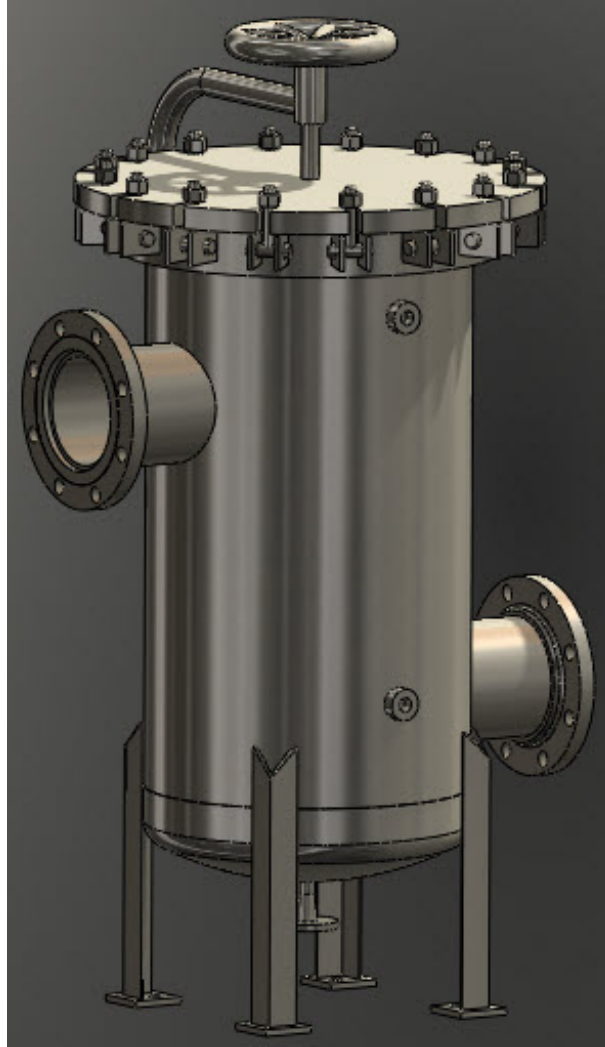


Key Design Engineering

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COMPRESS Pressure Vessel Design Calculations

Item: Sample Filter

Vessel No: KEY-026

Designer: David Burr

Date: March 31, 2011

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Settings Summary

COMPRESS Build 7110

Units: U.S. Customary

Datum Line Location: 0.00" from bottom seam

Design

ASME Section VIII Division 1, 2010 Edition

| | |
|---|--|
| Design or Rating: | Get Pressure Rating and Calculate Required Thickness |
| Minimum thickness: | 0.0625" per UG-16(b) |
| Design for cold shut down only: | No |
| Design for lethal service (full radiography required): | No |
| Design nozzles for: | Find nozzle MAWP and MAP |
| Corrosion weight loss: | 100% of theoretical loss |
| UG-23 Stress Increase: | 1.20 |
| Skirt/legs stress increase: | 1.0 |
| Minimum nozzle projection: | 0.01" |
| Juncture calculations for $\alpha > 30$ only: | Yes |
| Preheat P-No 1 Materials $> 1.25\text{"}^{\#34}$ and $\leq 1.50\text{"}^{\text{thick}}$: | No |
| UG-37(a) shell tr calculation considers longitudinal stress: | No |
| Butt welds are tapered per Figure UCS-66.3(a). | |

Hydro/Pneumatic Test

| | |
|-------------------------------|--------------------|
| Shop Hydrotest Pressure: | 1.3 times design P |
| Test liquid specific gravity: | 1.00 |
| Maximum stress during test: | 90% of yield |

Required Marking - UG-116

| | |
|------------------------------------|------|
| UG-116(e) Radiography: | RT4 |
| UG-116(f) Postweld heat treatment: | None |

Code Cases\Interpretations

| | |
|-------------------------------------|-----|
| Use Code Case 2547: | No |
| Apply interpretation VIII-1-83-66: | No |
| Apply interpretation VIII-1-86-175: | Yes |
| Apply interpretation VIII-1-83-115: | No |
| Apply interpretation VIII-1-01-37: | Yes |
| No UCS-66.1 MDMT reduction: | No |
| No UCS-68(c) MDMT reduction: | No |
| Disallow UG-20(f) exemptions: | No |

UG-22 Loadings

| | |
|--|-----|
| UG-22(a) Internal or External Design Pressure : | Yes |
| UG-22(b) Weight of the vessel and normal contents under operating or test conditions: | Yes |
| UG-22(c) Superimposed static reactions from weight of attached equipment (external loads): | No |
| UG-22(d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs: | Yes |
| UG-22(f) Wind reactions: | No |
| UG-22(f) Seismic reactions: | No |
| UG-22(j) Test pressure and coincident static head acting during the test: | Yes |

Note: UG-22(b),(c) and (f) loads only considered when supports are present.

Deficiencies Summary

No deficiencies found.

Pressure Summary

Pressure Summary for Chamber bounded by Item 2 - F&D Head and Item 6 - Bolted Cover

| Identifier | P Design (psi) | T Design (°F) | MAWP (psi) | MAP (psi) | MAEP (psi) | T _e external (°F) | MDMT (°F) | MDMT Exemption | Impact Tested |
|--|----------------|---------------|------------|-----------|------------|------------------------------|-----------|----------------|---------------|
| Item 6 - Bolted Cover | 150 | 250 | 175.42 | 179.91 | 253.91 | 250 | -320 | Note 1 | No |
| Item 1 - Shell | 150 | 250 | 266.28 | 273.11 | 93.73 | 250 | -320 | Note 1 | No |
| Straight Flange on Item 2 - F&D Head | 150 | 250 | 231.49 | 237.43 | 46.41 | 250 | -320 | Note 1 | No |
| Item 2 - F&D Head | 150 | 250 | 177.2 | 181.75 | 50.44 | 250 | -320 | Note 2 | No |
| Item 13 - Legs | 150 | 250 | 159.21 | N/A | N/A | N/A | N/A | N/A | N/A |
| Item 5 - Flange (21") | 150 | 250 | 159.21 | 165.35 | 494.68 | 250 | -55 | Note 3 | No |
| Item 3 - Pipe (6") (Itm3) | 150 | 250 | 245 | N/I | 68.55 | 250 | -55 | Note 4 | No |
| Copy of Item 3 - Pipe (6") (Itm3b) | 150 | 250 | 242.26 | N/I | 66.07 | 250 | -55 | Note 5 | No |
| Item 7 - Half Coupling (1") (Itm7) | 150 | 250 | 409.67 | N/I | 93.73 | 250 | -55 | Note 5 | No |
| Item 9 - Pipe (3/4") (Itm9) | 150 | 250 | 245 | N/I | 46.41 | 250 | -55 | Note 4 | No |

Chamber design MDMT is -20 °F

Chamber rated MDMT is -55 °F @ 159.21 psi

Chamber MAWP was used in the MDMT determination

Chamber MAWP hot & corroded is 159.21 psi @ 250 °F

Chamber MAP cold & new is 165.35 psi @ 70 °F

Chamber MAEP is 46.41 psi @ 250 °F

Vacuum rings did not govern the external pressure rating.

