
| CALCULATED Waste void volume = | -0.00 Ft3 | |
| CALCULATED Package interior volume = | 2.[illegible]E+07 cc | |
| CALCULATED Waste volume = | 5.731E+04 cc | |
| CALCULATED Total void volume = | 2.[illegible]E+07 cc | |
| Enter waste weight——> | 146 Lbs | |
| CALCULATED Weight = | 6.[illegible]E+04 gms | |
| CALCULATED Waste bulk density = | 1.1[illegible] gms/cc | |
| Enter G-H2 (molecules/100 ev)——> | 0.45 | |
| 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 = | [illegible]E+06 | Rads |
| H2 Volume = | [illegible]E+02 | cm3 |
| H2 Concentration = | 0.00 | % |
| H2 Generation Rate = | 2.[illegible]E+01 | cc/hr |
| Pressure Buildup Rate = | [illegible]E-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* = | [illegible]E+02 | Ci (*Excludes Daughters with T 1/2 < 10 days) |
| Specific Activity, Total* = | [illegible] | mCi/cc |
| Specific Activity*, T 1/2 < 5 Years = | [illegible]E+0[illegible] | µCi/cc |
| T 1/2 > 5 Years = | 1.[illegible]E+04 | µCi/cc >> Verify Disposal Limits |
| Decay Heat @ Shipment: | | |
| Decay Heat @ Shipment = | [illegible] | Watts |
| or | [illegible] | BTU/hr |
| Fissile Material: | | |
| Fissile Material (49 CFR 173 & 10 CFR 71) = | [illegible] | gms |
| Other DOE Fissile Material (DOE 5480.1A) | [illegible] | gms >> Isotope list is incomplete |
| Special Nuclear Material: | | |

INPUT: LISTED ISOTOPES
( **** = Daughter Product )

Total Curies (ONLY if entering %) =

| Isotope | Curies | or | % | Curies when Sealed | Curies when Shipped |
|---|---|---|---|---|---|
| H-3——> | | | | [illegible] | [illegible] |
| C-14——> | [illegible]E-05 | | | [illegible]E-05 | [illegible]E-05 |
| Na-22——> | | | | [illegible] | [illegible] |
| Cr-51——> | | | | [illegible] | [illegible] |
| Mn-54——> | | | | [illegible] | [illegible] |
| Fe-55——> | | | | [illegible] | [illegible] |
| Co-57——> | | | | [illegible] | [illegible] |
| Co-58——> | | | | [illegible] | [illegible] |
| Fe-59——> | | | | [illegible] | [illegible] |
| Ni-59——> | | | | [illegible] | [illegible] |
| Co-60——> | 1.[illegible]E-0[illegible] | | | 1.[illegible]E-0[illegible] | 1.[illegible]E-0[illegible] |
| Ni-63——> | | | | [illegible] | [illegible] |
| Zn-65——> | | | | [illegible] | [illegible] |
| Se-7[illegible]——> | 1.700E-04 | | | 1.700E-04 | 1.700E-04 |
| Kr-85——> | | | | [illegible] | [illegible] |
| Sr-89——> | | | | [illegible] | [illegible] |
| Sr-90——> | [illegible]E+0[illegible] | | | [illegible]E+0[illegible] | [illegible]E+0[illegible] |
| Y-90——> | **** | | **** | [illegible]E+0[illegible] | [illegible]E+0[illegible] |
| Y-91——> | | | | [illegible] | [illegible] |
| Zr-93——> | | | | [illegible] | [illegible] |
| Nb-93m——> | | | | [illegible] | [illegible] |
| Nb-94——> | | | | [illegible] | [illegible] |
| Zr-95——> | | | | [illegible] | [illegible] |
| Nb-95——> | | | | [illegible] | [illegible] |
| Nb-95m——> | | | | [illegible] | [illegible] |
| Tc-99——> | 7.[illegible]E-04 | | | 7.[illegible]E-04 | 7.[illegible]E-04 |
| Ru-103——> | | | | [illegible] | [illegible] |
| Rh-103m——> | **** | | **** | [illegible] | [illegible] |
| Ru-106——> | | | | [illegible] | [illegible] |
| Rh-106——> | **** | | **** | [illegible] | [illegible] |
| Pd-107——> | | | | [illegible] | [illegible] |
| Cd-109——> | | | | [illegible] | [illegible] |
| Ag-110m——> | | | | [illegible] | [illegible] |
| Ag-110——> | **** | | **** | [illegible] | [illegible] |
| Sn-113——> | | | | [illegible] | [illegible] |
| In-113m——> | **** | | **** | [illegible] | [illegible] |
| Cd-113m——> | | | | [illegible] | [illegible] |
| Cd-115m——> | | | | [illegible] | [illegible] |
| Sn-119m——> | | | | [illegible] | [illegible] |
| Sn-121m——> | | | | [illegible] | [illegible] |
| Sn-123——> | | | | [illegible] | [illegible] |
| Te-123m——> | | | | [illegible] | [illegible] |
| Sb-124——> | | | | [illegible] | [illegible] |
| Sb-125——> | [illegible]E-01 | | | [illegible]E-01 | [illegible]E-01 |
| Te-125m——> | | | | [illegible] | [illegible] |
| Sn-126——> | | | | [illegible] | [illegible] |
| Sb-126m——> | **** | | **** | [illegible] | [illegible] |
| Sb-126——> | | | | [illegible] | [illegible] |
| Te-127m——> | | | | [illegible] | [illegible] |
| Te-127——> | **** | | **** | [illegible] | [illegible] |
| Te-129m——> | | | | [illegible] | [illegible] |
| Te-129——> | **** | | **** | [illegible] | [illegible] |
| I-129——> | [illegible]E-05 | | | [illegible]E-05 | [illegible]E-05 |
| I-131——> | | | | [illegible] | [illegible] |
| Cs-134——> | | | | [illegible] | [illegible] |
| Cs-135——> | | | | [illegible] | [illegible] |
| Cs-136——> | | | | [illegible] | [illegible] |
| Cs-137——> | 1.[illegible]E-01 | | | 1.[illegible]E-01 | 1.[illegible]E-01 |
| Ba-137m——> | **** | | **** | 1.447E-01 | 1.447E-01 |
| Ba-140——> | | | | [illegible] | [illegible] |
| La-140——> | **** | | **** | [illegible] | [illegible] |
| Ce-141——> | | | | [illegible] | [illegible] |
| Pr-143——> | | | | [illegible] | [illegible] |
| Ce-144——> | | | | [illegible] | [illegible] |
| Pr-144——> | **** | | **** | [illegible] | [illegible] |
| Pr-144m——> | | | | [illegible] | [illegible] |
| Nd-147——> | | | | [illegible] | [illegible] |
| Pm-147——> | | | | [illegible] | [illegible] |
| Pm-148m——> | | | | [illegible] | [illegible] |
| Pm-148——> | **** | | **** | [illegible] | [illegible] |
| Sm-151——> | | | | [illegible] | [illegible] |
| Eu-152——> | | | | [illegible] | [illegible] |
| Gd-153——> | | | | [illegible] | [illegible] |
| Eu-154——> | 1.[illegible]E+00 | | | 1.[illegible]E+00 | 1.[illegible]E+00 |
| Eu-155——> | | | | [illegible] | [illegible] |
| Eu-156——> | | | | [illegible] | [illegible] |
| Tb-160——> | | | | [illegible] | [illegible] |
| Ta-182——> | | | | [illegible] | [illegible] |
| Ra-226——> | | | | [illegible] | [illegible] |
| U-[illegible]——> | | | | [illegible] | [illegible] |
| U-234——> | | | | [illegible] | [illegible] |
| U-235——> | | | | [illegible] | [illegible] |
| U-236——> | | | | [illegible] | [illegible] |
| U-237——> | | | | [illegible] | [illegible] |
| U-238——> | | | | [illegible] | [illegible] |

| | | | | |
|---|---|---|---|---|
| Special Nuclear Material (SNM) | = | 1.[illegible] | gms | |
| Other DOE Accountable Material (DOE 5633.3) | = | 0.17[illegible] | gms | >> Isotope list is incomplete |
| Transuranics: | | | | |
| Specific Activity, Transuranics | = | 1113[illegible] | nCi/gm | >>Potential GTCC |
| 10 CFR 61.55 Classification: | | Unity Fraction | | Classification |
| Table 1 Isotopes | = | 1112.[illegible] | A | Class > C |
| (Long Lived) | | N/A | B | |
| | | 111.[illegible] | C | Limiting Isotope |
| | | | | Am-241 |
| Table 2 Isotopes | = | [illegible] | A | |
| (Short Lived) | | 107.[illegible] | B | Miscellaneous |
| | | 2.[illegible] | C | |
| Transportation Classification | | Unity Fraction | | |
| LSA Determination | = | 2.[illegible]E+03 | > LSA | |
| Type Determination | = | 2.[illegible]E+03 | Type 'B' | |
| Highway Route Control (HRC) Determination | = | [illegible].172E-01 | Non HRC | |
| Limited Quantity (LQ) Determination | = | 2.[illegible]E+06 | > LQ | |
| Advance Notification Quantity ? | = | Yes | | |
| EPA Reportable Quantity (RQ) Determination | = | [illegible] | Reportable Quantity | |

| | | | | |
|---|---|---|---|---|
| Np-237 ——> | | | [illegible] | [illegible] |
| Pu-238 ——> | [illegible]E-02 | | [illegible]E-02 | [illegible]E-02 |
| Pu-239 ——> | 1.1[illegible]E-01 | | 1.1[illegible]E-01 | 1.1[illegible]E-01 |
| Pu-240 ——> | | | 0.000E+00 | 0.000E+00 |
| Pu-241 ——> | | | 0.000E+00 | 0.000E+00 |
| Pu-242 ——> | | | 0.000E+00 | 0.000E+00 |
| Am-241 ——> | [illegible]E-01 | | [illegible]E-01 | [illegible]E-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 |
| Cm-243 ——> | 1.[illegible]E-[illegible] | | 1.[illegible]E-[illegible] | 1.[illegible]E-[illegible] |
| Cm-244 ——> | 1.[illegible]E-02 | | 1.[illegible]E-02 | 1.[illegible]E-02 |

PROGRAM to CLASSIFY RADIOACTIVE WASTE CONTAINERS for TRANSPORTATION and DISPOSAL
OP Dolton...Analytical Resources, Inc., 2/88 & 6/90
(Modified for DOE Radionuclides and Thermal Wattage, RP Bonetti/JS Field Westinghouse-Hanford Co...6/93)

Originally Published by the Electric Power Research Institute in NP-4830 and NP-4757

FILE REF. 101-AY Agitator Pump (WHC-SD-TP-PDC-010)
DATE: 1/10/94 Revised
BY: R.P. Bonetti
CHECKED: [signature]

