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		Env.									

18. BA Crea Signature of EDT Originator	19. CR Miska Authorized Representative for Receiving Organization	20. MJ Schliebe Design Authority/ Cognizant Manager	21. DOE APPROVAL (if required) Ctrl No. _____ ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments
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TEMPERED WATER LOWER PORT CONNECTOR STRUCTURAL ANALYSIS VERIFICATION

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

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TEMPERED WATER LOWER PORT CONNECTOR STRUCTURAL ANALYSIS VERIFICATION

Total page 60

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Date Published
April 2000

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Appendix B: "Design and Structural Analysis of the CVDF Tempered Water Safety Class Piping from the Mezzanine Hood to the Transportation Cask"

1.0 SCOPE

1.1 Introduction

Structural analysis of the lower port connection of the Tempered Water System of the Cold Vacuum Drying Facility was performed. Subsequent detailed design changes to enhance operability resulted in the need to re-evaluate the bases of the original analysis to verify its continued validity. This evaluation is contained in Appendix A of this report. The original evaluation is contained in Appendix B.

APPENDIX "A"

STRUCTURAL ASSESSMENT OF DESIGN CHANGES

TO

CVDF TEMPERED WATER PIPING

FROM THE

MEZZANINE HOOD TO THE TRANSPORTATION CASK

PROJECT W-441

Prepared by Fluor Hanford, Inc.

April 2000

ADDENDUM 1

STRUCTURAL ASSESSMENT OF DESIGN CHANGES TO CVDF TEMPERED WATER PIPING
FROM THE MEZZANINE HOOD TO THE TRANSPORTATION CASK

1.0 INTRODUCTION AND OBJECTIVE

The configuration and layout of the Cold Vacuum Drying Facility (CVDF) tempered water (TW) piping assembly has been changed (modified). The design analysis of the original piping system configuration appears in Pac Tec (1999).

The objective of this Addendum is to assess the design changes using the load results obtained in Pac Tec (1999) and Merrick (2000). The final design drawing is presented in DOE (2000).

2.0 CONCLUSIONS.

The evaluation of the modified design shows that the TW piping system of the CVDF is structurally acceptable. The analysis details appear in Section 5.0.

3.0 REVISED SYSTEM CONFIGURATION AND REQUIRED ANALYSIS REVISIONS

3.1 DESIGN COMPARISONS

The final revised configuration of the TW piping system is shown in Figures 1-3. A comparison of the main differences between the original and the modified design are described below. In addition, the components that require analysis revisions are identified for each assembly. The piping system can be divided to three regions (or assemblies).

1- Lower Port Connector Assembly:

This region consists of cask attachment fitting (connector), four cask fitting attachment (connecting) bolts, and a 24-in. long pipe-in-pipe portion (see Figure 1).

The cask connector is a massive component with several internal components and outside flange. The new design does not have internal spring and spring support plate. These two items are in section 6.1.5 of Pac Tec (1999). The flange of the cask connector has the same dimensions in both designs, and is subjected to the same loads.

The four connecting bolts were 1 7/8-in. long in the original design. They are replaced by 11 3/8-in. long extension bolts. The bolt thread size in both designs are 1/2-13 UNC, and are subjected to the same loads at the threads. The extension part of the bolt is subjected only to the torque loads for tightening.

The outside pipe of the 24-in. long pipe-in-pipe portion is the same size in both designs (2 1/2-in. Sch. 10S). The inside pipe was 1-in. flexible pipe in the original design, and has changed to 1-in. Sch. 10S steel pipe in the new design.

Therefore, only the 1-in. Sch. 10S inside pipe needs to be analyzed. All other components in this assembly are acceptable as analyzed in Pac Tec (1999).

2- Flexible Hose Assembly:

This region consists of a Teflon hose-in-hose line assembly (see figure 2). The original design consists of an inside 1-in. hose and an outside 3-in. hose attached to the cask fitting at the lower end and to the rigid stand pipe at the upper end, with a total length of about 8-ft. The line is attached at the lower end to a flange at the end of the 2 ½ -in. pipe of the lower connector assembly and at the upper end is attached to a supported flange (middle support) located at the bottom of the rigid standpipe. The new design does not have a flange at the lower end of the hose assembly.

The new design consists of an inside 1-in. hose and an outside 2-in. hose. The hose line has two intermediate supports. One is a rigid middle support with the same configuration as the middle support of the original design and the other one is a hanging support of ½-in. diameter and 48-in long rod. The total length of the hose assembly is about 14-ft, 8-ft between the lower end of the cask fitting and the middle support, and about 6-ft between the middle support and the rigid stand pipe. The middle support is subjected to less severe loads than the middle support of the original design, because in the new design, the standpipe is shorter in length and the outside flexible hose is smaller in diameter. Thus, the middle support is enveloped by the original support in Section 6.4.1 of Pac Tec (1999).

The 2-in. flexible hose should be enveloped by the results of section 6.2 of Pac tec (1999) which includes the vendor data and evaluation of the 1-in. and the 3-in. hoses.

Therefore, the new design flexible hoses and middle support are acceptable, and no further evaluation will be performed.

3- Upper Rigid Stand Pipe Assembly:

This region consists of a rigid pipe assembly that is attached to the flexible line at the lower end and near to the process hood assembly at the upper end. The new design is completely different and shorter than the original design (see Figures 3a and 3b for comparison). Also, the upper support of the new design is ~~much~~ *much* stronger than the upper U-bolt support of the original design.

Therefore, the new upper standpipe assembly will be re-evaluated in this Addendum.

3.2 REQUIRED ANALYSIS REVISIONS

The discussion in section 3.1 above indicates that the components that require re-evaluation are:

- The 1-in. Sch.10 inside pipe of the lower port connector assembly.
- The 1-in. Sch.40 and 2-in. Sch.40 pipes, and the upper support of the upper rigid stand pipe assembly.

Section 5.0 includes the details of the revised evaluation.

4.0 CRITERIA AND ASSUMPTIONS

The design criteria, seismic response spectra, allowable stresses, and assumptions reported in Pac Tec (1999), Sec. 5.0, are applicable for this re-evaluation. However, the seismic accelerations in Table 5-1 of Pac Tec (1999) has some mix up values. The cask-lower attachment vertical acceleration for frequency greater than 10Hz is interchanged with the maximum horizontal acceleration. Also, the East-West accelerations at 56-in. and 181-in. are interchanged with the North-South accelerations. The stress calculations in Pac Tec (1999) were checked in accordance with the proper accelerations. The results of the adjusted stresses are either not affected or slightly higher (not more than 15%), and do not affect the conclusions.

5.0 REVISED ANALYSIS AND EVALUATION

This re-evaluation will go through section by section of Pac Tec (1999), Section 6.0. The pipe stresses are evaluated in accordance with ASME (1996) and the fillet welds are evaluated in accordance with ANSI/ASCE (1994).

5.1 LOWER PORT CONNECTOR ASSEMBLY (CASK ATTACHMENT FITTING)

This section modifies the corresponding Section 6.1 in Pac Tec (1999). The following are the design changes from the original design.

- The 24-in. long inside pipe is 1-in. Sch. 10S instead of 1-in. hose.
- No flange at the end of the 24-in. Pipe-in-pipe assembly.
- The flexible hose is 2-in. instead of 3-in.
- The four connecting bolts are 11 3/8-in. long extension bolts with the same thread dimensions (1/2-13 UNC) as the original 1 7/8-in. bolts.
- The cask connector does not have internal spring and spring support plate.

All the components are enveloped by the Pac Tec (1999) analysis except the 1-in. Sch. 10S inside pipe with 24-in. length.

5.1.1 Cask Fitting Inside Pipe

The inside 24-in. long 1-in. Schedule 10S pipe is attached with an 1/8-in. fillet weld to the fitting at one end and to a flexible 1-in. hose on the other end.

Outside diameter (d) = 1.315 in

Wall thickness (t) = 0.109 in

Area (A) = 0.413 in²

Pipe Wt. = 1.4 lbf/ft

Water Wt. = 0.41 lbf/ft

Total Wt. = 1.81 lbf/ft

Section modulus (S) = 0.115 in³

Moment of inertia (I) = 0.076 in⁴

Assume the pipe is a cantilever fixed at the cask fitting and loaded by the weight of the 8-ft long (length up to the middle support) 1-in. flexible line (filled with water) at the other end. Assume the weight of the 1-in. flexible line is 1 lbf/ft and including water of 0.5 lbf/ft. Assume weight of the attached components is 8 lbf (conservative).

Weight at end of pipe = $8 \times 1.5 + 8 = 20$ lbf

Weight of pipe = $2 \times 1.81 = 3.62$ lbf

Weight of cask fitting = 14.3 lbf (used for seismic axial load)

Total axial load (Fa) = $20 + 3.62 + 14.3 = 38$ lbf (approx.)