Notes for MDMT Rating:

| Note # | Exemption | Details |
|--------|---|---|
| 1. | Rated MDMT per UHA-51(d)(1)(a) = -320 °F | |
| 2. | Material Rated MDMT per UHA-51(d)(1)(a) = -320 °F | |
| 3. | Flange Rated MDMT per UHA-51(d)(1)(a) = -320 °F | Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F |
| 4. | Flange rating governs: | UCS-66(b)(1)(b) |
| 5. | Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20 °F Fig UCS-66.1 MDMT reduction = 116.1 °F, (coincident ratio = 0.38091) Rated MDMT is governed by UCS-66(b)(2) | UCS-66 governing thickness = 0.1875 in. |

Design notes are available on the [Settings Summary](#) page.

Thickness Summary

| Component Identifier | Material | Diameter (in) | Length (in) | Nominal t (in) | Design t (in) | Total Corrosion (in) | Joint E | Load |
|--|------------|---------------|-------------|----------------|---------------|----------------------|---------|----------|
| Item 6 - Bolted Cover | SA-240 304 | 21 OD | 1.25 | 1.25* | 1.1559 | 0 | 1.00 | Internal |
| Item 1 - Shell | SA-240 304 | 18 OD | 32 | 0.1875 | 0.1061 | 0 | 0.65 | Internal |
| Straight Flange on Item 2 - F&D Head | SA-240 304 | 18 OD | 2 | 0.125 | 0.0812 | 0 | 0.85 | Internal |
| Item 2 - F&D Head | SA-240 304 | 18 OD | 4.8285 | 0.125* | 0.106 | 0 | 0.85 | Internal |

Nominal t: Vessel wall nominal thickness

Design t: Required vessel thickness due to governing loading + corrosion

Joint E: Longitudinal seam joint efficiency

* Head minimum thickness after forming

Load

internal: Circumferential stress due to internal pressure governs

external: External pressure governs

Wind: Combined longitudinal stress of pressure + weight + wind governs

Seismic: Combined longitudinal stress of pressure + weight + seismic governs

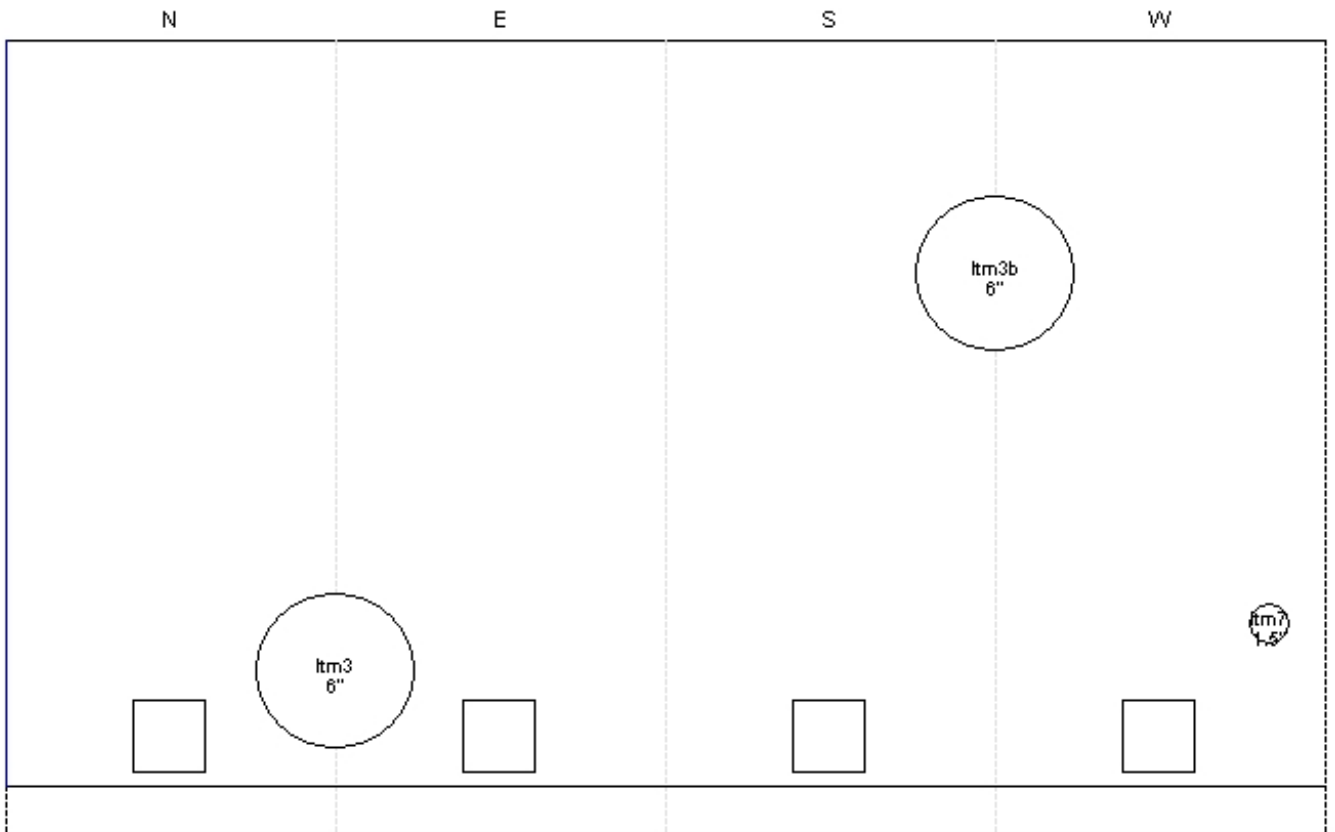
Long Seam Summary

| Shell Long Seam Angles | |
|--------------------------------|--------|
| Component | Seam 1 |
| Item 1 - Shell | 315° |

| Shell Plate Lengths | | |
|--------------------------------|----------------|----------|
| Component | Starting Angle | Plate 1 |
| Item 1 - Shell | 315° | 55.9596" |

*North is located at 0°

*Plate Lengths use the circumference of the vessel based on the mid diameter of the components



Shell Rollout

Hydrostatic Test

Shop test pressure determination for Chamber bounded by Item 2 - F&D Head and Item 6 - Bolted Cover based on design P per UG-99(b)

Shop hydrostatic test gauge pressure is 195 psi at 70 °F (the chamber design P = 150 psi)

The shop test is performed with the vessel in the horizontal position.