*** WASTE GENERAL INFORMATION ***

| | | | |
|---|---|---|---|
| Enter waste description --- > | | | |
| " --- > | | | |
| " --- > | | | |
| Enter waste form ("Special" or "Normal") --- > | Normal | | >> Required input for DOT calculations |
| Enter physical form ("Solid", "Liquid" or "Gas") --- > | Solid | | >> Required input for DOT calculations |
| Is waste Activated Metal ? ("Yes", or "No") --- > | no | | >> Required input for 10CFR61 calculations |
| Enter container type (1=55 gal drum, 2=4x4 Box, 3=6x6 liner, 4=8x8 liner) --- > | 4 | | >> Required input for H2 calculations |
| Is container a vented HIC ? ("Yes", or "No") --- > | No | | "Note: For a vented HIC, examine "Date sealed" is date shipped in Cask |
| Enter date of curie calculations --- > | 09/09/91 | | |
| Enter date last sealed* --- > | 09/09/91 | | >> |
| Enter date to be shipped --- > | 08/27/2000 | | >> Must be later than CI calcs |
| Enter date of shipment receipt --- > | 08/27/2000 | | |
| CALCULATED Decay before sealing (years) = | 0.00 | Days= | 0 |
| CALCULATED Decay before shipment (years) = | 8.87 | Days= | 3244 |
| CALCULATED Duration package is sealed (years) = | 8.87 | Days= | 3244 |
| Enter package interior volume --- > | 884.110 | Ft3 | |
| Enter waste volume --- > | 2.004 | Ft3 | |
| CALCULATED Container void volume. | 882.1 | Ft3 | |
| Enter estimated waste void volume --- > | | Ft3 | |
| ** OR ** | | | |
| Enter waste true density (vendor data) --- > | 72.1 | Lbs/Ft3 | |
| CALCULATED Waste void fraction = | -0.001 | | |
| CALCULATED Waste void volume = | -0.00 | Ft3 | |
| CALCULATED Package interior volume = | 2.504E+07 | cc | |
| CALCULATED Waste volume = | 5.731E+04 | cc | |
| CALCULATED Total void volume = | 2.498E+07 | cc | |
| Enter waste weight --- > | 146 | Lbs | |
| CALCULATED Weight = | 6.622E+04 | gms | |
| CALCULATED Waste bulk density = | 1.1555 | gms/cc | |
| Enter G-H2 (molecules/100 ev) --- > | 0.45 | | |
| OR | | | |
| Enter volume cation resin (cu ft) --- > | | | |
| Enter volume anion resin (cu ft) --- > | | | |
| Enter volume mixed 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 = | 1.891E+00 | Rads | |
| H2 Volume = | 1.314E+00 | cm3 | |
| H2 Concentration = | 0.00 | % | |
| H2 Generation Rate = | 2.153E-01 | cc/hr | |
| Pressure Buildup Rate = | 3.942E-04 | 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* = | 7.822E+02 | Ci | (*Excludes Daughters with T 1/2 < 10 days) |
| Specific Activity, Total* = | 13.640 | mCi/cc | |
| Specific Activity*, T 1/2 < 5 Years = | 8.428E-01 | µCi/cc | |
| T 1/2 > 5 Years = | 1.365E+04 | µCi/cc | >> Verify Disposal License |
| Decay Heat @ Shipment: | | | |
| Decay Heat @ Shipment = | 5.288 | Watts | |
| or | 17.880 | BTU/hr | |
| Fissile Material: | | | |
| Fissile Material (49 CFR 173 & 10 CFR 71) = | 1.584 | gms | |
| Other DOE Fissile Material (DOE 5480.1A) | 0.000 | gms | >> Isotope list is incomplete |
| Special Nuclear Material: | | | |

INPUT: LISTED ISOTOPES (**** = Daughter Product)
Total Curies (ONLY if entering %) =

| Isotope | Curies | or % | Curies when Sealed | Curies when Shipped |
|---|---|---|---|---|
| H-3 ---> | | | 0.000E+00 | 0.000E+00 |
| C-14 ---> | 3.100E-05 | | 3.100E-05 | 3.097E-05 |
| Na-22 ---> | | | 0.000E+00 | 0.000E+00 |
| Cr-51 ---> | | | 0.000E+00 | 0.000E+00 |
| Mn-54 ---> | | | 0.000E+00 | 0.000E+00 |
| Fe-55 ---> | | | 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 ---> | | | 0.000E+00 | 0.000E+00 |
| Co-60 ---> | 1.000E-06 | | 1.000E-06 | 4.400E-07 |
| Ni-63 ---> | | | 0.000E+00 | 0.000E+00 |
| Zn-65 ---> | | | 0.000E+00 | 0.000E+00 |
| Se-79 ---> | 1.700E-04 | | 1.700E-04 | 1.700E-04 |
| Sr-85 ---> | | | 0.000E+00 | 0.000E+00 |
| Sr-89 ---> | | | 0.000E+00 | 0.000E+00 |
| Sr-90 ---> | 9.240E+02 | | 9.240E+02 | 7.690E+02 |
| Y-90 ---> | **** | **** | 9.240E+02 | 7.690E+02 |
| Y-91 ---> | | | 0.000E+00 | 0.000E+00 |
| Zr-93 ---> | | | 0.000E+00 | 0.000E+00 |
| Nb-93m ---> | | | 0.000E+00 | 0.000E+00 |
| Nb-94 ---> | | | 0.000E+00 | 0.000E+00 |
| 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 ---> | 7.000E-04 | | 7.000E-04 | 7.000E-04 |
| 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 ---> | 5.000E-01 | | 5.000E-01 | 5.400E-02 |
| 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 ---> | 3.700E-05 | | 3.700E-05 | 3.700E-05 |
| 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 ---> | 1.500E-01 | | 1.500E-01 | 1.204E-01 |
| Ba-137m ---> | **** | **** | 1.447E-01 | 1.228E-01 |
| 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 ---> | 1.000E+00 | | 1.000E+00 | [illegible]E-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 |
| Tm-170 ---> | | | 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 ---> | | | 0.000E+00 | 0.000E+00 |
| U-236 ---> | | | 0.000E+00 | 0.000E+00 |
| U-237 ---> | | | 0.000E+00 | 0.000E+00 |
| U-238 ---> | | | 0.000E+00 | 0.000E+00 |

| | | | |
|---|---|---|---|
| Special Nuclear Material (SNM) = | 1.[illegible] | gms | |
| Other DOE Accountable Material (DOE 5633.3) = | [illegible] | gms | >> Isotope list is Incomplete |
| Transuranics: | | | |
| Specific Activity, Transuranics = | 11123.[illegible] | nCi/gms | >>Potential STCC |
| 10 CFR 61.55 Classification: | Unity Fraction | | Classification |
| Table 1 Isotopes = | [illegible] | A | Class > C |
| (Long Lived) | N/A | B | |
| | [illegible] | C | Limiting Isotope |
| | | | Am-241 |
| Table 2 Isotopes = | [illegible]417.[illegible] | A | |
| (Short Lived) | [illegible] | B | [illegible] |
| | 1.[illegible] | C | |
| Transportation Classification: | Unity Fraction | | |
| LSA Determination = | [illegible] | > LSA | |
| Type Determination = | [illegible] | Type 'B' | |
| Highway Route Control (HRC) Determination = | [illegible]-01 | Non HRC | |
| Limited Quantity (LQ) Determination = | [illegible] | > LQ | |
| Advance Notification Quantity ? = | Yes | | |
| EPA Reportable Quantity (RQ) Determination = | 7.[illegible] | Reportable Quantity | |

| | | | | | |
|---|---|---|---|---|---|
| Np-237 ------> | | | | [illegible] | [illegible] |
| Pu-238 ------> | [illegible] | | | [illegible] | [illegible] |
| Pu-239 ------> | 1.1[illegible]E-01 | | | 1.1[illegible]E-01 | 1.1[illegible]E-01 |
| Pu-240 ------> | | | | [illegible] | [illegible] |
| Pu-241 ------> | | | | [illegible] | [illegible] |
| Pu-242 ------> | | | | [illegible] | [illegible] |
| Am-241 ------> | [illegible]-01 | | | [illegible]-01 | [illegible]-01 |
| Am-242m ------> | | | | [illegible] | [illegible] |
| Am-243 ------> | **** | | **** | [illegible] | [illegible] |
| Am-[illegible] ------> | | | | [illegible] | [illegible] |
| Cm-242 ------> | 1.[illegible] | | | 1.[illegible] | [illegible]-14 |
| Cm-244 ------> | 1.[illegible] | | | 1.[illegible] | 1.[illegible] |

PROGRAM to CLASSIFY RADIOACTIVE WASTE
CONTAINERS for TRANSPORTATION and DISPOSAL
[illegible]
[illegible]
[illegible]

Originally Published by the Electric Power Research Institute in NP-[illegible] and NP-4787

FILE REF: 100-C Heat Pump (WHC-SD-TP-PDC-016)
DATE: [illegible] Revised
BY: R.P. [illegible]
CHECKED: [illegible]

*** WASTE GENERAL INFORMATION ***

| | | |
|---|---|---|
| Enter waste description ————> | | |
| Enter waste form ("Special" or "Normal") ————> | Normal | >> Req'd input for DOT calculations |
| Enter physical form ("Solid", "Liquid" or "Gas") ————> | Solid | >> Req'd input for DOT calculations |
| Is waste Activated Metal ? ("Yes", or "No") ————> | no | >> Req'd input for 10CFR61 calculations |
| Enter container type (1=55 gal. drum, 2=[illegible] liner, 3=[illegible] liner, 4=[illegible] liner) ————> | 4 | >> Req'd input for H2 calculations |
| Is container a vented HIC ? ("Yes", or "No") ————> | No | *Note: For a vented HIC, assume "Date sealed" is date shipped to Cask |
| Enter date of curie calculations ————> | [illegible] | |
| Enter date last sealed* ————> | [illegible] | >> |
| Enter date to be shipped ————> | [illegible] | >> Must be later than CI calc |
| Enter date of shipment receipt ————> | [illegible] | |
| CALCULATED Decay before sealing (years) = | 0.00 | Days |
| CALCULATED Decay before shipment (years) = | 0.00 | Days |
| CALCULATED Duration package is sealed (years) = | 0.00 | Days |
| Enter package interior volume ————> | [illegible] | Ft3 |
| Enter waste volume ————> | [illegible] | Ft3 |
| CALCULATED Container void volume | [illegible] | Ft3 |
| Enter estimated waste void volume ————> | | Ft3 |
| ** OR ** | | |
| Enter waste true density (wonder data) ————> | [illegible] | Lbs/Ft3 |
| CALCULATED Waste void fraction = | [illegible] | |
| CALCULATED Waste void volume = | [illegible] | Ft3 |
| CALCULATED Package interior volume = | [illegible] | cc |
| CALCULATED Waste volume = | [illegible] | cc |
| CALCULATED Total void volume = | [illegible] | cc |
| Enter waste weight ————> | [illegible] | Lbs |
| CALCULATED Weight = | [illegible] | gms |
| CALCULATED Waste bulk density = | [illegible] | g/cc |
| Enter G-H2 (molecules/100 ev) ————> | [illegible] | |
| 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 = | [illegible] | |