Internal pressure (p) = 45 lbf/in²

Moment (M) = $20 \times 24 + 3.62 \times 12 = 523.4$ in-lbf

Bending stress (σ_b) = $M/S = 523.4/0.115 = 4,551$ lbf/in²

Axial (lateral) stress (σ_a) = $F_a/A = 38/0.413 = 92$ lbf/in²

Longitudinal pressure stress (σ_p) = $pd/4t = 45 \times 1.315/4 \times 0.109 = 136$ lbf/in²

Sustained stress (σ_s)

$$\sigma_s = 4,551 + 136 = 4,687 \text{ lb/in}^2 < 16,700 \text{ lb/in}^2 \text{ allowable stress.}$$

$$\text{M.S.} = 16,700 / 4,687 = 3.56$$

Occasional Stress (σ_o)

The fundamental frequency (f_n) is calculated from Roark (1975) for cantilever beam with concentrated load at the end.

$$F_n = (1.732/2\pi) (EI_g/WL^3)^{1/2} = (1.732/2\pi)(29,000,000 \times 0.076 \times 386 / 20 \times 24^3)^{1/2} = 48.4 \text{ Hz}$$

Thus, use the g levels for frequency greater than 10 Hz.

Seismic horizontal acceleration = 1.6 g (interchange values in table 5-1 of Pac Tec (1999))

Seismic vertical acceleration = 1.2 g

$$\text{Seismic stress} = [(1.2 \times 4,551)^2 + (1.6 \times 92)^2 + (1.6 \times 4,551)^2]^{1/2} = 9,103 \text{ lb/in}^2$$

Multiply the seismic stress by a factor of 1.5 for static method.

$$\sigma_o = 4,551 + 136 + 1.5 \times 9,103 = 18,341 \text{ lb/in}^2 < 22,200 \text{ lb/in}^2 \text{ allowable occasional stress}$$

$$\text{M.S.} = 22,200 / 18,341 = 1.21$$

5.1.2 Fillet Weld at Inside Pipe End (1/8-in.)

The weld formulas of Blodgett (1982) are used in the 1/8-in. fillet weld evaluation.

$$\text{Allowable stress} = 0.3 \times 60,000 \times 0.707 \times 0.125 = 1,590 \text{ lb/in}$$

$$\text{Weld area} = \pi d = \pi \times 1.315 = 4.13 \text{ in}$$

$$S_{\text{weld}} = \pi r^2 = \pi (1.315/2)^2 = 1.358 \text{ in}^2$$

$$\text{Bending stress} = 523.4 / 1.358 = 385.4 \text{ lb/in}$$

$$\text{Lateral (axial) stress} = 38 / 4.13 = 9.2 \text{ lb/in}$$

$$\text{Shear stress} = 20 / 4.13 = 4.8 \text{ lb/in}$$

$$\text{Pressure stress} = pr/2 = 45 (1.315 + .25) / 2 = 35.2 \text{ lb/in}$$

Sustained Stress

$$\sigma_s = 385.4 + 4.8 + 35.2 = 425.4 \text{ lb/in}$$

$$\text{M.S.} = 1590 / 425.4 = 3.74$$

Occasional Stress

$$\text{Seismic stress} = [(1.2 \times 385.4)^2 + (1.6 \times 9.2)^2 + (1.6 \times 385.4)^2]^{1/2} = 772.3 \text{ lb/in}$$

$$\sigma_o = 385.4 + 4.8 + 35.2 + 1.5 \times 772.3 = 1,584 \text{ lb/in} < 2,115 \text{ lb/in} (1.33 \times 1,590 \text{ lb/in})$$

$$\text{M.S.} = 2,115 / 1,584 = 1.33$$

5.1.3 Connectors

The male and threaded connectors (parts 18 and 19 of DOE (2000)) are captured and confined during connection. Thus no bending or seismic loads are expected at the connection, only hydrostatic or axial fitting loads are applicable. Therefore, the connectors are acceptable by inspection.

5.2 FLEXIBLE HOSE ASSEMBLY

The following are the design changes from the original design.

- The 3-in. flexible outer hose is replaced by a 2-in. flexible hose.
- The location of the supports changed. However, the configuration of the middle support did not change, and does not require a revised analysis.

The 2-in. flexible hose has the following characteristics.

Size I.D. = 2 in	Size O.D. = 2.65 in	Approximate weight = 1.5 lbf/in
Recommended working pressure = 250 lbf/in ²		
Test pressure = 375 lbf/in ²		
Minimum burst pressure = 1200 lbf/in ²		

$$\begin{aligned} \text{The longitudinal force in pipe connections due to pressure} &= (p-45) (\pi/4) D^2 \\ &= (250-45) \times (\pi/4) \times 2^2 = 644 \text{ lbf} \end{aligned}$$

$$\text{The longitudinal force in pipe connections due to burst pressure} = 3,628 \text{ lbf}$$

The evaluation of the 2-in. hose follows the same logic of evaluation in Section 6.2 of Pac Tec (1999). The longitudinal load at any connection will be much less than the 644 lbf. Thus, it is judged that the 2-in. flexible hose is acceptable.

5.3 UPPER RIGID STAND PIPE ASSEMBLY

This section replaces Section 6.3 in Pac Tec (1999). The upper standpipe assembly is completely different than the original design. The following are the design changes from the original design.

- The inside pipe is 1-in. Sch. 40 instead of 1 1/2-in. Sch. 40. Its total length is about 18-in., and is eccentric between the hood assembly flange and the flexible hose assembly flange, with several bends as shown in Figure 3a. The original pipe was straight with a length of about 108-in.
- The outside pipe is about 8-in. long instead of 108-in., and is 2-in. Sch. 40 instead of 3-in. Sch. 40.
- The upper support is made of welded plate and angles instead of a U-bolt support. The upper support is fixing the upper end of the outside pipe.

5.3.1 Inside Pipe

The inside 1-in. Sch. 40 pipe is attached to the flange of the hood assembly at the upper end. The lower end is attached to the outside pipe through a disk that is welded to both the inside and outside pipes by 1/8-in. fillet welds. The 1-in. Sch. 40 pipe has the following properties.

Outside diameter (d) = 1.315 in	Wall thickness (t) = 0.133 in	Area (A) = 0.494 in ²
Section modulus (S) = 0.133 in ³	Moment of inertia = 0.087 in ⁴	

The pipe is short, thus the loads due to the weight is not significant. The stresses due to the sustained loads will not be significant and can be enveloped by the sustained stress results of Section 6.3.3 of Pac Tec

(1999). Only occasional pipe stresses (seismic loads) will be considered in this section. The method of calculating the seismic loads in Pac Tec (1999) cannot be used in this analysis, because the configuration is completely different than the original design

Occasional Loads (seismic loads)

Assume the pipe is free at the top flange end and is fixed at the connection with the outside pipe. The seismic loads imposed on the top flange (at the connection with hood assembly) are the main occasional loads on this pipe. Neglect the stresses due to the pipe weight and pressure.

A seismic analysis of the process hood piping appears in Merrick (2000). The reaction loads at the support just above the hood flange were conservatively used as the loads on the upper free end of the inside pipe. These loads are the maximum combination of operation loads plus seismic or sustained loads plus seismic. The reaction loads are those at node 290 of the finite element model used in Merrick (2000).

$F_x = 95 \text{ lbf}$ (lateral load as shown on the sketch)

$F_z = 90 \text{ lbf}$ (other lateral load)

$F_y = 0 \text{ lbf}$ (no vertical load)

The bending moments and torsion at the weld connection are as follows.

$$T = 6.75 \times 95 + 5 \times 90 = 1,091 \text{ in-lbf}$$

$$M_z = 8.83 \times 95 = 839 \text{ in-lbf}$$

$$M_x = 8.83 \times 90 = 795 \text{ in-lbf}$$

Occasional Stress (σ_o)

$$\sigma_x = M_x/S = 795/0.133 = 5,975 \text{ lbf/in}^2 \text{ (bending)}$$

$$\sigma_z = M_z/S = 839/0.133 = 6,307 \text{ lbf/in}^2 \text{ (bending)}$$

$$\tau = T/2S = 1,091/0.226 = 4,102 \text{ lbf/in}^2 \text{ (shear)}$$

$$\text{Resultant bending stress } (\sigma_b) = [(5,975)^2 + (6,307)^2]^{1/2} = 8,687 \text{ lbf/in}^2$$

$$\text{Stress intensity } (\sigma_o) = 2\tau_{\max} = 2 [(\sigma_b/2)^2 + (\tau)^2]^{1/2} = 2 [(8,687/2)^2 + (4,102)^2]^{1/2} \\ = 11,949 \text{ lbf/in}^2 < 22,200 \text{ lbf/in}^2 \text{ (occasional allowable stress)}$$

$$M.S. = 22,200/11,949 = 1.85$$

5.3.2 Fillet Weld at Inside Pipe

The weld formulas of Blodgett (1982) are used in the 1/8-in. fillet weld evaluation.