| Identifier | Local test pressure psi | Test liquid static head psi | UG-99 stress ratio | UG-99 pressure factor | Stress during test psi | Allowable test stress psi | Stress excessive? |
|--|-------------------------|-----------------------------|--------------------|-----------------------|------------------------|---------------------------|-------------------|
| Item 1 - Shell | 195.778 | 0.778 | 1.0256 | 1.30 | 9,299 | 27,000 | No |
| Straight Flange on Item 2 - F&D Head | 195.781 | 0.781 | 1.0256 | 1.30 | 13,998 | 27,000 | No |
| Item 2 - F&D Head | 195.781 | 0.781 | 1.0256 | 1.30 | 14,096 | 27,000 | No |
| Item 6 - Bolted Cover | 195.778 | 0.778 | 1.0256 | 1.30 | 21,764 | 40,500 | No |
| Item 5 - Flange (21") | 195.787 | 0.787 | 1.0256 | 1.30 | 17,307 | 40,500 | No |
| Copy of Item 3 - Pipe (6") (Itm3b) (1) | 195.921 | 0.921 | 1 | 1.30 | 21,170 | 40,500 | No |
| Item 3 - Pipe (6") (Itm3) | 195.308 | 0.308 | 1.0256 | 1.30 | 21,103 | 40,500 | No |
| Item 7 - Half Coupling (1") (Itm7) | 195.318 | 0.318 | 1 | 1.30 | 9,180 | 40,500 | No |
| Item 9 - Pipe (3/4") (Itm9) | 195.475 | 0.475 | 1 | 1.30 | 18,105 | 40,500 | No |

Notes:

- (1) Copy of Item 3 - Pipe (6") (Itm3b) limits the UG-99 stress ratio.
- (2) P_L stresses at nozzle openings have been estimated using the method described in PVP-Vol. 399, pages 77-82.
- (3) $1.5 \cdot 0.9 \cdot S_y$ used as the basis for the maximum local primary membrane stress at the nozzle intersection P_L .
- (4) The zero degree angular position is assumed to be up, and the test liquid height is assumed to the top-most flange.

The field test condition has not been investigated for the Chamber bounded by Item 2 - F&D Head and Item 6 - Bolted Cover.

The test temperature of 70 °F is warmer than the minimum recommended temperature of -25 °F so the brittle fracture provision of UG-99(h) has been met.

Nozzle Summary

| Nozzle mark | OD (in) | t _n (in) | Req t _n (in) | A ₁ ? | A ₂ ? | Shell | | | Reinforcement Pad | | Corr (in) | A _a / A _r (%) |
|-----------------------|---------|---------------------|-------------------------|------------------|------------------|------------|---------------|-------------|-------------------|-----------------------|-----------|-------------------------------------|
| | | | | | | Nom t (in) | Design t (in) | User t (in) | Width (in) | t _{pad} (in) | | |
| itm3 | 6.625 | 0.28 | 0.1286 | Yes | Yes | 0.1875 | 0.1528 | | N/A | N/A | 0 | 100.0 |
| itm3b | 6.625 | 0.28 | 0.1272 | Yes | Yes | 0.1875 | 0.1113 | | N/A | N/A | 0 | 100.0 |
| itm7 | 1.75 | 0.2175 | 0.0625 | Yes | Yes | 0.1875 | N/A | | N/A | N/A | 0 | Exempt |
| itm9 | 1.05 | 0.113 | 0.113 | Yes | Yes | 0.125* | N/A | | N/A | N/A | 0 | Exempt |

t_n: Nozzle thickness

Req t_n: Nozzle thickness required per UG-45/UG-16

Nom t: Vessel wall thickness

Design t: Required vessel wall thickness due to pressure + corrosion allowance per UG-37

User t: Local vessel wall thickness (near opening)

A_a: Area available per UG-37, governing condition

A_r: Area required per UG-37, governing condition

Corr: Corrosion allowance on nozzle wall

* Head minimum thickness after forming

Nozzle Schedule

| Nozzle mark | Service | Size | Materials | | | | | | | | |
|-----------------------|-----------------------------|-----------------------------|------------------------------|--------|------|------------|-----|--------|------|------------|-------------------|
| | | | Nozzle | Impact | Norm | Fine Grain | Pad | Impact | Norm | Fine Grain | Flange |
| itm3 | Item 3 - Pipe (6") | NPS 6 Sch 40S (Std) | SA-312 TP304 Wld & smls pipe | No | No | No | N/A | N/A | N/A | N/A | WN A105 Class 150 |
| itm3b | Copy of Item 3 - Pipe (6") | NPS 6 Sch 40 (Std) | SA-106 B Smls pipe | No | No | No | N/A | N/A | N/A | N/A | WN A105 Class 300 |
| itm7 | Item 7 - Half Coupling (1") | NPS 1 Class 3000 - threaded | SA-105 | No | No | No | N/A | N/A | N/A | N/A | N/A |
| itm9 | Item 9 - Pipe (3/4") | NPS 0.75 Sch 40 (Std) | SA-106 B Smls pipe | No | No | No | N/A | N/A | N/A | N/A | WN A105 Class 150 |

Weight Summary

| Component | Weight (lb) Contributed by Vessel Elements | | | | | | | Surface Area ft ² |
|---------------------------------------|---|-----------------|-----------------------|----------|-----------------|------------------|--------------|------------------------------|
| | Metal New* | Metal Corroded* | Insulation & Supports | Lining | Piping + Liquid | Operating Liquid | Test Liquid | |
| Item 6 - Bolted Cover | 125.6 | 125.6 | 0 | 0 | 0 | 0 | 0 | 3 |
| Item 1 - Shell | 93.5 | 93.5 | 0 | 0 | 0 | 0 | 291.9 | 12 |
| Item 2 - F&D Head | 17.5 | 17.5 | 0 | 0 | 0 | 0 | 47.7 | 4 |
| Item 13 - Legs | 11.3 | 11.3 | 0 | 0 | 0 | 0 | 0 | 4 |
| TOTAL: | 247.8 | 247.8 | 0 | 0 | 0 | 0 | 339.6 | 22 |

* Shells with attached nozzles have weight reduced by material cut out for opening.

| Component | Weight (lb) Contributed by Attachments | | | | | | | | Surface Area ft ² | |
|---------------------------------------|---|-------------|-------------------|-------------|-------------|---------------------|------------------|---------------|------------------------------|----------------|
| | Body Flanges | | Nozzles & Flanges | | Packed Beds | Ladders & Platforms | Trays & Supports | Rings & Clips | | Vertical Loads |
| | New | Corroded | New | Corroded | | | | | | |
| Item 6 - Bolted Cover | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Item 1 - Shell | 67.3 | 67.3 | 76.6 | 76.6 | 0 | 0 | 0 | 0 | 0 | 8 |
| Item 2 - F&D Head | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Item 13 - Legs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTAL: | 67.3 | 67.3 | 78.6 | 78.6 | 0 | 0 | 0 | 0 | 0 | 4 |