*** CALCULATED RESULTS ***

| | | |
|---|---|---|
| H2 Generation Summary: | | |
| Total Integrated Dose = | [illegible] | Rads |
| H2 Volume = | [illegible] | cm3 |
| H2 Concentration = | 0.00 | % |
| H2 Generation Rate = | [illegible] | cc/hr |
| Pressure Buildup Rate = | [illegible] | psi/day |
| Pressure (total 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* = | [illegible] | Ci (*Excludes Daughters with T 1/2 < 10 days) |
| Specific Activity, Total* = | [illegible] | uCi/cc |
| Specific Activity*, T 1/2 < 5 Years = | [illegible] | uCi/cc |
| T 1/2 > 5 Years = | [illegible] | uCi/cc >> Verify Disposal Limits |
| Decay Heat @ Shipment: | | |
| Decay Heat @ Shipment = | [illegible] | Watts |
| or | [illegible] | BTU/hr |
| Fissile Material: | | |
| Fissile Material (49 CFR 173 & 10 CFR 71) = | [illegible] | gms |
| Other DOE Fissile Material (DOE 5400 1A) = | [illegible] | gms >> [illegible] |
| Special Nuclear Material: | | |

INPUT: LISTED ISOTOPES (**** = Daughter Product)

Total Curies (ONLY if entering %) =

| Isotope | Curies | or % | Curies when Sealed | Curies when Shipped |
|---|---|---|---|---|
| H-3 ————> | | | [illegible] | [illegible] |
| C-14 ————> | [illegible] | | [illegible] | [illegible] |
| Na-22 ————> | | | [illegible] | [illegible] |
| Cr-51 ————> | | | [illegible] | [illegible] |
| Mn-54 ————> | | | [illegible] | [illegible] |
| Fe-55 ————> | | | [illegible] | [illegible] |
| Co-57 ————> | | | [illegible] | [illegible] |
| Co-58 ————> | | | [illegible] | [illegible] |
| Fe-59 ————> | | | [illegible] | [illegible] |
| Ni-59 ————> | 2.100E-02 | | 2.100E-02 | 2.100E-02 |
| Co-60 ————> | [illegible] | | [illegible] | [illegible] |
| Ni-63 ————> | [illegible] | | [illegible] | [illegible] |
| Zn-65 ————> | | | [illegible] | [illegible] |
| [illegible] ————> | [illegible] | | [illegible] | [illegible] |
| [illegible] ————> | | | [illegible] | [illegible] |
| [illegible] ————> | | | [illegible] | [illegible] |
| [illegible] ————> | [illegible] | | [illegible] | [illegible] |
| Y-90 ————> | **** | **** | [illegible] | [illegible] |
| Y-91 ————> | | | [illegible] | [illegible] |
| [illegible] (remaining isotope rows) | [illegible] | [illegible] | [illegible] | [illegible] |

| | | | | |
|---|---|---|---|---|
| Special Nuclear Material (SNM) | = | [illegible] | gms | |
| Other DOE Accountable Material (DOE 5633.3) | = | [illegible] | gms | >> Isotope list is incomplete |
| Transuranics: | | | | |
| Specific Activity, Transuranics | = | [illegible] | nCi/gms | >>Potential GTCC |
| 10 CFR 61.55 Classification | | Unity Fraction | | Classification |
| Table 1 Isotopes | = | [illegible] | A | Class > C |
| (Long Lived) | | N/A | B | |
| | | [illegible] | C | Limiting Isotope |
| | | | | Am-241 |
| Table 2 Isotopes | = | [illegible] | A | |
| (Short Lived) | | [illegible] | B | Miscellaneous |
| | | [illegible] | C | |
| Transportation Classification | | Unity Fraction | | |
| LSA Determination | = | [illegible] | > LSA | |
| Type Determination | = | [illegible] | Type "B" | |
| Highway Route Control (HRC) Determination | = | [illegible] | Non HRC | |
| Limited Quantity (LQ) Determination | = | [illegible] | > LQ | |
| Advance Notification Quantity ? | = | Yes | | |
| EPA Reportable Quantity (RQ) Determination | = | [illegible] | Reportable Quantity | |

| | | | | |
|---|---|---|---|---|
| [illegible] ——> | | | [illegible] | [illegible] |
| [illegible] ——> | [illegible] | | [illegible] | [illegible] |
| [illegible] ——> | [illegible] | | [illegible] | [illegible] |
| [illegible] ——> | | | [illegible] | [illegible] |
| [illegible] ——> | | | [illegible] | [illegible] |
| [illegible] ——> | [illegible] | | [illegible] | [illegible] |
| [illegible] ——> | [illegible] | | [illegible] | [illegible] |
| [illegible] ——> | | | [illegible] | [illegible] |
| [illegible] ——> | **** | **** | [illegible] | [illegible] |
| [illegible] ——> | [illegible] | | [illegible] | [illegible] |
| [illegible] ——> | [illegible] | | [illegible] | [illegible] |
| [illegible] ——> | [illegible] | | [illegible] | [illegible] |

* [illegible]

PROGRAM to CLASSIFY RADIOACTIVE WASTE CONTAINERS for TRANSPORTATION and DISPOSAL
[illegible]

FILE REF. [illegible]

DATE [illegible]

BY R.P. [illegible]

*** WASTE GENERAL INFORMATION ***

[illegible]

*** CALCULATED RESULTS ***

[illegible]

INPUT: LISTED ISOTOPES

| | Curies | | % | Curies when Sealed | Curies when Shipped |
|---|---|---|---|---|---|
| Total Curies | [illegible] | | | [illegible] | [illegible] |
| [illegible] | [illegible] | | | [illegible] | [illegible] |

| | | | | |
|---|---|---|---|---|
| Special Nuclear Material (SNM) | = | [illegible] | gms | |
| Other DOE Accountable Material (DOE 5633.3) | = | 0.271 | gms | >> Isotope list is incomplete |
| Transuranics, Specific Activity, Transuranics | = | [illegible] | nCi/gms | >>Potential GTCC |
| 10 CFR 61.55 Classification | | Unity Fraction | | Classification |
| Table 1 Isotopes | = | [illegible] | A | Class > C |
| (Long Lived) | | N/A | B | |
| | | [illegible] | C | Limiting Isotope Am-241 |
| Table 2 Isotopes | = | [illegible] | A | |
| (Short Lived) | | [illegible] | B | [illegible] |
| | | 0.010 | C | |
| Transportation Classification | | Unity Fraction | | |
| LSA Determination | = | [illegible] | > LSA | |
| Type Determination | = | [illegible] | Type B | |
| Highway Route Control (HRC) Determination | = | [illegible] | Non HRC | |
| Limited Quantity (LQ) Determination | = | [illegible] | > LQ | |
| Advance Notification Quantity ? | = | Yes | | |
| EPA Reportable Quantity (RQ) Determination | = | [illegible] | Reportable Quantity | |

| | | | | |
|---|---|---|---|---|
| Np-237 → | | | [illegible] | [illegible] |
| Pu-238 → | 1.1[illegible]-01 | | 1.1[illegible]-01 | 1.[illegible]-01 |
| Pu-239 → | [illegible]-01 | | [illegible]-01 | [illegible]-01 |
| Pu-240 → | | | [illegible] | [illegible] |
| Pu-241 → | | | [illegible] | [illegible] |
| Pu-242 → | 1.[illegible]-04 | | 1.[illegible]-04 | 1.[illegible]-04 |
| Am-241 → | 7.[illegible]-01 | | 7.[illegible]-01 | 7.[illegible]-01 |
| [illegible] → | | | [illegible] | [illegible] |
| [illegible] → | **** | **** | [illegible] | [illegible] |
| [illegible] → | [illegible] | | [illegible] | [illegible] |
| [illegible] → | [illegible] | | [illegible] | [illegible] |
| [illegible] → | [illegible] | | [illegible] | [illegible] |

* [illegible]

PROGRAM to CLASSIFY RADIOACTIVE WASTE CONTAINERS for TRANSPORTATION and DISPOSAL
CP DuBois...Analytical Resources, Inc., 3/86 & 6/86
(Modified for DOE Radionuclides and Thermal Wattage.
RP Genoni/JG Field, Westinghouse-Hanford Co....8/90)

Originally Published by the Electric Power Research Institute in NP-4938 and NP-4787

FILE REF: 100-C Transfer Pump (WHC-SD-TP-PDO-019)
DATE: 5/16/94 Revised
BY: R.P. Genoni
CHECKED: jen

*** 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") ——— > | Solid | >> 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=Soft liner, 3=Soft liner, 4=Std liner) ——— > | 4 | >> Reqd input for H2 calculations | |
| Is container a vented HIC ? ("Yes", or "No") ——— > | No | *Note: For a vented HIC, estimate "Date sealed" is date shipped in Cask | |
| Enter date of mple calculations ——— > | 08/08/93 | | |
| Enter date last sealed* ——— > | 08/08/93 | >> | |
| Enter date to be shipped ——— > | 08/10/93 | >> Must be later than CI entry | |
| Enter date of shipment receipt ——— > | 08/10/93 | | |
| 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 ——— > | 600.950 | Ft3 | |
| Enter waste volume ——— > | 0.870 | Ft3 | |
| CALCULATED Container void volume | 600.1 | Ft3 | |
| Enter estimated waste void volume ——— > | | Ft3 | |
| ** OR ** | | | |
| Enter waste true density (vendor data) ——— > | 90.0 | Lbs/Ft3 | |
| CALCULATED Waste void fraction = | -0.000 | | |
| CALCULATED Waste void volume = | -0.00 | Ft3 | |
| CALCULATED Package interior volume = | 1.[illegible]E+07 | cc | |
| CALCULATED Waste volume = | 2.467E+04 | cc | |
| CALCULATED Total void volume = | 1.[illegible]E+07 | cc | |
| Enter waste weight ——— > | 85 | Lbs | |
| CALCULATED Weight = | [illegible]E+04 | gms | |
| CALCULATED Waste bulk density = | 1.[illegible] | gms/cc | |
| Enter G-H2 (molecules/100 ev) ——— > | 0.45 | | |
| 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 = | 1.344E+05 | Rads | |
| H2 Volume = | 5.447E+01 | cm3 | |
| H2 Concentration = | 0.00 | % | |
| H2 Generation Rate = | 2.270E+00 | cc/hr | |
| Pressure Building Rate = | 4.047E-05 | 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* = | [illegible]E+01 | Ci | (*Excludes Daughters with T 1/2 < 10 days) |
| Specific Activity, Total* = | [illegible] | mCi/cc | |
| Specific Activity*, T 1/2 < 5 Years = | [illegible]E+00 | µCi/cc | |
| T 1/2 > 5 Years = | [illegible]E+00 | µCi/cc | >> Verify Disposal License |
| Decay Heat @ Shipment | | | |
| Decay Heat @ Shipment = | 0.814 | Watts | |
| or | 2.[illegible] | BTU/hr | |
| Fissile Material | | | |
| Fissile Material (49 CFR 173 & 10 CFR 71) = | 1.737 | gms | |
| Other DOE Fissile Material (DOE 5480.1A) | 0.000 | gms | >> Isotope list is incomplete |
| Special Nuclear Material | | | |