$$\text{Allowable stress} = 0.3 \times 60,000 \times 0.707 \times 0.125 = 1,590 \text{ lbf/in}$$

$$\text{Weld area} = \pi d = \pi \times 1.315 = 4.13 \text{ in}$$

$$S_{\text{weld}} = \pi r^2 = \pi (1.315/2)^2 = 1.358 \text{ in}^2$$

$$SJ_{\text{weld}} = 2 \pi r^2 = 2 \times \pi \times (1.315/2)^2 = 2.716 \text{ in}^3$$

Occasional Stresses

$$\sigma_z = 839/1.358 = 618 \text{ lbf/in}$$

$$\sigma_x = 795/1.358 = 585 \text{ lbf/in}$$

$$\tau = 1,091/2.716 = 402 \text{ lbf/in}$$

$$\text{Total stress } (\sigma_o) = [(618)^2 + (585)^2]^{1/2} + 402 = 1,253 \text{ lbf/in} < 2,115 \text{ lbf/in (occasional allowable stress)}$$

$$\text{M.S.} = 2,115/1,253 = 1.68$$

5.3.3 Outside Pipe

The outside pipe is fixed at the upper support and extends about 8-in. below the support. The lower end is attached to the flexible hose line. The lower end carries the weight of the 6-ft flexible hose (the length between the middle support and bottom of the outside pipe). This is a small load and the pipe should be acceptable. Thus, no analysis is required.

5.3.4 Upper Support

The critical region is the 3/16-in. fillet weld joining the two 2-in. x 2-in. angel to the frame.

Assume only two vertical welds 2-in. long and 7-in. apart.

$$\begin{aligned} \text{Area} &= 2 d &&= 4 \text{ in} \\ S_z &= d^2/3 &&= 1.33 \text{ in}^2 \\ S_y &= b d &&= 14 \text{ in}^2 \\ J &= d/6 (3b^2 + d^2) = 50.33 \text{ in}^3 \\ C &= (b^2 + d^2)^{1/2}/2 = 3.64 \text{ in} \end{aligned}$$

$$\text{Torsional stress around x} = M_x C/J = 795 \times 3.64/50.33 = 57.5 \text{ lbf/in}$$

$$\text{Bending stress around y} = M_y/S_y = 1,091/14 = 77.9 \text{ lbf/in}$$

$$\text{Bending stress around z} = M_z/S_z = 839/1.33 = 631 \text{ lbf/in}$$

$$\text{Tension stress} = F_x/A = 95/4 = 23.75 \text{ lbf/in}$$

$$\text{Shear stress} = F_z/A = 90/4 = 22.5 \text{ lbf/in}$$

$$\text{Total stress } (\sigma_o) = 57.5 + 77.9 + 631 + 23.75 + 22.5 = 812.65 \text{ lbf/in} < 3,173 \text{ lbf/in (1.33} \times 2,386)$$

$$\text{Allowable stress for 3/16-in. fillet weld} = 0.3 \times 60,000 \times 0.707 \times 0.1875 = 2,386 \text{ lbf/in}$$

$$\text{M.S.} = 3,173/813 = 3.9$$

The actual weld will have larger margin.

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2 ASSEMBLY-LWR. PORT CONNECTOR
SCALE: NONE
New Design

Original Design

Figure 1: Lower Port Connector Assembly.

Figure 2: Flexible Hose Assembly.

Figure 3b: Upper Rigid Stand Pipe Assembly (Original Design).

APPENDIX "B"

DESIGN AND STRUCTURAL ANALYSIS

OF THE

CVDF TEMPERED WATER SAFETY CLASS PIPING

FROM THE

MEZZANINE HOOD TO THE TRANSPORTATION CASK

PROJECT W-441

Prepared by M&D Professional Services, Inc.

June 1999

M & D

Professional Services Inc.

**Design and Structural Analysis
of the
CVDF Tempered Water Safety Class Piping
From the Mezzanine Hood to the
Transportation Cask**

Calculation No. M&D 99-08
Rev 0

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6/29/99
Date

Reviewed by:

B.V. Winkel

6/29/99
Date

M&D Professional Services	CALCULATION SHEET		Page No. of 2 42
			Calculation No. M&D 99-08
Client / Location DE&S Hanford, Inc.	Prepared By / Date M.R. Lindquist 6/29/99		Revision No. 0
Subject Tempered Water Line	Checked By / Date B.V. Winkel 6/29/99		Contract No.
Ref. Drawing(s)	Revised By / Date		

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1.0 INTRODUCTION

The Cold Vacuum Drying Facility (CVDF) tempered water line provides a conditioned source of cooling water to the transportation cask/multi-canister overpack (MCO). The line of interest runs from a flange on the mezzanine process hood assembly to an attachment fitting at the bottom of the cask. The tempered water line design is required to fulfill the requirements of safety Performance Class 3 (PC-3). The purpose of this document is to describe and demonstrate the design, analysis and qualification of this tempered water line.

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2.0 SCOPE

The scope of the design and analyses described herein covers the tempered water line from an upper flange near the mezzanine process hood assembly to the drain port cavity at the bottom of the transportation cask. No assessment is provided of the process hood assembly and transportation cask components. Specifically not included in the analysis is the section of pipe that connects the top flange of the vertical pipe shown in Drawing 99007-104 to the hood assembly inlet tempered water line nozzle.

The only cask attachment tooling that will be considered will be that required to directly attach the water line to the cask. No special stands, dollies, or other handling fixtures will be considered.

The following drawings provide the configuration of the assessed components:

1. 99007-100, "Assembly of CVD Water Piping", Rev. 0.
2. 99007-101, "Tool Assembly, CVD Water Piping", Rev. 0.
3. 99007-103, "Support, CVD Water Piping", Rev. 0.
4. 99007-104, "Stand Pipe, CVD Water Piping", Rev. 0.

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3.0 SUMMARY

A design evaluation has been performed on components of the tempered water line that runs from a flange on the mezzanine process hood assembly to an attachment fitting at the bottom of the MCO cask. The line is composed of a "quick disconnect" fitting that attaches to the MCO cask, and lengths of flexible and rigid piping. The line is specified as Safety Class and has a double containment (pipe-within-pipe) configuration. In order to minimize ALARA concerns, the attachment to the MCO cask can be installed remotely (personnel at least 10 in. away).

Table 3-1 summarizes the maximum stresses and corresponding margins of safety for the tempered water line components based upon the criteria and assumptions of Section 5.0.

Table 3-1 -- Summary of Maximum Stresses and Corresponding Margins of Safety

Major Component	Item	Sustained Stress			Occasional Stress		
		Component Stress, psi	Allowable Stress, psi	Margin of Safety (1)	Component Stress, psi	Allowable Stress, psi	Margin of Safety(1)
Cask Attach Fitting Assembly	Attachment Bolts	4,232	20,000	+3.73	12,705	26,600	+1.09
	Rigid Pipe "Stub"	3,165	16,700	+4.28	11,852	22,200	+0.87
	Rigid Pipe Weld	3,797	18,000	+3.74	15,190	23,900	+0.57
	Flange	5,441	16,700	+2.07	16,345 ⁽²⁾	22,200	+0.36 ⁽²⁾
					19,098 ⁽³⁾	22,200	+0.16 ⁽³⁾
	Internal Spring Support Plate	1,133	20,000	+16.6	-	-	-
Flexible Piping (Hose)	Pipe	-	-	> 0.0	-	-	> 0.0
Rigid Vertical Pipe	Inner Pipe	203	16,700	+81.	7,910	22,200	+1.81
	Outer Pipe	217	16,700	+76.	3,280	22,200	+5.77
Pipe Support	Upper Support	-	-	-	10,451	21,600 ⁽⁴⁾	+1.07
	Lower Support	-	-	-	3,066	21,000 ⁽⁴⁾	+5.85

(1) Margin of Safety is defined as $\{(Allowable\ Value / Calculated\ Value) - 1\}$

(2) Seismic loading.

(3) 250 lb. vertical load at end of rigid pipe stub.

(4) Sustained loading allowable used for occasional loading.

The flange to attach the tempered water line end fitting to the MCO cask has attachment bolts that are "captured" in their respective holes. Such being the case, the only tools needed to install the fitting into the cask are conventional socket wrenches (with extensions).

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4.0 DESCRIPTION

The inlet tempered water line provides a conditioned source of cooling water to the transportation cask/MCO. The line of interest runs from a flange on the mezzanine process hood assembly to an attachment fitting at the bottom of the cask. Safety functions and requirements of the tempered water line are described in Carrell, 1998.

The inlet tempered water line configuration is a "pipe within a pipe" and consists of several major components. Proceeding upstream from the cask, these components are:

- 1) An attachment fitting to the cask.
- 2) A section of flexible pipe (hose) attached to the cask fitting.
- 3) A section of rigid vertical pipe that is attached to the flexible line on one end and terminates near the process hood assembly on the other end.