Vessel operating weight, Corroded: 394 lb
 Vessel operating weight, New: 394 lb
 Vessel empty weight, Corroded: 394 lb
 Vessel empty weight, New: 394 lb
 Vessel test weight, New: 733 lb
 Vessel surface area: 26 ft²

Vessel center of gravity location - from datum - lift condition

Vessel Lift Weight, New: 394 lb
 Center of Gravity: 22.1308"

Vessel Capacity

Vessel Capacity** (New): 40 US gal
 Vessel Capacity** (Corroded): 40 US gal

**The vessel capacity does not include volume of nozzle, piping or other attachments.

Item 1 - Shell

ASME Section VIII Division 1, 2010 Edition

Component: Cylinder
Material specification: SA-240 304 (II-D p. 86, ln. 25)
Rated MDMT per UHA-51(d)(1)(a) = -320 °F

Internal design pressure: $P = 150 \text{ psi @ } 250 \text{ °F}$

External design pressure: $P_e = 15 \text{ psi @ } 250 \text{ °F}$

Static liquid head:

$$P_{th} = 0.78 \text{ psi}_{head} \quad (SG = 1, H_s = 21.5634", \text{ Horizontal test})$$

Corrosion allowance Inner C = 0" Outer C = 0"

Design MDMT = -20 °F No impact test performed
Rated MDMT = -320 °F Material is not normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography: Longitudinal joint - None UW-11(c) Type 2
Top circumferential joint - N/A
Bottom circumferential joint - None UW-11(c) Type 1

Estimated weight New = 93.5 lb corr = 93.5 lb
Capacity New = 33.8 US gal corr = 33.8 US gal

OD = 18"
Length = 32"
 L_c
t = 0.1875"

Design thickness, (at 250 °F) Appendix 1-1

$$\begin{aligned} t &= P \cdot R_o / (S \cdot E + 0.40 \cdot P) + \text{Corrosion} \\ &= 150 \cdot 9 / (19,500 \cdot 0.65 + 0.40 \cdot 150) + 0 \\ &= 0.1061" \end{aligned}$$

Maximum allowable working pressure, (at 250 °F) Appendix 1-1

$$\begin{aligned} P &= S \cdot E \cdot t / (R_o - 0.40 \cdot t) - P_s \\ &= 19,500 \cdot 0.65 \cdot 0.1875 / (9 - 0.40 \cdot 0.1875) - 0 \\ &= 266.28 \text{ psi} \end{aligned}$$

Maximum allowable pressure, (at 70 °F) Appendix 1-1

$$\begin{aligned} P &= S \cdot E \cdot t / (R_o - 0.40 \cdot t) \\ &= 20,000 \cdot 0.65 \cdot 0.1875 / (9 - 0.40 \cdot 0.1875) \\ &= 273.11 \text{ psi} \end{aligned}$$

External Pressure, (Corroded & at 250 °F) UG-28(c)

$$L / D_o = 36.1178 / 18 = 2.0065$$

$$D_o / t = 18 / 0.0791 = 227.4320$$

From table G: A = 0.000191
 From table HA-1: B = 2,558.6055 psi

$$P_a = 4*B / (3*(D_o / t))$$

$$= 4*2,558.61 / (3*(18 / 0.0791))$$

$$= 15 \text{ psi}$$

Design thickness for external pressure $P_a = 15$ psi

$$t_a = t + \text{Corrosion} = 0.0791 + 0 = 0.0791''$$

Maximum Allowable External Pressure, (Corroded & at 250 °F) UG-28(c)

$$L / D_o = 36.1178 / 18 = 2.0065$$

$$D_o / t = 18 / 0.1875 = 96.0000$$

From table G: A = 0.000689
 From table HA-1: B = 6,748.7842 psi

$$P_a = 4*B / (3*(D_o / t))$$

$$= 4*6,748.78 / (3*(18 / 0.1875))$$

$$= 93.73 \text{ psi}$$

% Forming strain - UHA-44(a)(2)(a)

$$EFE = (50*t / R_f) * (1 - R_f / R_o)$$

$$= (50*0.1875 / 8.9063) * (1 - 8.9063 / \infty)$$

$$= 1.0526\%$$

External Pressure + Weight Check (Bergman, ASME paper 54-A-104)

$$P_v = W / (2*\pi*R_m) + M / (\pi*R_m^2)$$

$$= 359.9 / (2*\pi*8.9063) + 261 / (\pi*8.9063^2)$$

$$= 7.4778 \text{ lb/in}$$

$$\alpha = P_v / (P_e * D_o)$$

$$= 7.4778 / (15*18)$$

$$= 0.0277$$

$$n = 4$$

$$m = 1.23 / (L / D_o)^2$$

$$= 1.23 / (36.1178 / 18)^2$$

$$= 0.3055$$

$$\text{Ratio } P_e = (n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m)$$

$$= (4^2 - 1 + 0.3055 + 0.3055*0.0277) / (4^2 - 1 + 0.3055)$$

$$= 1.0006$$

Ratio $P_e * P_e \leq$ MAEP design cylinder thickness is satisfactory.

External Pressure + Weight Check at Bottom Seam (Bergman, ASME paper 54-A-104)

$$P_v = W / (2 * \pi * R_m) + M / (\pi * R_m^2)$$

$$= -22.5 / (2 * \pi * 8.9063) + 0 / (\pi * 8.9063^2)$$

$$= -0.4023 \text{ lb/in}$$

$$\alpha = P_v / (P_e * D_o)$$

$$= -0.4023 / (15 * 18)$$

$$= -0.0015$$

$$n = 4$$

$$m = 1.23 / (L / D_o)^2$$

$$= 1.23 / (36.1178 / 18)^2$$

$$= 0.3055$$

$$\text{Ratio } P_e = (n^2 - 1 + m + m * \alpha) / (n^2 - 1 + m)$$

$$= (4^2 - 1 + 0.3055 + 0.3055 * -0.0015) / (4^2 - 1 + 0.3055)$$

$$= 1.0000$$

Ratio $P_e * P_e \leq$ MAEP design cylinder thickness is satisfactory.

Design thickness = 0.1061"

The governing condition is due to internal pressure.

The cylinder thickness of 0.1875" is adequate.

The governing condition is due to pressure.