INPUT LISTED ISOTOPES (**** = Daughter Product)

| Isotope | Curies | or | % | Curies when Sealed | Curies when Shipped |
|---|---|---|---|---|---|
| Total Curies (ONLY if entering %) = | | | | [illegible] | [illegible] |
| H-3 ———> | | | | 0.000E+00 | 0.000E+00 |
| C-14 ———> | 7.700E-03 | | | 7.700E-03 | 7.700E-03 |
| Na-22 ———> | | | | 0.000E+00 | 0.000E+00 |
| Cr-51 ———> | | | | 0.000E+00 | 0.000E+00 |
| Mn-54 ———> | | | | 0.000E+00 | 0.000E+00 |
| Fe-55 ———> | | | | 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 ———> | 3.100E-03 | | | 3.100E-03 | 3.100E-03 |
| Co-60 ———> | 4.470E-02 | | | 4.470E-02 | 4.4[illegible]E-02 |
| Ni-63 ———> | 5.570E-01 | | | 5.570E-01 | 5.570E-01 |
| Zn-65 ———> | | | | 0.000E+00 | 0.000E+00 |
| Se-79 ———> | [illegible]E-05 | | | [illegible]E-05 | [illegible]E-05 |
| Kr-85 ———> | | | | 0.000E+00 | 0.000E+00 |
| Sr-89 ———> | | | | 0.000E+00 | 0.000E+00 |
| Sr-90 ———> | 7.600E+01 | | | 7.600E+01 | 7.600E+01 |
| Y-90 ———> | **** | | **** | 7.600E+01 | 7.600E+01 |
| Y-91 ———> | | | | 0.000E+00 | 0.000E+00 |
| Zr-93 ———> | | | | 0.000E+00 | 0.000E+00 |
| Nb-93m ———> | | | | 0.000E+00 | 0.000E+00 |
| Nb-94 ———> | | | | 0.000E+00 | 0.000E+00 |
| 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 ———> | [illegible]E-03 | | | [illegible]E-03 | [illegible]E-03 |
| 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 ———> | 2.100E-01 | | | 2.100E-01 | 2.1[illegible]E-01 |
| 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 | [illegible]E+00 |
| Te-127m ———> | | | | 0.000E+00 | [illegible]E+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 ———> | 3.000E-03 | | | 3.000E-03 | 3.000E-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 ———> | 1.940E+01 | | | 1.940E+01 | 1.940E+01 |
| Ba-137m ———> | **** | | **** | 1.[illegible]E+01 | 1.[illegible]E+01 |
| 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 ———> | 3.870E-01 | | | 3.870E-01 | 3.[illegible]E-01 |
| Eu-155 ———> | | | | 0.000E+00 | 0.000E+00 |
| Sm-153 ———> | | | | 0.000E+00 | 0.000E+00 |
| Tb-160 ———> | | | | 0.000E+00 | 0.000E+00 |
| Tm-170 ———> | | | | 0.000E+00 | 0.000E+00 |
| Ra-226 ———> | 2.300E-04 | | | 2.300E-04 | 2.300E-04 |
| U-233 ———> | 2.200E-08 | | | 2.200E-08 | 2.200E-08 |
| U-234 ———> | 1.300E-06 | | | 1.300E-06 | 1.300E-06 |
| U-235 ———> | 5.100E-07 | | | 5.100E-07 | 5.100E-07 |
| U-236 ———> | 2.720E-07 | | | 2.720E-07 | 2.720E-07 |
| U-237 ———> | 1.[illegible]E-08 | | | 1.215E-08 | 1.101E-08 |
| U-238 ———> | | | | 0.000E+00 | 0.000E+00 |

| | | | | |
|---|---|---|---|---|
| Special Nuclear Material (SNM) | = | 1.741 | gms | |
| Other DOE Accountable Material (DOE 5633.3) | = | 0.940 | gms | >> Isotope list is incomplete |
| Transuranics: | | | | |
| Specific Activity, Transuranics | = | [illegible].701 | nCi/gms | >>Potential GTCC |
| 10 CFR 61.55 Classification | | Unity Fraction | | Classification |
| Table 1 Isotopes | = | [illegible].639 | A | Class > C |
| (Long Lived) | | N/A | B | |
| | | [illegible].210 | C | Limiting Isotope |
| | | | | Am-241 |
| Table 2 Isotopes | = | 77402.[illegible] | A | |
| (Short Lived) | | [illegible] | B | Miscellaneous |
| | | 0.[illegible] | C | |
| Transportation Classification | | Unity Fraction | | |
| LSA Determination | = | 4.[illegible]E+02 | > LSA | |
| Type Determination | = | 2.[illegible]E+02 | Type 'B' | |
| Highway Route Control (HRC) Determination | = | [illegible]E-02 | Non HRC | |
| Limited Quantity (LQ) Determination | = | 2.[illegible]E+05 | > LQ | |
| Advance Notification Quantity ? | = | Yes | | |
| EPA Reportable Quantity (RQ) Determination | = | [illegible]E+02 | Reportable Quantity | |

| | | | | |
|---|---|---|---|---|
| Np-237-------> | | | [illegible]E+00 | [illegible]E+00 |
| Pu-238-------> | 1.870E-02 | | 1.870E-02 | 1.870E-02 |
| Pu-239-------> | [illegible]E-02 | | [illegible]E-02 | [illegible]E-02 |
| Pu-240-------> | | | [illegible]E+00 | [illegible]E+00 |
| Pu-241-------> | | | [illegible]E+00 | [illegible]E+00 |
| Pu-242-------> | 1.[illegible]E-05 | | 1.[illegible]E-05 | 1.[illegible]E-05 |
| Am-241-------> | 1.1[illegible]E-01 | | 1.1[illegible]E-01 | 1.1[illegible]E-01 |
| Am-242m-------> | | | [illegible]E+00 | [illegible]E+00 |
| Am-242-------> | **** | **** | [illegible]E+00 | [illegible]E+00 |
| Am-243-------> | [illegible]E-04 | | [illegible]E-04 | [illegible]E-04 |
| Cm-243-------> | 4.[illegible]E-04 | | 4.[illegible]E-04 | 4.[illegible]E-04 |
| Cm-244-------> | [illegible]E-05 | | [illegible]E-05 | [illegible]E-05 |

* Curie content for Ra-226 includes Ac-227, Pb-210, and Po-210. Ra-226 is 99% of total Ci; others have energies less than Ra-226.

PROGRAM to CLASSIFY RADIOACTIVE WASTE CONTAINERS for TRANSPORTATION and DISPOSAL
DP Dobelo... Analytical Resources, Inc., 2/83 & 8/90
Modified for DOE Radionuclides and Thermal Wattage..
RP Bernard/JS Field...Westinghouse-Hanford Co....8/90)

Originally Published by the Electric Power Research Institute in NP-4000 and NP-4757

| | | |
|---|---|---|
| FILE REF. | 105-C Transfer Pump (WHC-SD-TP-PDC-016) | |
| DATE: | 1/18/94 Revised | |
| BY: | R.P. Bernard | |
| CHECKED: | *[signature]* | |

*** WASTE GENERAL INFORMATION ***

| | | | |
|---|---|---|---|
| Enter waste description | > | | |
| Enter waste form ("Special" or "Normal") | > | Normal | >> Req'd input for DOT calculations |
| Enter physical form ("Solid", "Liquid" or "Gas") | > | Solid | >> Req'd input for DOT calculations |
| Is waste Activated Metal ? ("Yes", or "No") | > | no | >> Req'd input for 10CFR61 calculations |
| Enter container type (1=55 gal. drum, 2=4x4 Box, 3=B-25 Box, 4=Bull Bear) | > | 4 | >> Req'd input for H2 calculations |
| 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 waste calculations | > | 00/00/00 | |
| Enter date last sealed | > | 00/00/00 | >> |
| Enter date to be shipped | > | 00/00/2000 | >> Must be later than CI calc |
| Enter date of shipment receipt | > | 00/00/2000 | |
| CALCULATED Decay before sealing (years) | = | 0.00 | Days= 0 |
| CALCULATED Decay before shipment (years) | = | 100.07 | Days= [illegible] |
| CALCULATED Duration package is sealed (years) | = | 100.07 | Days= [illegible] |
| Enter package interior volume | > | [illegible] | Ft3 |
| Enter waste volume | > | 0.879 | Ft3 |
| CALCULATED Container void volume. | | [illegible].1 | Ft3 |
| Enter estimated waste void volume | > | | Ft3 |
| ** OR ** | | | |
| Enter waste true density (vendor data) | > | 86.9 | Lbs/Ft3 |
| CALCULATED Waste void fraction | = | -0.000 | |
| CALCULATED Waste void volume | = | -0.00 | Ft3 |
| CALCULATED Package interior volume | = | 1.882E+07 | cc |
| CALCULATED Waste volume | = | 2.487E+04 | cc |
| CALCULATED Total void volume | = | 1.880E+07 | cc |
| Enter waste weight | > | 85 | Lbs |
| CALCULATED Weight | = | 3.856E+04 | gms |
| CALCULATED Waste bulk density | = | 1.5520 | gms/cc |
| Enter G-H2 (molecules/100 ev) | > | 0.45 | |
| 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.[illegible]E+09 | Rads |
| H2 Volume | = | 7.[illegible]E+06 | cm3 |
| H2 Concentration | = | 3.71 | % |
| H2 Generation Rate | = | [illegible]E-01 | cc/hr |
| Pressure Buildup Rate | = | 1.[illegible]E-05 | psi/day |
| Pressure (seal to ship) | = | 0.57 | psi |
| Enter Measured H2 Concentration (If known) | > | 0.00 | % |
| Ratio Measured to Calculated H2 Concentrations | = | 0.00 | |
| Activity Summary @ Shipment: | | | |
| Total Activity* | = | [illegible]E+00 | Ci (*Excludes Daughters with T 1/2 < 10 days) |
| Specific Activity, Total* | = | 0.[illegible] | mCi/cc |
| Specific Activity*, T 1/2 < 5 Years | = | 1.161E-10 | µCi/cc |
| T 1/2 > 5 Years | = | [illegible]E+02 | µCi/cc >> Verify Disposal License |
| Decay Heat @ Shipment: | | | |
| Decay Heat @ Shipment | = | 0.0[illegible] | Watts |
| or | | 0.[illegible] | BTU/hr |
| Fissile Material: | | | |
| Fissile Material (49 CFR 173 & 10 CFR 71) | = | 1.7[illegible] | gms |
| Other DOE Fissile Material (DOE 5480.1A) | | 0.000 | gms >> Isotope list is incomplete |
| Special Nuclear Material: | | | |