The ends of the flexible piping and the rigid pipe utilize bolted flanges for connections.

The tempered water line is shown in Drawings 99007-100,-101,-103, and -104.

The cask attachment fitting provides a means of attaching the tempered water line to the MCO cask drain port cavity. This fitting has several design and functional features. These include: 1) "quick disconnect" capability with minimal water loss, 2) remote installation capability to minimize ALARA concerns, 3) double containment against water loss achieved by secondary seals within the fitting assembly.

The flexible portion of the tempered water line provides for operational needs such that the line may be handled and maneuvered during the cask connect/disconnect operations. The line consists of a 1 in. diameter hose that provides the source of cooling water for the MCO with the transportation cask. This pipe is further contained within an outer hose that is 3 in. in diameter. This "pipe within a pipe" concept provides containment of water should the main (inner) pipe fail.

The rigid portion of the tempered water line provides the transition for connecting the flexible line and the process hood assembly. This is also a pipe within a pipe configuration. The inner pipe is 1 1/2 in. diameter schedule 40 pipe and the outer pipe is 3 in. schedule 40 pipe. The pipe is oriented vertically and is mounted on the vertical column that supports the process hood assembly.

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5.0 CRITERIA AND ASSUMPTIONS

5.1 Design Criteria

The safety analysis of Carrell, 1998 requires that the tempered water line piping from the mezzanine process hood to the transportation cask be designated as "Safety Class". The line is designated a Performance Category 3 (PC-3) system by the definition of Hanford, 1997. To be compatible with the safety analysis of Carrell, 1998, the tempered water in the piping must be double contained. To meet this requirement, the design of the piping will be a "pipe within a pipe" configuration.

Design Requirements of the tempered water line are:

Design pressure: 45 psig

Design temperature: 150 °F.

Seismic Loading: Use local building response spectra.

Impact: Impact damage will be prevented by the placement of physical barriers to protect the piping in vulnerable areas.

The fitting that attaches directly to the cask will be evaluated for a 250 lb. vertical occasional load that is applied at the end of the 24 in. rigid pipe "stub".

Personnel must be at least 10 in. away from the cask because of ALARA concerns. Cask connection must be designed accordingly.

5.2 Seismic Response Spectra

The seismic response spectra that will be used for analysis of the tempered water line were developed during the analysis of the process hood assembly support structure (M&D, 1999) and the cask transportation trailer (M&D, 1998).

The vertical rigid pipe portion of the water line will be attached to the process hood assembly vertical column support. Building response spectra were obtained for three locations on this column, which rests on the floor (56 in., 123 in., and 181 in. up from the base of the column) for 2 sets of independent building-specific seismic time histories ("a" and "c"). The resulting spectra are shown in Figures 5-1 through 5-6. Corresponding spectra for the hood assembly flange are shown in Figures 5-7 and 5-8.

The response spectra for the cask lower attachment location is shown in Figure 5-9 taken from the analysis of M&D, 1998.

The acceleration values shown in Figures 5-1 through 5-9 were developed for the purpose of providing test response spectra to component vendors. As such, the spectra shown include a factor of 1.4 for testing purposes. The actual maximum accelerations (reduced by a 1.4 factor) imposed upon the components are

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summarized in Table 5-1 below. Also shown are the accelerations for the lower cask attachment at frequencies greater than 10 Hz.

Table 5-1 -- Seismic Accelerations

Location	Direction	Maximum Acceleration ⁽¹⁾ From Spectra, g	Actual Acceleration, g
Cask Lower Attachment	Vertical	3.5 ⁽²⁾	2.5
	Maximum Horizontal	3.0 ⁽²⁾	2.1
	Vertical	2.2 ⁽³⁾	1.6
	Maximum Horizontal	1.7 ⁽³⁾	1.2
Hood Assembly Support Column, Near Bottom (Height = 56 in.)	Vertical	0.7 ⁽²⁾	0.5
	East-West	1.3 ⁽²⁾	0.9
	North-South	1.7 ⁽²⁾	1.2
Hood Assembly Support Column, Top (Height = 181 in.)	Vertical	0.7 ⁽²⁾	0.5
	East-West	2.4 ⁽²⁾	1.7
	North-South	5.9 ⁽²⁾	4.2

- (1) Includes 1.4 factor for testing.
 (2) At peak of spectra (bounding values from time histories a and c)
 (3) Maximum value at frequency greater than 10 Hz.

The seismic loading in 3 directions will be combined by the square root of the sum of the squares. Seismic stress analyses of the tempered water line components will be performed using an equivalent static method. A factor of 1.5 will be applied to the peak accelerations to account for dynamic effects.

5.3 Allowable Stresses

The material properties and allowable stresses of ASME B31.3 will be used in the structural analyses of the piping and associated components.

The allowable material stress for sustained loading of piping is "S" from Table A-1 of ASME B31.3 (paragraph 302.3.5).

The allowable material stress for occasional loading of piping is 1.33S (ASME, B31.3, paragraph 302.3.6).

For welds and structural elements other than piping, the allowable stresses and criteria of ANSI/AISC-690 will be used.

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5.4 Assumptions

The outer containment pipe upper elevation must be above the elevation of the fuel in the cask (160.8 in. above the floor).

The inner pipe will terminate in a flange at an elevation of 188 in. above the floor.

Flexible or rigid (or combinations thereof) piping may be used.

There will be no water pressure in the tempered water line during the cask attachment fitting connect/disconnect operation.

There is a 6 psi pressure drop as water flow passes through the internal nozzles of the tempered water line end fitting assembly.

There will be water (13 ft. static pressure head) in the cask during the connect/disconnect operation.

The weld electrodes will be E60 or stronger.

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Figure 5-1, Hood Frame Column Response Spectra, 56 in. Up From Base, Time History a

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Figure 5-2, Hood Frame Column Response Spectra, 123 in. Up From Base, Time History a

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Figure 5-3, Hood Frame Column Response Spectra, 181 in. Up From Base, Time History a

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Figure 5-4, Hood Frame Column Response Spectra, 56 in. Up From Base, Time History c

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Figure 5-5, Hood Frame Column Response Spectra, 123 in. Up From Base, Time History c

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Figure 5-6, Hood Frame Column Response Spectra, 181 in. Up From Base, Time History c

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Figure 5-7, Hood Assembly Flange Response Spectra, Time History a

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Figure 5-8, Hood Assembly Flange Response Spectra, Time History c

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Figure 5-9, Response Spectra, Lower Cask Connection Fitting

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6.0 ANALYSIS

Table 6-1 presents the weight and strength characteristics of several diameters of rigid pipe that are applicable to the tempered water line design.

Table 6-1 -- Weight and Strength Characteristics of Rigid Pipe

Pipe Diameter, in.	Pipe Schedule	Pipe Wall Thickness, in.	Pipe Wt, lb./ft.	Water Wt, lb./ft.	Pipe + Water Wt, lb./ft	Section Modulus, S, In ³	Moment of Inertia, I, In ⁴
1	40	0.133	1.68	0.37	2.05	0.133	0.087
1 1/2	40	0.145	2.72	0.88	3.60	0.326	0.310
2 1/2	10	0.120	3.53	2.36	5.89	0.687	0.988
3	40	0.216	7.58	3.20	10.78	1.72	3.02

6.1 Cask Attachment Fitting

The cask attachment fitting is shown in Drawing 99007-101. The fitting will be analyzed for lateral and vertical loading due to dead weight and seismic accelerations. Pressure loading will also be considered. The weight of the attached flexible line will be included.

6.1.1 Weight of Cask Attachment Fitting and Attached Components.

It will be conservatively assumed that the portion of the fitting that connects to the cask drain cavity fills the entire cavity as shown below (dimensions approximate).

The weight of the fitting shown above will be:

$$W_{t_{fitting}} = (\pi/4)[(3056^2)(3.66) + (6.19^2)(0.75)](0.29) = 14.3 \text{ lb.}$$

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The inner pipe that is connected to the attachment fitting is a 1 in. flexible pipe. The weight of the flexible pipe may be conservatively taken as 1 lb./ft. The 2.5 in. rigid outer pipe stub that is attached to the attachment fitting is 24 in. long and is schedule 10. Weight will be (including water):

$$W_{t_{flex,inner}} = 2(1.0) = 2.0 \text{ lb.}$$

$$W_{t_{stub,outer}} = 2(5.89) = 11.8 \text{ lb.}$$

$$W_{t_{stub,total}} = 2 + 11.8 = 13.8 \text{ lb.}$$

The flange on the end of the rigid pipe weighs 10 lb. (3 in., 150 lb. blind flange).