Thickness Required Due to Pressure + External Loads

| Condition | Allowable Stress Before UG-23 Stress Increase (psi) | | Temperature (°F) | Corrosion C (in) | Location | Load | Pressure P (psi) | Req'd Thk Due to Tension (in) | Req'd Thk Due to Compression (in) |
|---------------------------|--|------------------------|-------------------|------------------|----------|--------|------------------------|-------------------------------|-----------------------------------|
| | S _t | S _c | | | | | | | |
| Operating, Hot & Corroded | 19,500 | 10.322 | 250 | 0 | Top | Weight | 838.15 | 0.0336 | 0.0335 |
| | | | | | Bottom | Weight | 836.82 | 0.0339 | 0.0339 |
| Operating, Hot & New | 19,500 | 10.322 | 250 | 0 | Top | Weight | 838.15 | 0.0336 | 0.0335 |
| | | | | | Bottom | Weight | 836.82 | 0.0339 | 0.0339 |
| Hot Shut Down, Corroded | 19,500 | 10.322 | 250 | 0 | Top | Weight | 0 | 0.0005 | 0.0007 |
| | | | | | Bottom | Weight | 0 | 0 | 0 |
| Hot Shut Down, New | 19,500 | 10.322 | 250 | 0 | Top | Weight | 0 | 0.0005 | 0.0007 |
| | | | | | Bottom | Weight | 0 | 0 | 0 |
| Empty, Corroded | 20,000 | 12.142 | 70 | 0 | Top | Weight | 0 | 0.0004 | 0.0006 |
| | | | | | Bottom | Weight | 0 | 0 | 0 |
| Empty, New | 20,000 | 12.142 | 70 | 0 | Top | Weight | 0 | 0.0004 | 0.0006 |
| | | | | | Bottom | Weight | 0 | 0 | 0 |

| | | | | | | | | | |
|--|--------|------------------------|-----|---|--------|--------|------------------------|------------------------|------------------------|
| Vacuum | 19,500 | 10.322 | 250 | 0 | Top | Weight | 441.28 | 0.0069 | 0.0071 |
| | | | | | Bottom | Weight | 443.1 | 0.0064 | 0.0064 |
| Hot Shut Down, Corroded, Weight & Eccentric Moments Only | 19,500 | 10.322 | 250 | 0 | Top | Weight | 0 | 0.0005 | 0.0007 |
| | | | | | Bottom | Weight | 0 | 0 | 0 |

Item 2 - F&D Head

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Component: F&D Head
Material Specification: SA-240 304 (II-D p.86, ln. 25)
Material Rated MDMT per UHA-51(d)(1)(a) = -320 °F

Internal design pressure: $P = 150 \text{ psi @ } 250 \text{ °F}$

External design pressure: $P_e = 15 \text{ psi @ } 250 \text{ °F}$

Static liquid head:

$P_s = 0 \text{ psi (SG=1, } H_s=0" \text{ Operating head)}$

$P_{th} = 0.7806 \text{ psi (SG=1, } H_s=21.6259" \text{ Horizontal test head)}$

Corrosion allowance: Inner C = 0" Outer C = 0"

Design MDMT = -20°F No impact test performed
Rated MDMT = -320°F Material is not normalized
Material is not produced to fine grain practice
PWHT is not performed
Do not Optimize MDMT / Find MAWP

Radiography: Category A joints - Spot UW-11(b) Type 1
Head to shell seam - None UW-11(c) Type 1

Estimated weight*: new = 17.5 lb corr = 17.5 lb
Capacity*: new = 5.7 US gal corr = 5.7 US gal
* includes straight flange

Outer diameter = 18"
Crown radius L = 18"
Knuckle radius r = 3.75"
Minimum head thickness = 0.125"
Straight flange length L_{sf} = 2"
Nominal straight flange thickness t_{sf} = 0.125"

Results Summary

The governing condition is internal pressure.

Minimum thickness per UG-16 = $0.0625" + 0" = 0.0625"$
Design thickness due to internal pressure (t) = [0.106"](#)
Design thickness due to external pressure (t_e) = [0.0543"](#)
Maximum allowable working pressure (MAWP) = [177.2](#) psi
Maximum allowable pressure (MAP) = [181.75](#) psi
Maximum allowable external pressure (MAEP) = [50.44](#) psi

Note: Appendix 1-4 footnote 1 used to determine allowable stress.

M (Corroded)

$$M = 1/4 * [3 + (L / r)^{1/2}] = 1/4 * [3 + (18 / 3.75)^{1/2}] = 1.297723$$

M (New)

$$M = 1/4 * [3 + (L / r)^{1/2}] = 1/4 * [3 + (18 / 3.75)^{1/2}] = 1.297723$$

Design thickness for internal pressure, (Corroded at 250 °F) Appendix 1-4(d)

$$\begin{aligned} t &= P * L_o * M / (2 * S * E + P * (M - 0.2)) + \text{Corrosion} \\ &= 150 * 18.125 * 1.2977 / (2 * 19,500 * 0.85 + 150 * (1.2977 - 0.2)) + 0 \\ &= 0.1059" \end{aligned}$$

The head internal pressure design thickness is [0.106"](#).

Maximum allowable working pressure, (Corroded at 250 °F) Appendix 1-4(d)

$$\begin{aligned} P &= 2 * S * E * t / (M * L_o - t * (M - 0.2)) - P_s \\ &= 2 * 19,500 * 0.85 * 0.125 / (1.2977 * 18.125 - 0.125 * (1.2977 - 0.2)) - 0 \\ &= 177.2 \text{ psi} \end{aligned}$$

The maximum allowable working pressure (MAWP) is [177.2](#) psi.

Maximum allowable pressure, (New at 70 °F) Appendix 1-4(d)

$$\begin{aligned} P &= 2 * S * E * t / (M * L_o - t * (M - 0.2)) - P_s \\ &= 2 * 20,000 * 0.85 * 0.125 / (1.2977 * 18.125 - 0.125 * (1.2977 - 0.2)) - 0 \\ &= 181.75 \text{ psi} \end{aligned}$$

The maximum allowable pressure (MAP) is [181.75](#) psi.

Design thickness for external pressure, (Corroded at 250 °F) UG-33(e)

$$\begin{aligned} \text{Equivalent outside spherical radius } (R_o) &= \text{Outside crown radius} \\ &= 18.125 \text{ in} \end{aligned}$$

$$\begin{aligned} A &= 0.125 / (R_o / t) \\ &= 0.125 / (18.125 / 0.054243) \\ &= 0.000374 \end{aligned}$$

$$\begin{aligned} \text{From Table HA-1: } B &= 5,012.2065 \text{ psi} \end{aligned}$$

$$\begin{aligned} P_a &= B / (R_o / t) \\ &= 5,012.207 / (18.125 / 0.0542) \\ &= 15 \text{ psi} \end{aligned}$$

$$t = 0.0542" + \text{Corrosion} = 0.0542" + 0" = 0.0542"$$

Check the external pressure per UG-33(a)(1) Appendix 1-4(d)

$$\begin{aligned} t &= 1.67 * P_e * L_o * M / (2 * S * E + 1.67 * P_e * (M - 0.2)) + \text{Corrosion} \\ &= 1.67 * 15 * 18.125 * 1.2977 / (2 * 19,500 * 1 + 1.67 * 15 * (1.2977 - 0.2)) + 0 \\ &= 0.0151" \end{aligned}$$

The head external pressure design thickness (t_e) is [0.0542"](#).