INPUT: LISTED ISOTOPES (**** = Daughter Product)

Total Curies (ONLY 1 entering %) =

| Nuclide | Curies | or | % | Curies when Sealed | Curies when Shipped |
|---|---|---|---|---|---|
| H-3 | | | | 0.000E+00 | 0.000E+00 |
| C-14 | 7.750E-03 | | | 7.750E-03 | 7.50[illegible]E-03 |
| Na-22 | | | | 0.000E+00 | 0.000E+00 |
| Cr-51 | | | | 0.000E+00 | 0.000E+00 |
| Mn-54 | | | | 0.000E+00 | 0.000E+00 |
| Fe-55 | | | | 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 | 5.150E-03 | | | 5.150E-03 | 5.127E-03 |
| Co-60 | 4.470E-02 | | | 4.470E-02 | [illegible]E-03 |
| Ni-63 | 5.570E-01 | | | 5.570E-01 | 1.7[illegible]E-01 |
| Zn-65 | | | | 0.000E+00 | 0.000E+00 |
| Se-79 | [illegible]E-05 | | | [illegible]E-05 | [illegible]E-05 |
| Sr-89 | | | | 0.000E+00 | 0.000E+00 |
| Sr-90 | | | | 0.000E+00 | 0.000E+00 |
| Sr-90 | 7.[illegible]E+01 | | | 7.[illegible]E+01 | [illegible]E+00 |
| Y-90 | **** | | **** | 7.[illegible]E+01 | [illegible]E+00 |
| Y-91 | | | | 0.000E+00 | 0.000E+00 |
| Zr-93 | | | | 0.000E+00 | 0.000E+00 |
| Nb-93m | | | | 0.000E+00 | 0.000E+00 |
| Nb-94 | | | | 0.000E+00 | 0.000E+00 |
| 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 | 5.[illegible]E-05 | | | 5.[illegible]E-05 | 5.[illegible]E-05 |
| 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 | 2.100E-01 | | | 2.100E-01 | 2.[illegible]E-12 |
| 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 | [illegible]E-08 | | | [illegible]E-08 | [illegible]E-08 |
| 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 | 1.840E+01 | | | 1.840E+01 | 1.[illegible]E+00 |
| Ba-137m | **** | | **** | 1.[illegible]E+01 | 1.[illegible]E+00 |
| 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 | 8.870E-01 | | | 8.870E-01 | 1.161E-04 |
| 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 | 2.[illegible]E-04 * | | | 2.[illegible]E-04 | 2.291E-04 |
| U-233 | 2.[illegible]E-06 | | | 2.[illegible]E-06 | 2.[illegible]E-06 |
| U-234 | 1.[illegible]E-06 | | | 1.[illegible]E-06 | 1.[illegible]E-06 |
| U-235 | 6.190E-07 | | | 6.190E-07 | 6.190E-07 |
| U-236 | 2.720E-07 | | | 2.720E-07 | 2.720E-07 |
| U-237 | 1.[illegible]E-06 | | | 1.21[illegible]E-0[illegible] | 0.000E+00 |
| U-238 | | | | 0.000E+00 | 0.000E+00 |

| | | | | |
|---|---|---|---|---|
| Special Nuclear Material (SNM) | = | 1.737 | gms | |
| Other DOE Accountable Material (DOE 5633.3) | = | 0.034 | gms | >> Isotope list is incomplete |
| Transuranics | | | | |
| Specific Activity, Transuranics | = | [illegible].791 | nCi/gm | >>Potential GTCC |
| 10 CFR 61.55 Classification | | Unity Fraction | | Classification |
| Table 1 Isotopes | = | 911.220 | A | Class > C |
| (Long Lived) | | N/A | B | |
| | | 84.135 | C | Limiting Isotope |
| | | | | Am-241 |
| Table 2 Isotopes | = | [illegible] | A | |
| (Short Lived) | | 3.[illegible] | B | Miscellaneous |
| | | 0.[illegible] | C | |
| Transportation Classification: | | Unity Fraction | | |
| LSA Determination | = | [illegible]E+01 | > LSA | |
| Type Determination | = | 7.78[illegible]E+01 | Type 'B' | |
| Highway Route Control (HRC) Determination | = | 2.[illegible]E-02 | Non HRC | |
| Limited Quantity (LQ) Determination | = | 7.7[illegible]E+04 | > LQ | |
| Advance Notification Quantity ? | = | No | | |
| EPA Reportable Quantity (RQ) Determination | = | [illegible]E+01 | Reportable Quantity | |

| | | | | | |
|---|---|---|---|---|---|
| Np-237 ---> | | | | 0.000E+00 | 0.000E+00 |
| Pu-238 ---> | 1.070E-02 | | | 1.070E-02 | 7.577E-05 |
| Pu-239 ---> | 9.290E-02 | | | 9.290E-02 | 9.225E-02 |
| Pu-240 ---> | | | | 0.000E+00 | 0.000E+00 |
| Pu-241 ---> | | | | 0.000E+00 | 0.000E+00 |
| Pu-242 ---> | 1.540E-05 | | | 1.540E-05 | 1.540E-05 |
| Am-241 ---> | 1.150E-01 | | | 1.150E-01 | 3.[illegible]E-02 |
| Am-242m ---> | | | | 0.000E+00 | 0.000E+00 |
| Am-242 ---> | **** | | **** | 0.000E+00 | 0.000E+00 |
| Am-243 ---> | 8.[illegible]E-04 | | | 8.[illegible]E-04 | 8.1[illegible]E-04 |
| Cm-243 ---> | 4.[illegible]E-04 | | | 4.[illegible]E-04 | 1.[illegible]E-11 |
| Cm-244 ---> | 8.170E-03 | | | 8.170E-03 | 1.121E-04 |

* Curie content for Ra-226 includes Ac-227, Pb-210, and Po-210. Ra-226 is 80% of total Ci; others have energies less than Ra-226

<<< MISCELLANEOUS CONSTANTS >>>

| | | | | | |
|---|---|---|---|---|---|
| K-value (ev-cm3/rad-gm-mole): | 2.330E-08 | | | | |
| A-value (rad-gm/Mev-yr-Ci): | 1.860E+10 | | | | |
| Absorption Coefficients | | | | | |
| A1= | -3.2073E-01 | A4= | -8.9368E-01 | A7= | 1.5401E+00 |
| A2= | 6.0128E-01 | A5= | -1.2519E+00 | A8= | 5.0155E-01 |
| A3= | 7.4785E-01 | A6= | -4.6194E-01 | A9= | -2.9473E-06 |
| Absorption @ 0.4 MeV = | 0.84 | | | | |
| Thermal Constants: (W/Ci-Mev/dis): | 5.9288E-03 | | | | |
| (BTU/h/Ci-Mev/dis): | 2.0230E-02 | | | | |
| APS 1 Limit= | 0.0001 | | | | |
| APS 2 Limit= | 0.005 | | | | |
| APS 3 Limit= | 0.30 | | | | |