A flexible line is attached to the upstream end of the rigid stub portion of the attachment fitting. This flexible line is a 3 in. diameter line that "contains" the continuous inner 1 in. flexible line. Vendor data shows that a conservative weight for the 1 in. line is 1 lb./ft. and 3 lb./ft. for the 3 in. line. Weight will be therefore taken as 4 lb./ft. Conservatively assume that the effective length of the flexible pipe that the fitting supports is 8 ft. Include conservative water weight of 3 lb./ft. Weight will be:

$$W_{t_{flex\ line}} = 8(4 + 3) = 56 \text{ lb.}$$

Assume another 10 lb. for flanges. Total weight will be:

$$W_{t_{total}} = 14.3 + 13.8 + 10 + 56 + 10 = 104 \text{ lb.}$$

The maximum moment on the pipe will be at the location where the rigid outer pipe stub is welded to the attachment fitting. The loading on this pipe as a result of dead weight loading will be:

The dead weight moment at location 1 will be:

$$M = 13.8(12) + (56+10+10)24 = 1990 \text{ in. lb.}$$

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6.1.2 Cask Fitting Attachment Bolts

The fitting is secured onto the cask with 4 bolts. The load in the bolts due to a 1 g lateral acceleration is

$$\text{Load}_{\text{bolt, lateral}} = 104/4 = 26 \text{ lb.}$$

Conservatively assume 2 of the bolts are effective to resist the dead weight bending moment. The diameter of the bolt circle is 4.63 in. This distance forms the couple resisting the dead weight bending moment. Calculate the bolt load for 1 g dead weight load.

$$\text{Load}_{\text{bolt, dead wt}} = 1990/4.63 = 430 \text{ lb}$$

The 4 bolts holding the fitting to the cask must resist the internal pressure. The cavity is 3.12 in. in diameter and the design pressure is 45 psig. The load that the bolts must resist is:

$$\text{Load}_{\text{pressure}} = (\pi/4)(3.12^2)45 = 344 \text{ lb.}$$

The pressure load in each bolt will be:

$$\text{Load}_{\text{bolt, pressure}} = 344/4 = 86 \text{ lb.}$$

6.1.3 Cask Fitting Rigid Pipe Section

The rigid pipe portion of the cask attachment fitting consists of a 24 in. long 2 ½ in. schedule 10 pipe. The pipe is attached with a 1/8 in. fillet weld to the fitting on one end and to a flat flange on the other end.

The maximum stress in the 2 ½ in. pipe due to the dead weight bending moment will be:

$$\text{Stress}_{\text{moment, 2 ½}} = Mc/I = [(1990)(2.875/2)]/0.988 = 2895 \text{ psi.}$$

The axial stress in the 2 ½ in. pipe due to the lateral load, P, of 1 g will be:

$$\text{Stress}_{\text{axial load, 2 ½}} = P/(\pi Dt) = (104)/[\pi(2.875)(0.120)] = 96 \text{ psi.}$$

The longitudinal stress in the 2 ½ in. pipe due to internal pressure will be:

$$\text{Stress}_{\text{pressure load, 2 ½}} = pR/(2t) = [(45)(2.875/2)]/[2(0.120)] = 270 \text{ psi.}$$

The moment of inertia of the fillet weld that joins the 2 ½ in. rigid stub pipe to the attachment fitting will be:

$$I = [\pi R^3 t (0.707)], \text{ where } R \text{ is the mean radius of the weld.}$$

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$$I = \pi[(2.875 + 0.125)/2]^3(0.125)(0.707) = 0.937 \text{ in.}^4$$

The stress in the 2 ½ in. pipe weld due to the dead weight bending moment will be:

$$\text{Stress}_{\text{weld, moment, 2 ½}} = Mc/I = [(1990)[(2.875 + 0.25)/2]/0.937 = 3318 \text{ psi.}$$

The stress in the 2 ½ in. pipe weld due to the dead weight transverse shear load, V, of 1 g will be:

$$\begin{aligned} \text{Stress}_{\text{weld, shear load, 2 ½}} &= V/[(\pi Dt)(0.707)] \\ &= (13.8 + 56 + 10 + 10)/[\pi(2.875)(0.125)(0.707)] = 113 \text{ psi.} \end{aligned}$$

The stress in the 2 ½ in. pipe weld due to the axial lateral load, P, of 1 g will be:

$$\begin{aligned} \text{Stress}_{\text{weld, lateral load, 2 ½}} &= P/[(\pi Dt)(0.707)] \\ &= (104)/[\pi(2.875)(0.125)(0.707)] = 130 \text{ psi.} \end{aligned}$$

The longitudinal stress in the 2 ½ in. pipe weld due to internal pressure will be:

$$\text{Stress}_{\text{weld, pressure load, 2 ½}} = PR/(2t) = [(45)(2.875/2)]/[2(0.125)(0.707)] = 366 \text{ psi.}$$

6.1.3.1 Sustained Stresses

The sustained stresses in the 2 ½ in. diameter rigid pipe will be the result of loading due to dead weight bending moment and pressure. The sustained stress will be:

$$\text{Stress}_{\text{pipe, sustained}} = 2895 + 270 = 3165 \text{ psi.}$$

The pipe is of ASTM A312 SS material. The allowable stress, S, is 16,700 psi.

The margin of safety for the pipe under sustained loading will be:

$$\text{M.S.} = (16,700/3165) - 1 = +4.28$$

The corresponding maximum dead weight plus pressure stress for the pipe weld will be:

$$\text{Stress}_{\text{pipe weld, sustained}} = 3318 + 113 + 366 = 3797 \text{ psi}$$

The allowable pipe weld stress is 0.3x nominal tensile strength of weld material (ANSI/ASCE, 1994) = 0.3(60,000) = 18,000 psi.

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The margin of safety for the pipe weld under sustained loading will be:

$$M.S. = (18,000/3797) - 1 = +3.74$$

6.1.3.2 Occasional Stresses

Occasional stresses in the cask attachment assembly will be induced by seismic loading. The fundamental frequency, f_n , of the 24 in. schedule 10 rigid pipe stub will be calculated from the equation of Young, 1989, Table 36, case 3a (cantilever beam with concentrated load, W, at end).

$$f_n = (1.732/2\pi)(EI_g/WL^3)^{1/2}$$

$$= (1.732/2\pi)\{[29,000,000(0.988)(386)]/[(76)(24)^3]\}^{1/2} = 28 \text{ Hz.}$$

Since the fundamental frequency is significantly to the right of the peak acceleration (which occurs at about 5 Hz.), accelerations away from the peak will be used. The stresses in the pipe and the pipe weld as a result of seismic loading are summarized in Table 6-2 below:

Table 6-2 -- Pipe and Pipe Weld Seismic Stresses

Item	Loading Direction	1 g Stress, psi	g Level From Table 5-1	Seismic Stress, psi	Resultant Stress, psi
Rigid Pipe Portion of Attachment Fitting	Vertical	2895	1.6	4632	5791
	Pipe Axial	96	1.2	118	
	Pipe Transverse	2895	1.2	3474	
Pipe Weld to Attachment Fitting	Vertical	3797	1.6	6075	7595
	Pipe Axial	130	1.2	160	
	Pipe Transverse	3797	1.2	4556	

The occasional stresses in the rigid pipe and pipe weld will be the result of loading due to dead weight, pressure, and seismic excitation. Since the stress evaluation is being done using static methods, a factor of 1.5 will be applied to the static seismic stresses to account for contribution from higher modes. Total maximum occasional stress in the pipe will be:

$$\text{Stress}_{\text{pipe, occasional}} = 2895 + 270 + 1.5(5791) = 11852 \text{ psi.}$$

The pipe is of ASTM A312 SS material. The occasional loading allowable stress, $1.33S$, is $1.33(16,700) = 22,200$ psi.

The margin of safety for the pipe under occasional loading will be:

$$M.S. = (22,200/11852) - 1 = +0.87$$

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Total maximum occasional stress in the pipe weld will be:

$$\text{Stress}_{\text{pipe weld, occasional}} = 3318 + 113 + 366 + 1.5(7595) = 15190 \text{ psi}$$

The allowable pipe weld stress is $0.3 \times$ nominal tensile strength of weld material (ANSI/ASCE, 1994) = $0.3(70,000) = 21,000$ psi. The allowable will be increased by a 1.33 factor when considering occasional loads ($1.33[18,000] = 23,900$ psi).

The margin of safety for the pipe weld under sustained loading will be:

$$\text{M.S.} = (23,900/15190) - 1 = +0.57$$

6.1.4 Cask Attachment Fitting Stresses

The portion of the cask attach fitting that fills the cask cavity is a massive component. The critical items for this portion of the fitting are the flange and the attachment bolts.

The flange has a minimum thickness of 0.577 in. at a location above the O-ring cutout.

The flange will be loaded by the attachment bolt load reactions and the maximum moment arm for loading the reduced section defined above will be $(4.63 - 3.47)/2 = 0.58$ in.