Maximum Allowable External Pressure, (Corroded at 250 °F) UG-33(e)

$$\text{Equivalent outside spherical radius } (R_o)$$

$$= \text{Outside crown radius}$$

$$= 18.125 \text{ in}$$

$$A = 0.125 / (R_o / t)$$

$$= 0.125 / (18.125 / 0.125)$$

$$= 0.000862$$

From Table HA-1: $B = 7,313.6406$
psi

$$P_a = B / (R_o / t)$$

$$= 7,313.641 / (18.125 / 0.125)$$

$$= 50.4389 \text{ psi}$$

Check the Maximum External Pressure, UG-33(a)(1) Appendix 1-4(d)

$$P = 2 * S * E * t / ((M * L_o - t * (M - 0.2)) * 1.67) - P_{s2}$$

$$= 2 * 19,500 * 1 * 0.125 / ((1.2977 * 18.125 - 0.125 * (1.2977 - 0.2)) * 1.67) - 0$$

$$= 124.84 \text{ psi}$$

The maximum allowable external pressure (MAEP) is [50.44](#) psi.

% Forming strain - UHA-44(a)(2)(b)

$$EFE = (75 * t / R_f) * (1 - R_f / R_o)$$

$$= (75 * 0.125 / 3.8125) * (1 - 3.8125 / \infty)$$

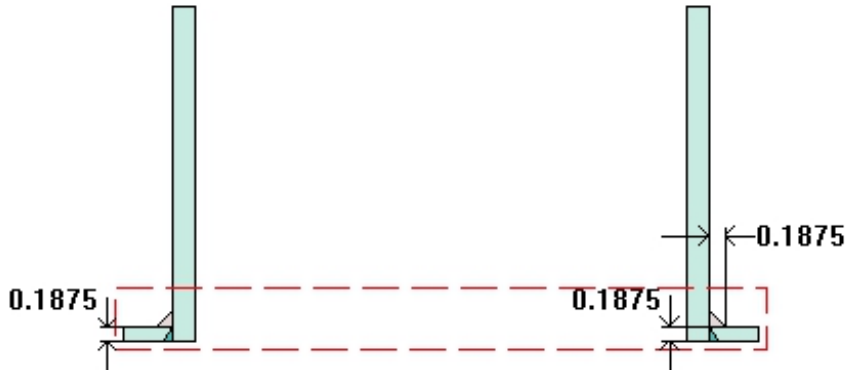
$$= 2.459\%$$

Item 3 - Pipe (6") (Itm3)

ASME Section VIII Division 1, 2010 Edition

$$t_{w(\text{lower})} = 0.1875 \text{ in}$$

$$\text{Leg}_{41} = 0.1875 \text{ in}$$



Note: round inside edges per UG-76(c)

| | |
|---|---|
| Located on: | Item 1 - Shell |
| Liquid static head included: | 0 psi |
| Nozzle material specification: | SA-312 TP304 Wld & smls pipe (II-D p. 86, In. 36) |
| Nozzle longitudinal joint efficiency: | 1 |
| Nozzle description: | NPS 6 Sch 40S (Std) |
| Flange description: | 6 inch Class 150 WN A105 |
| Bolt Material: | SA-193 B7 Bolt $\leq 2 \frac{1}{2}$ (II-D p. 334, In. 32) |
| Flange rated MDMT: (UCS-66(b)(1)(b)) | -55 °F |
| Liquid static head on flange: | 0 psi |
| ASME B16.5 flange rating MAWP: | 245 psi @ 250 °F |
| ASME B16.5 flange rating MAP: | 285 psi @ 70 °F |
| ASME B16.5 flange hydro test: | 450 psi @ 70 °F |
| Gasket Description: | Flexitallic Spiral Wound CGI 304 S.S. |
| PWHT performed: | No |
| Circumferential joint radiography: | None UW-11(c) Type 1 |
| Nozzle orientation: | 45° |
| Local vessel minimum thickness: | 0.1875 in |
| Nozzle center line offset to datum line: | 5 in |
| End of nozzle to shell center: | 15 in |
| Nozzle inside diameter, new: | 6.065 in |
| Nozzle nominal wall thickness: | 0.28 in |
| Nozzle corrosion allowance: | 0 in |
| Projection available outside vessel, Lpr: | 2.5 in |
| Projection available outside vessel to flange face, Lf: | 6 in |

Reinforcement Calculations for Internal Pressure

The attached ASME B16.5 flange limits the nozzle MAWP.

| UG-37 Area Calculation Summary (in ²) | | | | | | | UG-45 Nozzle Wall Thickness Summary (in) | |
|--|-------------|----------------|----------------|----------------|----------------|---------|--|------------------|
| For P = 245 psi @ 250 °F The opening is adequately reinforced | | | | | | | The nozzle passes UG-45 | |
| A required | A available | A ₁ | A ₂ | A ₃ | A ₅ | A welds | t _{req} | t _{min} |
| 0.6824 | 0.7165 | 0.4548 | 0.2265 | -- | -- | 0.0352 | 0.1125 | 0.245 |

| UG-41 Weld Failure Path Analysis Summary |
|--|
| The nozzle is exempt from weld strength calculations per UW-15(b)(1) |

| UW-16 Weld Sizing Summary | | | |
|---|--------------------------------|------------------------------|-----------------------|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet (Leg ₄₁) | 0.1312 | 0.1312 | weld size is adequate |

Calculations for internal pressure 245 psi @ 250 °F

Nozzle rated MDMT per UHA-51(d)(1)(a) = -320 °F.

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(6.065, 3.0325 + (0.28 - 0) + (0.1875 - 0)) \\
 &= 6.065 \text{ in}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.1875 - 0), 2.5*(0.28 - 0) + 0) \\
 &= 0.4688 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 245 \cdot 3.0325 / (19,500 \cdot 1 - 0.6 \cdot 245) \\
 &= 0.0384 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\
 &= 245 \cdot 9 / (19,500 \cdot 1 + 0.4 \cdot 245) \\
 &= 0.1125 \text{ in}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 19,500$, $S_v = 19,500$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 6.065 \cdot 0.1125 \cdot 1 + 2 \cdot 0.28 \cdot 0.1125 \cdot 1 \cdot (1 - 1) \\ &= \underline{0.6824} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.4548} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 6.065 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1125) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1125) \cdot (1 - 1) \\ &= 0.4548 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.1875 + 0.28) \cdot (1 \cdot 0.1875 - 1 \cdot 0.1125) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1125) \cdot (1 - 1) \\ &= 0.0701 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.2265} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.28 - 0.0384) \cdot 1 \cdot 0.1875 \\ &= 0.2265 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\ &= 5 \cdot (0.28 - 0.0384) \cdot 1 \cdot 0.28 \\ &= 0.3382 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.1875^2 \cdot 1 \\ &= \underline{0.0352} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.4548 + 0.2265 + 0.0352 \\ &= \underline{0.7165} \text{ in}^2 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t_{\neq} = 0.1875 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.1312 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.1875 = 0.1313 \text{ in}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