| <<< RADIONUCLIDE >>> <<< CONSTANTS >>> | Half Life (yrs) | Beta Energy Avg. Mev | * Low X-Ray Energy Avg. Mev | Gamma Energy Mev/Dis | Intensity Abundance (fraction) | Alpha Energy Avg. Mev | Gamma Absorption (fraction) | Absorbed: Disintegration Gamma Energy (Mev/dis.) | Absorbed: Isotope Tot. Gamma Energy | Adj Beta/Gamma Energy (Mev/dis) | Total: Isotope Gamma Energy (Mev/dis) | Total: Isotope Decay Energy (Mev/dis) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H-3: | 1.228E+01 | 0.0057 | 0.0000 | 0.0000 | 0.0000 | | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0057 |
| C-14: | 5.730E+03 | 0.0495 | 0.0000 | 0.0000 | 0.0000 | | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0495 |
| Na-22: | 2.602 | 0.1930 | 0.0001 | 1.2750 | 0.9994 | | 0.7912 | 1.0082 | 1.0082 | 1.2742 | 1.2742 | 1.4679 |
| Cr-51: | 7.595E-02 | 0.0000 | 0.0047 | 0.3201 | 0.0983 | | 0.8740 | 0.0275 | 0.0275 | 0.0315 | 0.0315 | 0.0362 |
| Mn-54: | 8.561E-01 | 0.0000 | 0.0052 | 0.8348 | 0.9998 | | 0.9121 | 0.0770 | 0.0770 | 0.0846 | 0.0846 | 0.0898 |
| Fe-55: | 2.700E+00 | 0.0000 | 0.0058 | 0.0000 | 0.0000 | | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0058 |
| Co-57: | 7.417E-01 | 0.0000 | 0.0232 | 0.1230 | 0.8720 | | 0.8510 | 0.1155 | 0.1147 | 0.1199 | 0.1207 | 0.1439 |
| | | | | 0.0820 | 0.0016 | | 0.9280 | 0.0000 | | 0.0011 | | |
| Co-58: | 1.936E-01 | 0.0290 | 0.0063 | 0.8110 | 1.0010 | | 0.0138 | 0.0804 | 0.7947 | 0.8510 | 0.8734 | 1.0077 |
| | | | | 1.6750 | 0.0054 | | 0.7772 | 0.0079 | | 0.0090 | | |
| | | | | 0.5110 | 0.2990 | | 0.9240 | 0.1275 | | 0.1530 | | |
| Fe-59: | 1.222E-01 | 0.1175 | 0.0000 | 0.1920 | 0.0433 | | 0.9248 | 0.0077 | 0.9469 | 0.0083 | 1.1873 | 1.3048 |
| | | | | 1.0992 | 0.5650 | | 0.7957 | 0.4901 | | 0.6211 | | |
| | | | | 1.2910 | 0.4370 | | 0.7900 | 0.4411 | | 0.5600 | | |
| Ni-59: | 7.500E+04 | 0.0000 | 0.0087 | 0.0000 | 0.0000 | | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0087 |
| Co-60: | 5.271E+00 | 0.0958 | 0.0000 | 1.1732 | 1.0000 | | 0.7864 | 0.9232 | 1.8848 | 1.1732 | 2.5057 | 2.6015 |
| | | | | 1.3325 | 1.0000 | | 0.7880 | 1.0518 | | 1.3325 | | |
| Ni-63: | 1.001E+02 | 0.0171 | 0.0000 | 0.0000 | 0.0000 | | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0171 |
| Zn-65: | 6.681E-01 | 0.0029 | 0.0077 | 1.1156 | 0.5075 | | 0.7980 | 0.4510 | 0.4630 | 0.5661 | 0.5806 | 0.5906 |
| | | | | 0.5110 | 0.0283 | | 0.8840 | 0.0121 | | 0.0145 | | |
| Se-79: | 6.500E+04 | 0.0522 | 0.0000 | 0.0000 | 0.0000 | | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0522 |
| Kr-85: | 1.072E+01 | 0.2505 | 0.0000 | 0.5140 | 0.0043 | | 0.8330 | 0.0018 | 0.0018 | 0.0022 | 0.0022 | 0.2527 |
| Sr-89: | 1.384E-01 | 0.5830 | 0.0000 | 0.9091 | 0.0002 | | 0.8081 | 0.0001 | 0.0001 | 0.0002 | 0.0002 | 0.5832 |
| Sr-90: | 2.860E+01 | 0.1958 | 0.0000 | 0.0000 | 0.0000 | | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1958 |
| Y-90: | | 0.9340 | 0.0000 | 0.0000 | 0.0000 | | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.9340 |
| Y-91: | 1.602E-01 | 0.6023 | 0.0000 | 1.2040 | 0.0030 | | 0.7941 | 0.0029 | 0.0029 | 0.0036 | 0.0036 | 0.6059 |
| Zr-93: | 1.530E+06 | 0.0195 | 0.0000 | 0.0000 | 0.0000 | | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0195 |
| Nb-93m: | 1.460E+01 | 0.0000 | 0.0303 | 0.0000 | 0.0000 | | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0303 |
| Nb-94: | 2.030E+04 | 0.1459 | 0.0011 | 0.7028 | 1.0000 | | 0.8201 | 0.5765 | 1.2819 | 0.7028 | 1.5737 | 1.7208 |
| | | | | 0.8711 | 1.0000 | | 0.8101 | 0.7057 | | 0.8711 | | |
| Zr-95: | 1.753E-01 | 0.1161 | 0.0029 | 0.7242 | 0.4370 | | 0.8190 | 0.2591 | 0.6000 | 0.3165 | 0.7340 | 0.8510 |
| | | | | 0.7567 | 0.5530 | | 0.8167 | 0.3419 | | 0.4185 | | |
| Nb-95: | 9.586E-02 | 0.0434 | 0.0000 | 0.7660 | 0.9981 | | 0.8162 | 0.6230 | 0.6230 | 0.7640 | 0.7640 | 0.8066 |
| Nb-95m: | 9.578E-03 | 0.0341 | 0.1830 | 0.2357 | 0.2500 | | 0.8576 | 0.0505 | 0.0505 | 0.0589 | 0.0589 | 0.2460 |
| Tc-99: | 2.130E+05 | 0.0846 | 0.0000 | 0.0000 | 0.0000 | | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0846 |
| Ru-103: | 1.077E-01 | 0.0674 | 0.0032 | 0.4970 | 0.8940 | | 0.8352 | 0.3711 | 0.4031 | 0.4449 | 0.4031 | 0.5256 |
| | | | | 0.6100 | 0.0636 | | 0.8200 | 0.0320 | | 0.0387 | | |
| Rh-103m: | | 0.0000 | 0.0000 | 0.0007 | 0.0007 | | 0.9944 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Ru-106: | 1.008E+00 | 0.0100 | 0.0000 | 0.0000 | 0.0000 | | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0100 |
| Rh-106: | | 1.4110 | 0.0000 | 0.5119 | 0.2000 | | 0.8330 | 0.0879 | 0.1407 | 0.1054 | 0.1769 | 1.5879 |
| | | | | 0.6210 | 0.1040 | | 0.8257 | 0.0533 | | 0.0646 | | |
| | | | | 1.2010 | 0.0055 | | 0.7922 | 0.0055 | | 0.0066 | | |
| Pd-107: | 6.500E+06 | 0.0093 | 0.0000 | 0.0000 | 0.0000 | | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0093 |
| Cd-109: | 1.270E+00 | 0.0000 | 0.0190 | 0.0000 | 0.0000 | | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0190 |
| Ag-110m: | 6.827E-01 | 0.0668 | 0.0016 | 0.6179 | 1.3640 | | 0.8260 | 0.0000 | 2.1573 | 0.8554 | 2.0000 | 2.7062 |
| | | | | 0.8850 | 1.4115 | | 0.8190 | 0.9620 | | 1.2111 | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1.4080 | 0.4200 | 0.7940 | 0.4000 | | 0.0100 | | |
| Ag-110 : | 7.922E-07 | 1.1000 | 0.0000 | 0.0677 | 0.0440 | 0.8231 | 0.0243 | 0.0240 | 0.0250 | 0.0000 | 1.2145 |
| Sn-113 : | 3.151E-01 | 0.0000 | 0.0232 | 0.2551 | 0.0193 | 0.9000 | 0.0044 | 0.0044 | 0.0040 | 0.0040 | 0.0281 |
| In-113m : | 1.004E-04 | 0.0000 | 0.1300 | 0.3017 | 0.6490 | 0.0465 | 0.2162 | 0.2152 | 0.3542 | 0.3542 | 0.5002 |
| Cd-113m : | 1.370E+01 | 0.1054 | 0.0000 | 0.0000 | 0.0090 | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1054 |
| Cd-115m : | 1.220E-01 | 0.0062 | 0.0000 | 0.0340 | 0.0133 | 0.0067 | 0.0100 | 0.0100 | 0.0124 | 0.0200 | 0.0262 |
| | | | | 1.2910 | 0.0058 | 0.7900 | 0.0000 | | 0.0070 | | |
| Sn-119m : | 8.027E-01 | 0.0000 | 0.0000 | 0.0230 | 0.1816 | 0.9000 | 0.0030 | 0.0030 | 0.0030 | 0.0030 | 0.0071 |
| Sn-121m : | 7.600E+01 | 0.1400 | 0.0400 | 0.0000 | 0.0090 | 1.0000 | 0.0000 | | 0.0000 | | |
| Sn-123 : | 3.537E-01 | 0.5203 | 0.0000 | 1.0000 | 0.0000 | 0.7982 | 0.0062 | 0.0062 | 0.0065 | 0.0065 | 0.5200 |
| Te-123m : | 3.200E-01 | 0.0000 | 0.1121 | 0.1590 | 0.0410 | 0.9877 | 0.1264 | 0.1264 | 0.1937 | 0.1937 | 0.2450 |
| Sb-124 : | 1.640E-01 | 0.3776 | 0.0200 | 0.6030 | 0.9830 | 0.0270 | 0.4002 | 1.4013 | 0.0827 | 1.8714 | 2.2800 |
| | | | | 0.6400 | 0.0740 | 0.0230 | 0.0504 | | 0.0470 | | |
| | | | | 0.7240 | 0.1500 | 0.0100 | 0.0037 | | 0.1144 | | |
| | | | | 1.0000 | 0.0070 | 0.9031 | 0.0006 | | 0.0300 | | |
| | | | | 1.3540 | 0.0545 | 0.7801 | 0.0002 | | 0.0730 | | |
| | | | | 1.4750 | 0.0381 | 0.7837 | 0.0440 | | 0.0002 | | |
| | | | | 1.0010 | 0.4000 | 0.7787 | 0.0435 | | 0.0200 | | |
| | | | | 2.0910 | 0.0573 | 0.7657 | 0.0017 | | 0.1190 | | |
| Sb-125 : | 2.770E+00 | 0.0005 | 0.0254 | 0.1760 | 0.0016 | 0.9010 | 0.0134 | 0.3012 | 0.0143 | 0.4000 | 0.8310 |
| | | | | 0.3000 | 0.0224 | 0.9011 | 0.0072 | | 0.0005 | | |
| | | | | 0.4370 | 0.4020 | 0.0404 | 0.1470 | | 0.1767 | | |
| | | | | 0.6170 | 0.3000 | 0.0200 | 0.1000 | | 0.3218 | | |
| Te-125m : | 1.000E-01 | 0.0000 | 0.1410 | 0.1900 | 0.0020 | 0.9672 | 0.0003 | 0.0003 | 0.0003 | 0.0003 | 0.1410 |
| Sn-126 : | 1.000E+05 | 0.0701 | 0.0022 | 0.0640 | 0.0000 | 0.0740 | 0.0000 | 0.0440 | 0.0002 | 0.0400 | 0.1700 |
| | | | | 0.0900 | 0.0000 | 0.9050 | 0.0076 | | 0.0077 | | |
| | | | | 0.0876 | 0.3700 | 0.9057 | 0.0013 | | 0.0004 | | |
| Sb-126m : | 3.010E-05 | 0.8700 | 0.0211 | 0.4150 | 0.0000 | 0.0424 | 0.3027 | 1.3012 | 0.3004 | 1.5750 | 2.1744 |
| | | | | 0.6700 | 0.0150 | 0.0257 | 0.0077 | | 0.0080 | | |
| | | | | 0.0000 | 0.0040 | 0.0220 | 0.4733 | | 0.6784 | | |
| | | | | 0.0050 | 0.0340 | 0.0206 | 0.4020 | | 0.0005 | | |
| | | | | 0.8700 | 0.0130 | 0.0071 | 0.0007 | | 0.0121 | | |
| | | | | 1.0350 | 0.0190 | 0.0017 | 0.0140 | | 0.0100 | | |
| Sb-126 : | 3.400E-02 | 0.2000 | 0.1420 | 0.0000 | 0.0000 | 0.0220 | 0.5400 | 2.1001 | 0.0003 | 2.0007 | [illegible] |
| | | | | 0.6050 | 0.0006 | 0.0200 | 0.3601 | | 0.0022 | | |
| | | | | 0.4147 | 0.0330 | 0.0424 | 0.2910 | | 0.3454 | | |
| | | | | 0.5730 | 0.0670 | 0.0291 | 0.0310 | | 0.0004 | | |
| | | | | 0.6030 | 0.0750 | 0.0277 | 0.0300 | | 0.0440 | | |
| | | | | 0.6970 | 0.2000 | 0.0206 | 0.1000 | | 0.2021 | | |
| | | | | 0.7205 | 0.5300 | 0.0100 | 0.3175 | | 0.0070 | | |
| | | | | 0.0500 | 0.1700 | 0.0100 | 0.1223 | | 0.1000 | | |
| | | | | 0.0000 | 0.0000 | 0.0030 | 0.0041 | | 0.0073 | | |
| | | | | 1.2130 | 0.0230 | 0.7900 | 0.0200 | | 0.0200 | | |
| Te-127m : | 2.900 | 0.0040 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0002 |
| Te-127 : | 1.087E-03 | 0.2230 | 0.0000 | 0.4180 | 0.0090 | 0.9421 | 0.0009 | 0.0006 | 0.0041 | 0.0041 | 0.2271 |
| Te-129m : | 9.100E-02 | 0.2120 | 0.0716 | 0.1060 | 0.0018 | 0.0006 | 0.0002 | 0.0100 | 0.0002 | 0.0231 | 0.3067 |
| | | | | 0.0000 | 0.0330 | 0.0200 | 0.0100 | | 0.0230 | | |
| Te-129 : | 1.329E-04 | 0.3220 | 0.0190 | 0.0270 | 0.1630 | 0.0001 | 0.0045 | 0.0372 | 0.0045 | 0.0430 | 0.0051 |
| | | | | 0.4500 | 0.0710 | 0.0000 | 0.0274 | | 0.0230 | | |
| | | | | 0.4874 | 0.0131 | 0.0060 | 0.0005 | | 0.0004 | | |
| I-129 : | 1.570E+07 | 0.0400 | 0.0300 | 0.0300 | 0.0752 | 0.0046 | 0.0020 | 0.0000 | 0.0030 | 0.0000 | 0.0010 |
| I-131 : | 2.201E-02 | 0.1017 | 0.0124 | 0.2840 | 0.0000 | 0.0007 | 0.0176 | 0.0231 | 0.0100 | 0.3700 | 0.0727 |
| | | | | 0.3640 | 0.0140 | 0.0074 | 0.0540 | | 0.2000 | | |
| | | | | 0.6370 | 0.0777 | 0.0240 | 0.0400 | | 0.0400 | | |
| | | | | 0.7230 | 0.0190 | 0.0100 | 0.0107 | | 0.0130 | | |
| Cs-134 : | 2.062E+00 | 0.1570 | 0.0005 | 0.4750 | 0.0146 | 0.0070 | 0.0000 | 1.2794 | 0.0000 | 1.5002 | 1.7170 |
| | | | | 0.5670 | 0.2300 | 0.0200 | 0.1120 | | 0.1340 | | |
| | | | | 0.6000 | 0.9700 | 0.0200 | 0.0002 | | 0.0005 | | |
| | | | | 0.7970 | 0.0410 | 0.0143 | 0.0107 | | 0.7500 | | |
| | | | | 1.0300 | 0.0100 | 0.0015 | 0.0000 | | 0.0104 | | |