Conservatively assuming that a 1 in. wide section of the flange is effective. This gives a section modulus for the flange of:

$$S_{\text{flange}} = (1)(0.577^2)/6 = 0.055 \text{ in.}^3$$

6.1.4.1 Sustained Stresses

The sustained stresses will be the result of loading due to dead weight and pressure. The total load in an attachment bolt will be:

$$\text{Load}_{\text{bolt, sustained}} = 430 + 86 = 516 \text{ lb.}$$

The moment on the flange minimum section will be $516(0.58) = 299$ in. lb. The stress in the flange will be:

$$\text{Stress}_{\text{flange, sustained}} = 299/0.055 = 5441 \text{ psi}$$

The flange is of ASTM A276 304 SS material. The allowable stress, S , is 16,700 psi.

The margin of safety for the flange under sustained loading will be:

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$$M.S. = (16,700/5441) - 1 = +2.07$$

The sustained loading for the bolt is 516 lb.

The ½ -13UNC bolt has been machined to a reduced diameter of 0.394 in. This gives a cross-section area of 0.122 in.².

The stress in the bolt under sustained loading is:

$$\text{Stress}_{\text{bolt,sustained}} = P/A = 516/0.092 = 4232 \text{ psi.}$$

The bolts are of 18-8 SS material. The allowable stress, S_u , is 20,000 psi.

The margin of safety for the bolts under sustained loading will be:

$$M.S. = (20,000/4232) - 1 = +3.73$$

6.1.4.2 Occasional Stresses

A summary of the attachment bolt loads as a result of seismic loading is shown in Table 6-3 below:

Table 6-3 -- Attachment Fitting Bolt Seismic Loads

Item	Loading Direction	1 g Load*, lb.	g Level From Table 5-1	Seismic Load, lb.	Resultant Load, lb.
Bolts 1 and 3	Vertical	430	1.6	688	689
	Pipe Axial	27	1.2	32	
	Pipe Transverse	-	1.2	-	
Bolts 2 and 4	Vertical	-	1.6	-	517
	Pipe Axial	27	1.2	32	
	Pipe Transverse	430	1.2	516	

*Assumes that moments are reacted by 2 bolts only.

The occasional loads in the attachment bolts will be the result of loading due to dead weight, pressure, and seismic excitation. Since the stress evaluation is being done using static methods, a factor of 1.5 will be applied to the static seismic loads to account for higher mode effects. Total maximum occasional load in the bolts will be:

$$\text{Load}_{\text{bolt,occasional}} = 430 + 86 + 1.5(689) = 1550 \text{ lb.}$$

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The moment on the flange minimum section will be $1550(0.58) = 899$ in. lb. The stress in the flange will be:

$$\text{Stress}_{\text{flange, occasional}} = 899/0.055 = 16345 \text{ psi}$$

The flange is of ASTM A276 304 SS material. The allowable stress, $1.33S$, is $1.33(16,700) = 22,200$ psi.

The margin of safety for the flange under seismic loading will be:

$$\text{M.S.} = (22,200/16345) - 1 = +0.36$$

The occasional loading for the bolt is 1550 lb.

The tensile area for the bolt is 0.122 in.^2 .

The stress in the bolt under sustained loading is:

$$\text{Stress}_{\text{bolt, occasional}} = P/A = 1550/0.122 = 12705 \text{ psi.}$$

The bolts are of 18-8 SS material. The allowable stress, $1.33S$, is $1.33(20,000) = 26,600$ psi.

The margin of safety for the bolts under sustained loading will be:

$$\text{M.S.} = (26,600/12705) - 1 = +1.09$$

Another occasional vertical loading of 250 lb. applied at the end of the rigid stub will be assessed. The flange has the least margin of safety under similar (seismic) loading, so it will be the critical component. The moment arm for the 250 lb. load will be 24 in. It will be resisted by the top and bottom attach bolts with a resistance couple arm of 4.63 in. The load in the bolts will be

$$\text{Load}_{\text{bolt}} = (250)24/4.63 = 1295 \text{ lb.}$$

The dead weight plus pressure plus occasional load in the bolt will be:

$$\text{Load}_{\text{bolt, total}} = 430 + 86 + 1295 = 1811 \text{ lb.}$$

The moment on the flange minimum section will be $1811(0.58) = 1050$ in. lb. The stress in the flange will be:

$$\text{Stress}_{\text{flange, occasional}} = 1050/0.055 = 19098 \text{ psi}$$

The margin of safety for the flange under this sustained loading will be:

$$\text{M.S.} = (22,200/19098) - 1 = +0.16$$

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6.1.5 Cask Attachment Fitting, Miscellaneous Items

Several of the smaller items in the tempered water line end cask fitting will be assessed.

Pressure fluctuations across the orifices within the attachment could cause the spring loaded internal valves to "chatter". The pressure drop, Δp , across the orifice is 6 psi. The diameter of the orifice is 0.46 in. (orifice area = $(\pi/4)(0.46^2) = 0.166 \text{ in.}^2$). If the force necessary to move the spring loaded valve is greater than the pressure drop force, then the valves will not chatter. The force, F , associated with the 6 psi pressure drop will be:

$$F_{\text{pressure drop}} = \Delta p(\text{Area}) = 6(0.166) = 1.0 \text{ lb.}$$

From Drawing 99007-101, the maximum distance that the orifice can open is 0.14 in. The spring rate, k , associated with a 1.0 lb. force moving 0.14 in. would be:

$$k = 1.0/0.14 = 7 \text{ lb./in.}$$

The valve opening distance will be less than the maximum, therefore the required spring rate will be greater than 7 lb./in. Assume that the opening distance is one half of the maximum. The required spring rate will then be $2(7) = 14 \text{ lb./in.}$

The spring rate that will be used (Drawing 99007-101, Part 15, spring rate from vendor catalog) will have a spring rate of 21.5 lb./in., therefore it is concluded that valve chatter will not occur.

Part 7 of 99007-101 is a base support for the spring that opens and closes that valve. This item is a plate that is cruciform in shape with a hole in the center that reduces the available area to resist bending. The hole leaves $0.54 - 0.28 = 0.26 \text{ in.}$ of beam width to carry bending loads. The thickness of the item is 0.12 in. and the length is 0.937 in. The section modulus at the reduced section is:

$$S = bt^2/6 = 0.26(0.12^2)/6 = 0.00062 \text{ in.}^3$$

The force needed to move the spring through the full distance is distance times spring rate:

$$F_{\text{spring}} = (0.14)21.5 = 3 \text{ lb.}$$

The moment in the cruciform plate will be:

$$M = FL/4 = 3(0.937)/4 = 0.7 \text{ in. lb.}$$

The resulting stress will be:

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$$\text{Stress} = M/S = 0.7/0.00062 = 1133 \text{ psi.}$$

The pipe is of ASTM A240 SS material. The allowable stress, S, is 20,000 psi.

The margin of safety for Part 7 will be:

$$M.S. = (20,000/1133) - 1 = +16.6$$

6.2 Flexible Line

The flexible pipe (hose) is procured as a Commercial Grade Item (CGI) qualified component. This provides that the product is of high quality from a reputable vendor. Additionally, the product will be inspected and pressure tested to a level of 150% above the system design pressure.

It is difficult to perform a rigorous stress analysis of the flexible line, however some scoping calculations may be performed to show that large margins of safety exist between actual requirements and stated vendor data.

Table 6-4 summarizes vendor data characteristics for the flexible pipe used in the tempered water line.

Table 6-4 -- Characteristics of Flexible Pipe

Size, I.D., In.	Size, O.D., In.	Recommended Working Pressure, psi	Test Pressure, psi	Minimum Burst Pressure, psi	Approximate Weight, lb./ft.
1	1.5	450	675	2100	0.75
3	3.7	150	225	700	2.5

The above table shows that there is a factor of greater than 4 between recommended working pressure and minimum burst pressure. The design pressure of the tempered water line (45 psi) is significantly less than the recommended vendor stated working pressure for the pipe.

For the low pressure condition of the tempered water system, dead weight or seismic load of the end fittings of the flexible pipe will be critical.

The capacity of the end fittings may be estimated by calculating the longitudinal force in the pipe due to vendor stated conditions of pressure rating. The longitudinal force, P, that the pipe must sustain due to pressure, p, may be calculated by:

$$P_{\text{pressure}} = p(\pi/4)D^2$$

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In the case of the tempered water system, some capacity of the pipe will be required to sustain the internal pressure. Accounting for the tempered water system design pressure gives a formula for pipe longitudinal force of:

$$P_{\text{pressure}} = (p - 45)(\pi/4)D^2$$

Table 6-5 summarizes the forces developed in the flexible pipe for various pressures. The reduction in force due to the design pressure has been included.