$$\begin{aligned} t_{a \text{ UG-27}} &= P * R / (S * E - 0.6 * P) + \text{Corrosion} \\ &= 245 * 3.0325 / (19,500 * 1 - 0.6 * 245) + 0 \\ &= 0.0384 \text{ in} \end{aligned}$$

$$\begin{aligned} t_a &= \max[t_{a \text{ UG-27}}, t_{a \text{ UG-22}}] \\ &= \max[0.0384, 0] \\ &= 0.0384 \text{ in} \end{aligned}$$

$$\begin{aligned} t_{b1} &= P * R_o / (S * E + 0.4 * P) + \text{Corrosion} \\ &= 245 * 9 / (19,500 * 1 + 0.4 * 245) + 0 \\ &= 0.1125 \text{ in} \end{aligned}$$

$$\begin{aligned} t_{b1} &= \max[t_{b1}, t_{b \text{ UG16}}] \\ &= \max[0.1125, 0.0625] \\ &= 0.1125 \text{ in} \end{aligned}$$

$$\begin{aligned} t_b &= \min[t_{b3}, t_{b1}] \\ &= \min[0.245, 0.1125] \\ &= 0.1125 \text{ in} \end{aligned}$$

$$\begin{aligned} t_{\text{UG-45}} &= \max[t_a, t_b] \\ &= \max[0.0384, 0.1125] \\ &= 0.1125 \text{ in} \end{aligned}$$

Available nozzle wall thickness new, $t = 0.875 * 0.28 = 0.245 \text{ in}$

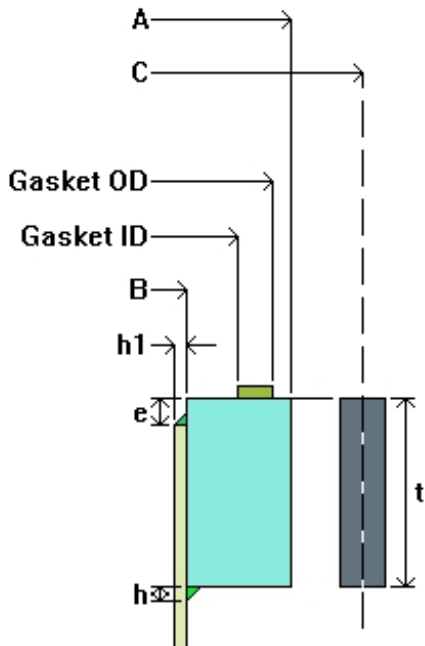
The nozzle neck thickness is adequate.

Item 5 - Flange (21")

ASME VIII-1, 2010 Edition, Appendix 2 Flange Calculations

| | | |
|--|--|---|
| Flange is attached to: | Item 1 - Shell (Top) | |
| Flange type: | Ring type loose | |
| Flange material specification: | SA-240 304 (II-D p. 86, In. 25) | |
| Bolt material specification: | SA-193 B7 Bolt $\leq 2\ 1/2$ (II-D p. 334, In. 32) | |
| Bolt Description: | 0.625 in Coarse Thread | |
| Internal design pressure, P: | 150 psi @ 250 °F | |
| Required flange thickness: t_r : | 2.5734 in | |
| Maximum allowable working pressure, MAWP: | 159.21 psi @ 250 °F | |
| Maximum allowable pressure, MAP: | 165.35 psi @ 70 °F | |
| External design pressure, P_e : | 15 psi @ 250 °F | |
| Maximum allowable external pressure, MAEP: | 494.68 psi @ 250 °F | |
| Corrosion allowance: | Bore = 0 in | Flange = 0 in |
| Bolt corrosion (root), C_{bolt} : | 0 in | |
| Design MDMT: | -20 °F | No impact test performed |
| Rated MDMT: | -55 °F | Flange material is not normalized |
| | | Material is produced to fine grain practice |
| | | PWHT is not performed |
| Estimated weight: | New = 67.3 lb | corroded = 67.3 lb |

Flange dimensions, new



| | |
|-------------------|--------------------|
| flange OD | A = 21 in |
| bolt circle | C = 23 in |
| gasket OD | = 20.5 in |
| gasket ID | = 19.5 in |
| flange ID | B = 18.125 in |
| thickness | t = 2.625 in |
| bolting | = 16- 0.625 in dia |
| lower fillet weld | h = 0.1875 in |
| upper fillet weld | h1 = 0.1875 in |
| length | e = 0.375 in |
| gasket factor | m = 2 |
| seating stress | y = 2,500 psi |
| Gasket thickness | T = 0.175 in |

Item 6 - Bolted Cover

ASME Section VIII Division 1, 2010 Edition

Component: Bolted Cover
Attached to: Item 5 - Flange (21")
Material specification: SA-240 304 (II-D p. 86, ln. 25)
Rated MDMT per UHA-51(d)(1)(a) = -320 °F

Internal design pressure: $P = 150 \text{ psi @ } 250 \text{ °F}$
External design pressure: $P_e = 15 \text{ psi @ } 250 \text{ °F}$

Static liquid head:

$$P_{th} = 0.79 \text{ psi}_{\text{head}} \quad (SG = 1, H_s = 21.8134", \text{ Horizontal test})$$

Corrosion allowance: Inner C = 0" Outer C = 0"

Design MDMT = -20 °F No impact test performed
Rated MDMT = -320 °F Material is not normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography: Category A joints - Seamless No RT

Estimated weight: New = 125.6 lb corr = 125.6 lb

Head diameter, $d = 20"$

Cover thickness, $t = 1.25"$

Design thickness, (at 250 °F) UG-34 (c)(2), flange operating

$$\begin{aligned} t &= d \cdot \text{Sqr}(C \cdot P / (S \cdot E) + 1.9 \cdot W \cdot h_G / (S \cdot E \cdot d^3)) + \text{Corrosion} \\ &= 20 \cdot \text{Sqr}(0.3 \cdot 150 / (19,500 \cdot 1) + 1.9 \cdot 56,520 \cdot 1.5 / (19,500 \cdot 1 \cdot 20^3)) + 0 \\ &= 1.1559 \text{ in} \end{aligned}$$

Design thickness, (at 70 °F) UG-34 (c)(2), gasket seating

$$\begin{aligned} t &= d \cdot \text{Sqr}(1.9 \cdot W \cdot h_G / (S \cdot E \cdot d^3)) + \text{Corrosion} \\ &= 20 \cdot \text{Sqr}(1.9 \cdot 68,660 \cdot 1.5 / (20,000 \cdot 1 \cdot 20^3)) + 0 \\ &= 0.6994 \text{ in} \end{aligned}$$