| | | | | 1.1680 | 0.0180 | 0.7027 | 0.0107 | | 0.0210 | | |
| | | | | 1.3650 | 0.0304 | 3.7877 | 0.0007 | | 0.0015 | | |
| Cs-135 : | 2.000E+06 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Cs-136 : | 3.003E-02 | 0.1001 | 0.0300 | 0.0000 | 0.2200 | 0.0005 | 0.0170 | 1.7054 | 0.0104 | 2.1000 | 2.3030 |
| | | | | 0.1000 | 0.2000 | 0.0042 | 0.0422 | | 0.0402 | | |
| | | | | 0.2740 | 0.1270 | 0.0020 | 0.0011 | | 0.0040 | | |
| | | | | 0.3410 | 0.4010 | 0.0004 | 0.1401 | | 0.1074 | | |
| | | | | 0.8070 | 0.0000 | 0.0043 | 0.0041 | | 0.0000 | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0.0100 | 0.0070 | 0.0130 | [illegible] | | 0.0165 | | |
| | | | | 1.0400 | 0.7900 | 0.0011 | [illegible] | | 0.0042 | | |
| | | | | 1.2360 | 0.1970 | 0.7920 | 0.1920 | | 0.2433 | | |
| Cs-137 : | 3.017E+01 | 0.1700 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 | 0.0000 | 0.4000 | 0.0000 | 0.1700 |
| Ba-137m : | | 0.0000 | 0.0057 | 0.0010 | [illegible] | 0.0220 | 0.4000 | 0.4000 | 0.0064 | 0.0064 | 0.0011 |
| Ba-140 : | 3.501E-02 | 0.2720 | 0.0384 | 0.1930 | 0.0087 | 0.0301 | 0.0105 | 0.1530 | 0.0112 | 0.1022 | 0.4930 |
| | | | | 0.3050 | 0.0450 | 0.0000 | 0.0121 | | 0.0137 | | |
| | | | | 0.4300 | 0.0535 | 0.0410 | 0.0190 | | 0.0230 | | |
| | | | | 0.5370 | 0.2400 | 0.0710 | 0.1117 | | 0.1340 | | |
| La-140 : | 4.000E-03 | 0.5260 | 0.0060 | 0.3280 | 0.2100 | 0.0711 | 0.0010 | 1.0001 | 0.0711 | 2.3100 | 2.0400 |
| | | | | 0.4040 | 0.0040 | 0.0300 | 0.1000 | | 0.2040 | | |
| | | | | 0.8160 | 0.3330 | 0.0132 | 0.2222 | | 0.2734 | | |
| | | | | 0.9250 | 0.1000 | 0.0072 | 0.0704 | | 0.0071 | | |
| | | | | 1.5960 | 0.0000 | 0.7797 | 1.1004 | | 1.8242 | | |
| | | | | 2.4000 | 0.0442 | 0.7370 | 0.0000 | | 0.1100 | | |
| Ce-141 : | 6.000E-07 | 0.1447 | 0.0010 | 0.1454 | 0.4040 | 0.0430 | 0.0004 | 0.0004 | 0.0704 | 0.0704 | 0.2407 |
| Pr-143 : | 3.713E-02 | 0.3100 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.3100 |
| Ce-144 : | 7.704E-01 | 0.0027 | 0.0140 | 0.1340 | 0.1190 | 0.0479 | 0.0151 | 0.0015 | 0.0150 | 0.0072 | 0.1330 |
| | | | | 1.4000 | 0.0030 | 0.7030 | 0.0000 | | 0.0040 | | |
| | | | | 2.1000 | 0.0077 | 0.7000 | 0.0120 | | 0.0100 | | |
| Pr-144 : | 8.770E-01 | 1.2072 | 0.0000 | 0.0000 | 0.0140 | 0.0200 | 0.0005 | 0.0240 | 0.0100 | 0.0015 | 1.2000 |
| | | | | 2.1000 | 0.0007 | 0.7030 | 0.0102 | | 0.0012 | | |
| Pr-144m : | 1.300E-05 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Nd-147 : | 8.030E-02 | 0.2333 | 0.0025 | 0.0910 | 0.2800 | 0.0040 | 0.0240 | 0.0000 | 0.0005 | 0.1121 | 0.4070 |
| | | | | 0.3194 | 0.0190 | 0.0740 | 0.0000 | | 0.0000 | | |
| | | | | 0.4300 | 0.0120 | 0.0001 | 0.0044 | | 0.0003 | | |
| | | | | 0.5310 | 0.1310 | 0.0304 | 0.0570 | | 0.0000 | | |
| | | | | 0.0000 | 0.0001 | 0.0212 | 0.0040 | | 0.0000 | | |
| Pm-147 : | 2.023E+00 | 0.0620 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Pm-148m : | 1.131E-01 | 0.1400 | 0.0207 | 0.0005 | 0.0047 | 0.0014 | 0.0023 | 1.0040 | 0.0024 | 1.0000 | 2.1000 |
| | | | | 0.1900 | 0.0110 | 0.0200 | 0.0010 | | 0.0021 | | |
| | | | | 0.7000 | 0.1200 | 0.0071 | 0.0022 | | 0.0000 | | |
| | | | | 0.3120 | 0.0300 | 0.0777 | 0.0107 | | 0.0122 | | |
| | | | | 0.4140 | 0.1070 | 0.0426 | 0.0002 | | 0.0774 | | |
| | | | | 0.4000 | 0.9540 | 0.0007 | 0.0107 | | 0.0304 | | |
| | | | | 0.5010 | 0.0000 | 0.0340 | 0.0204 | | 0.0041 | | |
| | | | | 0.5900 | 0.0400 | 0.0300 | 0.4307 | | 0.0220 | | |
| | | | | 0.0000 | 0.1254 | 0.0272 | 0.0022 | | 0.0758 | | |
| | | | | 0.9110 | 0.0040 | 0.0204 | 0.0277 | | 0.0000 | | |
| | | | | 0.0000 | 0.0000 | 0.0200 | 0.4000 | | 0.0007 | | |
| | | | | 0.7200 | 0.3200 | 0.0107 | 0.1940 | | 0.2001 | | |
| | | | | 0.0150 | 0.1720 | 0.0077 | 0.1271 | | 0.1074 | | |
| | | | | 1.0140 | 0.2030 | 0.0027 | 0.1002 | | 0.2000 | | |
| Pm-149 : | 1.470E-08 | 0.7200 | 0.0051 | 0.5500 | 0.2200 | 0.0300 | 0.1000 | 0.4020 | 0.1210 | 0.0005 | 1.2076 |
| | | | | 0.0110 | 0.0102 | 0.0204 | 0.0002 | | 0.0000 | | |
| | | | | 0.0000 | 0.0000 | 0.2000 | 0.0071 | | 0.0000 | | |
| | | | | 0.0150 | 0.1100 | 0.0077 | 0.0000 | | 0.1002 | | |
| | | | | 1.4050 | 0.2220 | 0.7041 | 0.2300 | | 0.3052 | | |
| Sm-151 : | 9.000E+01 | 0.0100 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0100 |
| Eu-152 : | 1.360E+01 | 0.1100 | 0.0400 | 0.1220 | 0.2000 | 0.0022 | 0.0200 | 0.0270 | 0.0200 | 0.0030 | 0.0175 |
| | | | | 0.2450 | 0.0542 | 0.0040 | 0.0120 | | 0.0100 | | |
| | | | | 0.4440 | 0.0202 | 0.0307 | 0.0075 | | 0.0000 | | |
| | | | | 0.0000 | 0.0001 | 0.0216 | 0.0004 | | 0.0042 | | |
| | | | | 0.0076 | 0.0300 | 0.0105 | 0.0211 | | 0.0200 | | |
| | | | | 0.0040 | 0.1040 | 0.0002 | 0.0007 | | 0.1002 | | |
| | | | | 1.0000 | 0.0722 | 0.7002 | 0.0027 | | 0.0704 | | |
| | | | | 1.1120 | 0.0000 | 0.7007 | 0.0002 | | 0.1000 | | |
| | | | | 1.2130 | 0.0100 | 0.7000 | 0.0000 | | 0.0021 | | |
| | | | | 1.4000 | 0.1405 | 0.7007 | 0.1054 | | 0.2104 | | |
| | | | | 0.3440 | 0.0707 | 0.0002 | 0.0210 | | 0.0000 | | |
| | | | | 0.3000 | 0.0024 | 0.0000 | 0.0000 | | 0.0000 | | |
| | | | | 0.4110 | 0.0001 | 0.0420 | 0.0021 | | 0.0000 | | |
| | | | | 0.7790 | 0.0300 | 0.0104 | 0.0226 | | 0.0277 | | |
| | | | | 1.0000 | 0.0007 | 0.7001 | 0.0041 | | 0.0001 | | |
| | | | | 1.2000 | 0.0045 | 0.7000 | 0.0040 | | 0.0000 | | |
| Gd-153 : | 6.019E-01 | 0.0000 | 0.0000 | 0.0007 | 0.0357 | 0.0727 | 0.0017 | 0.0000 | 0.0010 | 0.0001 | 0.1020 |
| | | | | 0.0074 | 0.3100 | 0.0010 | 0.0200 | | 0.0000 | | |
| | | | | 0.1030 | 0.2220 | 0.0000 | 0.0010 | | 0.0020 | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Eu-154: | 0.000E+00 | 0.2200 | 0.0040 | 0.1200 | 0.4000 | 0.0010 | 0.0474 | 0.0070 | 0.0400 | 1.1904 | 1.0102 |
| | | | | 0.2480 | 0.0000 | 0.0020 | 0.0148 | | 0.0104 | | |
| | | | | 0.0020 | 0.0004 | 0.0265 | 0.0041 | | 0.0040 | | |
| | | | | 0.9020 | 0.0453 | 0.0270 | 0.0237 | | 0.0200 | | |
| | | | | 0.0000 | 0.0140 | 0.0200 | 0.0000 | | 0.0117 | | |
| | | | | 0.7230 | 0.1070 | 0.0100 | 0.1100 | | 0.1404 | | |
| | | | | 0.7570 | 0.0433 | 0.0107 | 0.0200 | | 0.0330 | | |
| | | | | 0.8730 | 0.1190 | 0.0100 | 0.0013 | | 0.1004 | | |
| | | | | 0.9040 | 0.0002 | 0.0000 | 0.0000 | | 0.0074 | | |
| | | | | 0.0000 | 0.1000 | 0.0000 | 0.0024 | | 0.1030 | | |
| | | | | 1.0050 | 0.1700 | 0.0040 | 0.1440 | | 0.1700 | | |
| | | | | 1.2400 | 0.0000 | 0.7824 | 0.0000 | | 0.0112 | | |
| | | | | 1.2750 | 0.3850 | 0.7912 | 0.3901 | | 0.4530 | | |
| | | | | 1.4940 | 0.0005 | 0.7881 | 0.0076 | | 0.0007 | | |
| | | | | 1.5900 | 0.0100 | 0.7790 | 0.0120 | | 0.0104 | | |
| | | | | 1.5970 | 0.0165 | 0.7790 | 0.0200 | | 0.0205 | | |
| Eu-155: | 4.000E+00 | 0.0457 | 0.0200 | 0.0453 | 0.0129 | 0.0002 | 0.0000 | 0.0470 | 0.0000 | 0.0497 | 0.1225 |
| | | | | 0.0600 | 0.0111 | 0.0705 | 0.0007 | | 0.0007 | | |
| | | | | 0.0865 | 0.3000 | 0.0001 | 0.0200 | | 0.0207 | | |
| | | | | 0.1050 | 0.2070 | 0.0900 | 0.0205 | | 0.0217 | | |
| Eu-156: | 4.100E-02 | 0.0040 | 0.0770 | 0.0000 | 0.0000 | 0.0001 | 0.0077 | 1.0040 | 0.0000 | 1.2744 | 1.7400 |
| | | | | 0.5000 | 0.0230 | 0.0272 | 0.0114 | | 0.0130 | | |
| | | | | 0.6463 | 0.0710 | 0.0230 | 0.0370 | | 0.0450 | | |
| | | | | 0.7089 | 0.0082 | 0.0197 | 0.0054 | | 0.0000 | | |
| | | | | 0.7235 | 0.0000 | 0.0100 | 0.0095 | | 0.0404 | | |
| | | | | 0.8118 | 0.1040 | 0.0130 | 0.0007 | | 0.0044 | | |
| | | | | 0.8670 | 0.0140 | 0.0100 | 0.0000 | | 0.0121 | | |
| | | | | 0.9444 | 0.0130 | 0.0002 | 0.0100 | | 0.0131 | | |
| | | | | 0.9605 | 0.0182 | 0.0054 | 0.0125 | | 0.0100 | | |
| | | | | 1.0404 | 0.0053 | 0.0016 | 0.0044 | | 0.0000 | | |
| | | | | 1.0651 | 0.0820 | 0.0000 | 0.0443 | | 0.0054 | | |
| | | | | 1.0702 | 0.0400 | 0.7800 | 0.0420 | | 0.0020 | | |
| | | | | 1.1535 | 0.0720 | 0.7800 | 0.0001 | | 0.0031 | | |
| | | | | 1.1641 | 0.0830 | 0.7900 | 0.0407 | | 0.0012 | | |
| | | | | 1.2007 | 0.0000 | 0.7800 | 0.0000 | | 0.1005 | | |
| | | | | 1.2424 | 0.0080 | 0.7826 | 0.0079 | | 0.0046 | | |
| | | | | 1.2774 | 0.0320 | 0.7811 | 0.0020 | | 0.0400 | | |
| | | | | 1.3004 | 0.0170 | 0.7077 | 0.0100 | | 0.0240 | | |
| | | | | 1.0021 | 0.0030 | 0.7700 | 0.0030 | | 0.0000 | | |
| | | | | 1.0574 | 0.0025 | 0.7710 | 0.0000 | | 0.0042 | | |
| | | | | 1.0779 | 0.0173 | 0.7718 | 0.0250 | | 0.0025 | | |
| | | | | 1.0077 | 0.0214 | 0.7000 | 0.0310 | | 0.0415 | | |
| | | | | 1.0000 | 0.0420 | 0.7000 | 0.0000 | | 0.0020 | | |
| | | | | 2.0200 | 0.0800 | 0.7073 | 0.0544 | | 0.0700 | | |
| | | | | 2.0077 | 0.0430 | 0.7000 | 0.0001 | | 0.0002 | | |
| | | | | 2.1000 | 0.0040 | 0.7000 | 0.0400 | | 0.0023 | | |
| | | | | 2.1007 | 0.0400 | 0.7035 | 0.0000 | | 0.0075 | | |
| | | | | 2.2054 | 0.0100 | 0.7000 | 0.0100 | | 0.0021 | | |
| | | | | 2.2000 | 0.0112 | 0.7016 | 0.0104 | | 0.0054 | | |
| Tb-160 | 1.070E-01 | 0.2300 | 0.0500 | 0.0000 | 0.1230 | 0.0004 | 0.0110 | 0.0500 | 0.0114 | 1.0075 | 1.3400 |
| | | | | 0.1070 | 0.0400 | 0.0220 | 0.0000 | | 0.0007 | | |
| | | | | 0.2150 | 0.6071 | 0.0164 | 0.0073 | | 0.0000 | | |
| | | | | 0.2000 | 0.2718 | 0.0020 | 0.6715 | | 0.0010 | | |
| | | | | 0.3020 | 0.0128 | 0.0404 | 0.0042 | | 0.0050 | | |
| | | | | 0.7000 | 0.0103 | 0.0102 | 0.0121 | | 0.0140 | | |
| | | | | 0.8700 | 0.2050 | 0.0007 | 0.2000 | | 0.2005 | | |
| | | | | 0.0020 | 0.0000 | 0.0053 | 0.0007 | | 0.0000 | | |
| | | | | 0.0000 | 0.2420 | 0.0001 | 0.1000 | | 0.2000 | | |
| | | | | 1.0030 | 0.0007 | 0.0000 | 0.0075 | | 0.0007 | | |
| | | | | 1.1050 | 0.0052 | 0.7005 | 0.0040 | | 0.0057 | | |
| | | | | 1.1150 | 0.0100 | 0.7030 | 0.0130 | | 0.0107 | | |
| | | | | 1.1700 | 0.1440 | 0.7002 | 0.1340 | | 0.1000 | | |
| | | | | 1.2000 | 0.0230 | 0.7043 | 0.0225 | | 0.0000 | | |
| | | | | 1.2730 | 0.0790 | 0.7013 | 0.0700 | | 0.0000 | | |
| | | | | 1.3120 | 0.0205 | 0.7000 | 0.0285 | | 0.0074 | | |
| Tb-162: | 3.140E-01 | 0.1230 | 0.1223 | 0.0077 | 0.4200 | 0.0730 | 0.0270 | 1.0000 | 0.0000 | 1.2470 | 1.4000 |
| | | | | 0.1001 | 0.1410 | 0.0000 | 0.0130 | | 0.0141 | | |
| | | | | 0.1024 | 0.0717 | 0.0400 | 0.0100 | | 0.0100 | | |