Table 6-5 -- Forces Developed in Pipe Due to Internal Pressure

Size, I.D., In.	Recommended Working Pressure		Minimum Burst Pressure	
	Pressure, psi	Longitudinal Force in Pipe, lb.	Pressure, psi	Longitudinal Force in Pipe, lb.
1	450	318	2100	1614
3	150	742	700	4630

Longitudinal loading will occur in the tempered water flexible pipe at the end that is attached to the vertical rigid line. Conservatively assuming that 8 feet are supported by this flange (include 4 lb./ft. for pipe and 3 lb./ft. for water) gives a load of:

$$P = 8(3 + 4) = 56 \text{ lb.}$$

Assuming that all of the dead weight load is carried by the 1 in. flexible line gives a margin of safety for dead weight of:

$$M.S. = (318/56) - 1 = +4.7$$

Seismic accelerations are 2 g's or less at the floor level where the flexible line will be located. It is judged that, based upon the above considerations, the line is adequate for the seismic occasional loading.

No definitive value will be stated for the margin of safety for the flexible pipe other than to recognize that the margin of safety will be greater than 0.0.

6.3 Rigid Vertical Line

The portion of the tempered water line that lies upstream of the flexible pipe is a rigid vertical pipe assembly that is attached to the process hood assembly support column. The configuration consists of a 1 1/2 in. diameter schedule 40 pipe inside of a 3 in. diameter schedule 40 pipe. The pipes are welded to a blind flange at the bottom end, which in turn is bolted to a support bracket. This support thus provides moment and three directional force restraint. The 1 1/2 in. pipe is also supported within the 3 in. pipe near the top of the 1 1/2

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in. pipe. The 3 in. pipe is in turn is supported by a U-bolt near its upper end. The rigid vertical line is shown in Drawing 99007-104.

6.3.1 Analysis of 1 1/2 in. Diameter Inner Pipe Under 1 g Lateral Static Loading

The inner vertical pipe is a 1 1/2 in. diameter pipe that has a lower fixed end support and ends in a flange near the process hood assembly. The configuration under lateral loading is a cantilever beam with an end support. The combined weight of the pipe plus water is 3.60 lb./ft. The upper flange and contributing attached pipe weight will conservatively be taken as 20 lb. The configuration of the 1 1/2 in. line is then as follows:

To simplify the analysis, the above configuration may be reduced to:

The force P is the sum of the flange weight at the end of the pipe and the distributed load in the region to the right of the support.

$$P = 20 + 7(3.60/12) = 22 \text{ lb.}$$

The applied moment at the end will be:

$$M_0 = 20(7) + (3.60/12)(7^2)/2 = 147 \text{ in. lb.}$$

Combining cases 5B and 5E of Reference Blodgett, 1966, Section 8, gives the following moments and reactions (maximum moment is at location 2):

$$M_2 = wL^2/8 - M_0/2 = (3.60/12)(108^2)/8 - (147/2) = 364 \text{ in. lb.}$$

$$R_1 = 3wL/8 + 3M_0/2L + P = [3(3.60/12)108]/8 + [3(147)]/[(2)108] + 22 = 36.2 \text{ lb.}$$

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$$R_2 = 5wL/8 - 3M_0/2L = [5(3.60/12)108]/8 - [3(147)]/[(2)108] = 18.2 \text{ lb.}$$

Bending stress in the 1 1/2 in. pipe under 1 g static lateral load will be:

$$\text{Stress}_{\text{bending}} = M/S = 364/0.326 = 1117 \text{ psi}$$

6.3.2 Analysis of 3 in. Diameter Outer Pipe Under 1 g Lateral Static Loading

The outer pipe is a 3 in. diameter vertical pipe that runs from the lower fixed end support up to a location near the process hood assembly. There is a U-bolt support near the upper end. The upper end of the 3 in. line provides support for one end of the inner 1 in. pipe. The configuration under lateral loading is similar to that for the 1 in. line described above (cantilever beam with an end support). The load at the end of the beam will be the reaction of the 1 in. pipe at that location as calculated above. Conservatively assume that the 3 in. pipe is filled with water. The combined weight of the pipe plus water is 10.8 lb./ft. The configuration of the 3 in. line is then as follows:

To simplify the analysis, the above configuration may be reduced to:

The force P is the sum of the 1 1/2 in. pipe reaction and the distributed load in the region to the right of the support.

$$P = 36.2 + 13(10.8/12) = 48 \text{ lb.}$$

The applied moment at the end will be:

$$M_0 = 36.2(13) + (10.8/12)(13^2)/2 = 545 \text{ in. lb.}$$

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Again combining cases 5B and 5E of Reference www, Section 8, gives the following moments and reactions (moment is at location 2):

$$M_2 = wL^2/8 - M_0/2 = (10.8/12)(96^2)/8 - (545/2) = 764 \text{ in. lb.}$$

$$R_1 = 3wL/8 + 3M_0/2L + P = [3(10.8/12)96]/8 + [3(545)]/[(2)96] + 48 = 88.9 \text{ lb.}$$

$$R_2 = 5wL/8 - 3M_0/2L = [5(10.8/12)96]/8 - [3(545)]/[(2)96] = 45.5 \text{ lb.}$$

Bending stress in the 3 in. pipe under 1g static lateral load will be:

$$\text{Stress}_{\text{bending}} = M/S = 764/1.72 = 444 \text{ psi}$$

6.3.3 Piping Stresses

6.3.3.1 Sustained pipe stresses

The sustained pipe stresses will be that of pressure and dead weight.

Longitudinal pressure stress in the 1 1/2 in. pipe will be:

$$\text{Stress}_{\text{pressure}} = pR/2t = 45(0.87)/2(0.145) = 135 \text{ psi}$$

The stress due to the vertical dead weight of the 1 1/2 in. diameter line (including the weight, P, of the flange at the top) will be:

$$\text{Stress}_{\text{dead weight}} = [wL + P]/\pi Dt = [(3.60/12)115 + 20]/[\pi(1.76)(0.145)] = 68 \text{ psi.}$$

Total sustained stress for the 1 1/2 in. pipe will be:

$$\text{Stress}_{\text{sustained, total, 1 1/2 in.}} = 135 + 68 = 203 \text{ psi.}$$

The pipe is of ASTM A312 SS material. The allowable stress, S, is 16,700 psi.

The margin of safety for the 1 1/2 in. pipe under sustained loading will be:

$$\text{M.S.} = (16,700/203) - 1 = +81.$$

Longitudinal pressure stress in the 3 in. pipe will be:

$$\text{Stress}_{\text{pressure}} = pR/2t = 45(1.64)/[2(0.216)] = 170 \text{ psi}$$

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The stress due to the vertical dead weight of the 3 in. diameter line will be:

$$\text{Stress}_{\text{dead weight}} = wL/\pi Dt = (10.8/12)116/[\pi(3.28)(0.216)] = 47 \text{ psi.}$$

Total sustained stress for the 3 in. pipe will be:

$$\text{Stress}_{\text{sustained, total, 3 in.}} = 170 + 47 = 217 \text{ psi.}$$

The margin of safety for the 3 in. pipe under sustained loading will be:

$$\text{M.S.} = (16,700/217) - 1 = +76.$$

6.3.3.2 Occasional Pipe Stresses

Since the pipe members must resist seismic loading from three simultaneous directions acting concurrently, the seismic loading levels of Table 5-1 (taken for the top of the column support) will be combined by the square root of the sum of the squares. Pipe stresses resulting from seismic loads are summarized in Table 6-6:

Table 6-6 – Pipe Stresses Resulting From Seismic Loads

Line Size, in.	Direction	Single Direction Acceleration, g's	Combined 3 Direction Acceleration, g's	Pipe Stress, 1 g Acceleration	Pipe Seismic Stress
1 1/2	Vertical	0.5	4.6	1117 psi	5138 psi
	E-W	1.7			
	N-S	4.2			
3	Vertical	0.5	4.6	444 psi	2042 psi
	E-W	1.7			
	N-S	4.2			

The occasional stresses in the rigid pipe and pipe weld will be the result of loading due to dead weight, pressure, and loading due to seismic excitation. Since the stress evaluation is being done using static methods, a factor of 1.5 will be applied to the static seismic stresses to account for dynamic effects.

Total maximum occasional stress in the 1 1/2 in. pipe will be:

$$\text{Stress}_{\text{pipe, occasional, 1 1/2 in.}} = 135 + 68 + 1.5(5138) = 7910 \text{ psi.}$$

The pipe is of ASTM A312 SS material. The allowable stress, 1.33S, is 1.33(16,700) = 22,200 psi.

The margin of safety for the 1 1/2 in. pipe under occasional loading will be:

$$\text{M.S.} = (22,200/7910) - 1 = +1.81$$

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Total maximum occasional stress in the 3 in. pipe will be:

$$\text{Stress}_{\text{pipe,occasional, 3in.}} = 170 + 47 + 1.5(2042) = 3280 \text{ psi.}$$

The margin of safety for the 3 in. pipe under occasional loading will be:

$$\text{M.S.} = (22,200/3280) - 1 = +5.77$$

6.4 Pipe Support Evaluation

The vertical rigid pipe is supported by two pipe supports. The lower support is a cantilever plate that provides both force and moment restraint. The upper support is a standard U-bolt pipe clamp support. Sustained (normal dead weight) loading on the supports is low, therefore only occasional (seismic) loading will be assessed. The supports are shown in Drawing 99007-103.