Maximum allowable working pressure, (at 250 °F)

$$\begin{aligned} P &= (S \cdot E / C) \cdot ((t / d)^2 - (1.9 \cdot W \cdot h_G / (S \cdot E \cdot d^3))) - P_s \\ &= (19,500 \cdot 1 / 0.3) \cdot ((1.25 / 20)^2 - (1.9 \cdot 66,096.93 \cdot 1.5 / (19,500 \cdot 1 \cdot 20^3))) - 0 \\ &= 175.42 \text{ psi} \end{aligned}$$

Maximum allowable pressure, (At 70 °F)

$$\begin{aligned} P &= (S \cdot E / C) \cdot ((t / d)^2 - (1.9 \cdot W \cdot h_G / (S \cdot E \cdot d^3))) \\ &= (20,000 \cdot 1 / 0.3) \cdot ((1.25 / 20)^2 - (1.9 \cdot 67,791.69 \cdot 1.5 / (20,000 \cdot 1 \cdot 20^3))) \\ &= 179.91 \text{ psi} \end{aligned}$$

Design thickness for external pressure, (at 250 °F) U-2(g)

$$t = d \cdot \text{Sqr}(C \cdot P_a / (S \cdot E)) + \text{Corrosion}$$

$$\begin{aligned} &= 20 \cdot \text{Sqr}(0.3 \cdot 15 / (19,500 \cdot 1)) + 0 \\ &= 0.3038 \text{ in} \end{aligned}$$

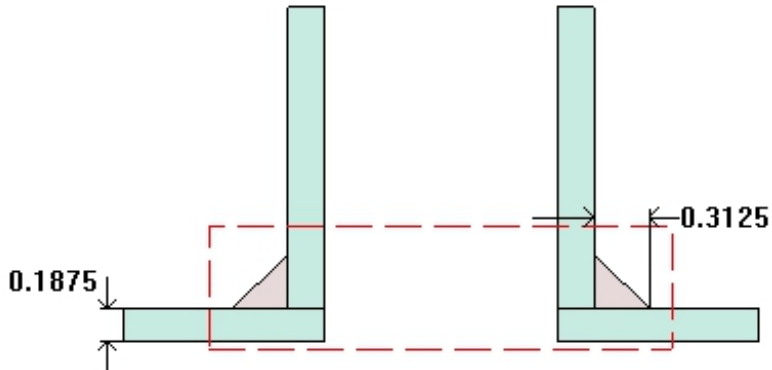
Maximum allowable external pressure, (At 250 °F) U-2(g)

$$\begin{aligned} P_a &= (S \cdot E / C) \cdot (t / d)^2 \\ &= (19,500 \cdot 1 / 0.3) \cdot (1.25 / 20)^2 \\ &= 253.91 \text{ psi} \end{aligned}$$

Item 7 - Half Coupling (1") (Itm7)

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$$t_{w(\text{lower})} = 0 \text{ in}$$
$$\text{Leg}_{41} = 0.3125 \text{ in}$$



Note: round inside edges per UG-76(c)

| | |
|--|-----------------------------|
| Located on: | Item 1 - Shell |
| Liquid static head included: | 0 psi |
| Nozzle material specification: | SA-105 (II-D p. 18, ln. 5) |
| Nozzle longitudinal joint efficiency: | 1 |
| Nozzle description: | NPS 1 Class 3000 - threaded |
| Nozzle orientation: | 300° |
| Local vessel minimum thickness: | 0.1875 in |
| Nozzle center line offset to datum line: | 7 in |
| End of nozzle to shell center: | 11 in |
| Nozzle inside diameter, new: | 1.315 in |
| Nozzle nominal wall thickness: | 0.2175 in |
| Nozzle corrosion allowance: | 0 in |
| Projection available outside vessel, L _{pr} : | 2 in |

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

| | | | | | | | | |
|---|-------------|----------------|----------------|----------------|----------------|---------|--|------------------|
| UG-37 Area Calculation Summary (in²) For P = 409.67 psi @ 250 °F | | | | | | | UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45 | |
| A required | A available | A ₁ | A ₂ | A ₃ | A ₅ | A welds | t _{req} | t _{min} |
| This nozzle is exempt from area calculations per UG-36(c)(3)(a) | | | | | | | 0.0625 | 0.2175 |

| |
|--|
| UG-41 Weld Failure Path Analysis Summary |
| The nozzle is exempt from weld strength calculations per UW-15(b)(2) |

| UW-16 Weld Sizing Summary | | | |
|---|--------------------------------|------------------------------|-----------------------|
| Weld description | Required weld throat size (in) | Actual weld throat size (in) | Status |
| Nozzle to shell fillet (Leg ₄₁) | 0.1268 | 0.2188 | weld size is adequate |

Calculations for internal pressure 409.67 psi @ 250 °F

Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
 Fig UCS-66.1 MDMT reduction = 116.1 °F, (coincident ratio = 0.38091)
 Rated MDMT is governed by UCS-66(b)(2).

Nozzle UCS-66 governing thk: 0.1875 in

Nozzle rated MDMT: -55 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.315, 0.6575 + (0.2175 - 0) + (0.1875 - 0)) \\
 &= 1.315 \text{ in}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.1875 - 0), 2.5*(0.2175 - 0) + 0) \\
 &= 0.4688 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P*R_n / (S_n*E - 0.6*P) \\
 &= 409.6698*0.6575 / (20,000*1 - 0.6*409.6698) \\
 &= 0.0136 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned}t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\ &= 409.6698 \cdot 9 / (19,500 \cdot 1 + 0.4 \cdot 409.6698) \\ &= 0.1875 \text{ in}\end{aligned}$$

This opening does not require reinforcement per UG-36(c)(3)(a)

Check the weld - From UW-16(f)(3)(a)(3)(a)

| | |
|---------------------------------------|--------------------------------------|
| Wall thickness per UG-45(a): | $t_{r1} = 0.0178 \text{ in (E = 1)}$ |
| Wall thickness per UG-45(b)(1): | $t_{r2} = 0.1875 \text{ in}$ |
| Wall thickness per UG-16(b): | $t_{r3} = 0.0625 \text{ in}$ |
| Standard wall pipe per UG-45(b)(4): | $t_{r4} = 0.1269 \text{ in}$ |
| The greater of t_{r2} or t_{r3} : | $t_{r5} = 0.1875 \text{ in}$ |
| The lesser of t_{r4} or t_{r5} : | $t_{r6} = 0.1269 \text{ in}$ |

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 0.1269 \text{ in}$

$$t_{w(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.3125 = 0.2188 \text{ in}$$

The fillet weld size is satisfactory.

ASME B16.11 Coupling Wall Thickness Check

| | |
|---|--------------------------------------|
| Wall thickness req'd per ASME B16.11 2.1.1: | $t_{r1} = 0.0178 \text{ in (E = 1)}$ |
| Wall thickness per UG-16(b): | $t_{r3} = 0.0625 \text{ in}$ |

Available nozzle wall thickness new, $t = 0.2175 \text{ in}$

The nozzle neck thickness is adequate.