| Container Absorption Coefficients | Container | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 55 Gallon Drum ----------> | 1 | [illegible] | [illegible] | -8.7130E-01 | [illegible] | 1.8841E+00 | [illegible] | [illegible] | [illegible] | [illegible] |
| 4x4 Liner ----------> | 2 | -4.3015E-02 | [illegible] | 1.1167E-01 | [illegible] | -1.3387E-01 | [illegible] | 1.3708E+00 | [illegible] | [illegible] |
| 6x6 Liner ----------> | 3 | -9.7712E-02 | 1.9719E-01 | 2.7598E-01 | [illegible] | [illegible] | -1.5781E-01 | 1.4270E+00 | [illegible] | [illegible] |
| 8x8 Liner ----------> | 4 | -3.2073E-01 | [illegible] | 7.4798E-01 | [illegible] | -1.2519E+00 | -4.0184E-01 | 1.9491E+00 | [illegible] | [illegible] |

# 9.0 REFERENCES

10 CFR 71, 1989, "Packaging and Transportation of Radioactive Materials, *Code of Federal Regulations*, as amended.

49 CFR 173, 1989, "Radioactive Materials," *Code of Federal Regulations*, as amended.

49 CFR 393, 1989, "Parts and Assessories Necessary for Safe Operation," *Code of Federal Regulations*, as amended.

Holman, W. R., and R. T. Langland, 1981, *Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers Up to Four Inches Thick*, NUREG/CR-1815, (under Lawrence Livermore National Laboratory contract to the NRC), U.S. Nuclear Regulatory Commission, Washington, D.C., August 1981.

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

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

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

WHC-CM-4-9, *Radiological Design*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-4-11, *ALARA Program Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-7-5, *Environmental Compliance*, Westinghouse Hanford Company, Richland, Washington.

Willis N. P., and G. C. Triner, 1991, *Hanford Site Solid Waste Acceptance Criteria*, WHC-EP-0063-3, Rev. 3, Westinghouse Hanford Company, Richland, Washington, September 1991.

WHC, 1993, *Packaging Design Criteria for Transfer and Disposal of Equipment, Tank 241-C-106 Waste Sluicing System*, WHC-SD-TP-PDC-015, Westinghouse Hanford Company, Richland, Washington.

WHC, 1994, *Report on Equivalent Safety for Transportation and Packaging of Radioactive Materials*, WHC-SD-TP-RPT-001, Westinghouse Hanford Company, Richland, Washington.

**Association for Information and Image Management**

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910

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