6.4.1 Lower Support

The vertical reaction and moment at the lower support will be a function of the weight of items above it. The following support loads are calculated for a 1 g dead weight condition.

The weight of the 1 1/2 in. pipe (plus the upper flange weight) will be:

$$W_{1 \frac{1}{2} \text{ in. pipe, vertical}} = (3.60/12)(115) + 20 = 54.5 \text{ lb.}$$

The weight of the 3 in. pipe (assume full of water) will be:

$$W_{3 \text{ in. pipe, vertical}} = (10.8/12)(96) = 86.4 \text{ lb.}$$

Piping reaction loads at the lower support are summarized in Table 6-7.

Table 6-7 – Pipe Reaction Loads at Lower Support

Load	1 g Load 1 1/2 in. Pipe	1 g Load 3 in. Pipe	Total 1 g Load	g Level From Table 5-1	Seismic Load
F _x	18.2 lb.	45.5 lb.	63.7 lb.	0.5	32 lb.
F _y	54.5 lb.	86.4 lb.	140.9 lb.	1.7+1.0*	380 lb.
F _z	18.2 lb.	45.5 lb.	63.7 lb.	4.2	267 lb.
M _x	364 in.-lb.	764 in.-lb.	1128 in.-lb.	0.5	564 in.-lb.
M _y	-	-	-	1.7	-
M _z	364 in.-lb.	764 in.-lb.	1128 in.-lb.	4.2	4738 in.-lb.

* Dead weight factor.

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The region where the support is welded to the vertical plate has the following configuration:

Maximum stresses in the lower support will occur at the base where the lateral plates are welded to the vertical plate. The effective throat of the two sided 1/8 fillet welds will be less than the thickness of the plate material. Since the weld and the plates have approximately the same allowable stress, the welds will be the critical items.

Conservatively ignore the 10 in. horizontal weld and assume that only the 5.41 in. vertical welds are effective.

The weld section modulus about the x axis will then be:

$$S_x = 2bd^2/6, \text{ where } b = \text{effective weld throat thickness} = 0.707(1/8)2$$

$$S_x = 2(1/8)(0.707)2(5.41^2)/6 = 1.72 \text{ in.}^3$$

The weld section modulus about the y axis will be:

$$S_y = 2(5.41)(1/8)2(0.707)5^2 = 47.8 \text{ in.}^3$$

The area of the weld will be:

$$A_{\text{weld}} = 2(5.41)2(1/8)(0.707) = 1.91 \text{ in.}^2$$

Torsional resistance of a two weld configuration about the z-z axis will be (Blodgett, 1966, page 7.4-7, Table 5):

$$J_{\text{weld}} = [d(3b^2 + d^2)/6](t),$$

where d = length of welds, b = distance between welds, and t = throat thickness.

$$J_{\text{weld}} = [5.41(3(10^2) + 5.41^2)/6](1/8)(2)(0.707) = 52.5 \text{ in.}^3$$

Stresses in the weld will be calculated for the loads from the above table.

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Bending about x-x weld axis:

Bending about the x-x axis will involve F_y , F_z , and M_x . The total moment in the weld will be (4.48 and 5.41/2 represent offset distances for the forces F_y and F_z):

$$M_{x-x} = F_y(4.48) + F_z(5.41/2) + M_x = 380(4.48) + 267(5.41/2) + 564 = 2989 \text{ in. lb.}$$

The stress in the weld is as follows (a factor of 1.5 to account for the static analysis will be included):

$$\text{Stress}_{\text{weld, bending x-x}} = 1.5(2989)/1.72 = 2607 \text{ psi.}$$

Bending about y-y weld axis:

Bending about the y-y axis will involve F_x , F_z , and M_y . The total moment in the weld will be (4.48 and 5/2 represent offset distances for the forces F_x and F_z):

$$M_{y-y} = F_x(4.48) + F_z(5/2) + M_y = 32(4.48) + 267(5/2) + 0 = 811 \text{ in. lb.}$$

The stress in the weld is as follows (a factor of 1.5 to account for the static analysis will be included):

$$\text{Stress}_{\text{weld, bending y-y}} = 1.5(811)/47.8 = 25 \text{ psi.}$$

Shear in the x-y plane

Shear in the x-y plane will involve the forces F_x and F_y .

$$F_{x-y} = (F_x^2 + F_y^2)^{1/2} = (32^2 + 380^2)^{1/2} = 381 \text{ lb.}$$

The stress in the weld is as follows (a factor of 1.5 to account for the static analysis will be included):

$$\text{Stress}_{\text{weld, shear x-y}} = 1.5(381)/1.91 = 299 \text{ psi.}$$

Torsion about the z axis

Torsion about the z axis will involve the moment M_z .

$$M_z = 4738 \text{ in. lb.}$$

The stress in the weld is as follows (a factor of 1.5 to account for the static analysis will be included):

$$\text{Stress}_{\text{weld, torsion z}} = 1.5(4738)/52.5 = 135 \text{ psi.}$$

Total stress in the lower support weld will be:

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$$\text{Stress}_{\text{weld}} = 2607 + 25 + 299 + 135 = 3066 \text{ psi.}$$

As a conservatism, the allowable stress for sustained loads will be used. The allowable weld stress is $0.3 \times$ nominal tensile strength of weld material (Ref N690) $= 0.3(70,000) = 21,000 \text{ psi.}$

The margin of safety for the lower support weld under occasional loading will be:

$$\text{M.S.} = (21,000/3066) - 1 = +5.85$$

6.4.2 Upper Support

Piping reaction loads at the upper support are summarized in Table 6-8.

Table 6-8 – Pipe Reaction Loads at the Upper Support

Load	1 g Load 1 1/2 in. Pipe	1 g Load 3 in. Pipe	Total 1 g Load	g Level From Table 5-1	Seismic Load
F _x	36.2 lb.	88.9 lb.	125 lb.	0.5	62.5 lb.
F _y	-	-	-	-	-
F _z	36.2 lb.	88.9 lb.	125 lb.	4.2	525 lb.

The upper support U-bolt clamp is made of a 0.5 in. diameter rod and loaded as shown below:

Conservatively assume that all of the x-direction load is resisted by one leg of the clamp.

The bending moment in the rod will be:

$$M = 62.5(1.75) = 109 \text{ in. lb.}$$

The section modulus for a circular section is:

$$S = (\pi/4)R^3 = (\pi/4)(0.25)^3 = 0.012 \text{ in.}^3$$

The bending stress in the clamp will be:

$$\text{Stress}_{\text{bending}} = M/S = 109/0.012 = 9114 \text{ psi.}$$

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The tensile load, P, in the rod will be carried equally between two legs of the clamp. The stress will be:

$$\text{Stress}_{\text{tensile}} = P/2A = (525)/[2(\pi/4)(0.5^2)] = 1337 \text{ psi.}$$

Total stress in the clamp will be:

$$\text{Stress}_{\text{clamp}} = 9114 + 1337 = 10451 \text{ psi}$$

The allowable stress will be taken from the criteria of ANSI/ASCE, 1994. Conservatively, the value for normal conditions will be used. The allowable is $0.6 F_y = 0.6(36000) = 21600 \text{ psi}$ for A36 material.

Margin of safety for the upper clamp is therefore:

$$\text{M.S.} = (21,600/10451) - 1 = +1.07$$

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7.0 INSTALLATION SEQUENCE AND ASSOCIATED TOOLING

The radiation level of the MCO cask lower port is such that remote methods must be used for the connecting/disconnecting the fitting at the end of the tempered water line to the cask. Personnel must remain at least 10 in. away from the cask during the procedure.

The cask cavity that will receive the attachment fitting currently has four existing bolt holes for receiving ½ in. diameter bolts to attach a cover plate. The holes have a tapped 1/2-13UNC thread and are equally spaced on a 4.63 in. diameter.

These exiting holes will be utilized to attach the cask fitting. The bolts on the tempered water line are spring loaded and "captured" in the end fitting.

The installation sequence is:

1. Relieve pressure in the tempered water line.
2. Slide the tempered water line end fitting into the lower MCO cask cavity.
3. Align the attachment bolts to the bolt holes.
4. Push the fitting into the cavity to engage and activate the internal valves.
5. Hold the fitting in place and secure the bolts using a socket wrench and extension.

The removal sequence is:

1. Relieve pressure in the tempered water line.
2. Hold the fitting in place and disengage the bolt threads using a socket wrench and extension.
3. Pull the fitting away from the cavity to disengage the internal valves.
4. Slide the tempered water line end fitting out of the lower MCO cask cavity.

No special installation tools are required other than standard socket wrenches.

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