CADEM SOFTWARES

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“CademPVD” is an integrated software encompassing all aspects of mechanical design of various process plant equipment. It is a very intelligent software and works with minimum inputs. For any data that is not provided by the user, the software uses the best possible estimates for them wherever possible. This makes the software very easy to use, thus greatly enhancing equipment design productivity.

eg: For a body flange of an equipment, none of the parameters like the Flange OD, Flange ID, PCD, Number and Size of bolts, Gasket OD & ID, etc. need to be specified. The software evaluates all these undefined parameters by itself, meeting the requirements of the specified equipment design code.

The software performs intricate calculations like design of tube plates, at just the click of a button, even for multiple design conditions.

In the software, the user defines the main features of the equipment. Any changes to the features of the model are automatically reflected in all other dependent components.

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- International and National Design Codes
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Design of Process Equipment
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Wind and Seismic Analysis
Finite Element Analysis

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Our flagship software product, CademPVD, encompasses all aspects of mechanical design of shell and tube heat exchangers, pressure vessels, self supported columns and chimneys etc.

We undertake design and preparation of fabrication drawings for pressure vessels, reactors with agitator shafts, heat exchangers, storage tanks, tall towers, chimneys etc. as per various international and national codes like ASME Sec. VIII Div. I, TEMA, API 620, API 650, IS 2825, IS 803, IS 6533 etc.

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Email: services@cadem.net
Website: www.cadem.net
EXAMPLE NO. PV-01

DESIGN OF PRESSURE VESSEL
(GAS FILTER)

This example covers design of a simple pressure vessel. This pressure vessel has a top flat cover and a bottom dished end. The top cover is of bolted type and is connected to the shell through top body flange. The pressure vessel is provided with lugs support and lifting lug.
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Description</th>
<th>Page No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Title page &amp; equipment info</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Design data</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Material of constructions</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Effective Pressures</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Weight summary report</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Wind load calculations</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Seismic load calculations</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Design of Bolted Cover (Front)</td>
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<tr>
<td>9</td>
<td>Design of Bolted Cover (Front)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Design of Shell Flng (Front)</td>
<td></td>
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<tr>
<td>11</td>
<td>Design of Shell Flng (Front)</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Design of Main Shell</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Design of Dished End (Rear)</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Design of Lug Support</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Design of Lug Support</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Design of N 01</td>
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<tr>
<td>17</td>
<td>Design of N 02</td>
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<tr>
<td>18</td>
<td>Design of N 03</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Design of Lifting Lugs</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Foundation load data</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>C.G. Data</td>
<td></td>
</tr>
</tbody>
</table>
Customer: ABC Company Ltd.
Project: Soap Plant
Location: Vapi Site
Plant: Refrigeration Plant

**EQUIPMENT INFORMATION:**
- **Design Code:** ASME VIII Div.1, 15
- **Equipment Name:** PV-01 - Gas Filter
- **Equipment Type:** Pressure Vessel
- **Equipment Class:** N.A.
- **Equipment Category:** N.A.
- **Reference Drawing No:** ---
- **Service:** Other Service
- **Support Type:** Lug Supports

**DESIGN & REVIEWAL:**
- **Designed By:**
- **Design Date:** 24/Aug/2018 11:17:33
- **Checked By:**
- **Approved By:**
- **Revision:** R00

**INSPECTION & APPROVAL:**
- **Inspection Agency:** ---
- **Reviewed By:** ---

**EQUIPMENT DATA:**
- **Front end:** Flat End
- **Front end flanged:** True
- **Rear end:** Dished End
- **Rear end flanged:** False
- **Shell ID:** 1250 mm
- **Shell OD:** 1274 mm
- **Length, Shell (W.L. to W.L) / Overall:** 1650 / 2122.8 mm

**OTHER DATA:**
- **Fabricated weight ( corr / uncorr )** 2415.5 / 2660.6 kgf
- **Empty weight + external weights ( corr / uncorr )** 2415.5 / 2660.6 kgf
- **Estimated operating weight ( corr / uncorr )** 4789.1 / 5009.7 kgf
- **Estimated hydrotest weight ( corr / uncorr )** 4701.6 / 4922.3 kgf
**VESSEL DESIGN DATA**

(1) **PROCESS DETAILS**

<table>
<thead>
<tr>
<th>MEDIA</th>
<th>DENSITY kg/m³</th>
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<tbody>
<tr>
<td>Operating</td>
<td>1000</td>
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<tr>
<td>Design1</td>
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<tr>
<td>Design2</td>
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<tr>
<td>Startup</td>
<td></td>
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<tr>
<td>Shutdown</td>
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<td>Upset</td>
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<tr>
<td>Hydrotest</td>
<td>1000</td>
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<tr>
<td>Pneumatic</td>
<td>1.2</td>
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(2) **PR. : kgf/mm² g**

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<tbody>
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<tr>
<td>Design2</td>
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<td></td>
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<td>Startup</td>
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<tr>
<td>Shutdown</td>
<td></td>
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<tr>
<td>Upset</td>
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<tr>
<td>Hydrotest</td>
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(3) **TEST PR. : kgf/mm² g**

Based on

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<td>MAP</td>
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<td>150</td>
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<td></td>
<td>15</td>
<td></td>
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<td>Hydrotest</td>
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<td>45</td>
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<tr>
<td>Pneumatic</td>
<td>21.67</td>
<td>45</td>
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(4) **TEMPERATURE : °C**

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<tr>
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<tr>
<td>Design1</td>
<td>15</td>
<td>150</td>
</tr>
<tr>
<td>Design2</td>
<td></td>
<td></td>
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<tr>
<td>Startup</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shutdown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrotest</td>
<td>21.67</td>
<td>45</td>
</tr>
<tr>
<td>Pneumatic</td>
<td>21.67</td>
<td>45</td>
</tr>
</tbody>
</table>

(5) **ALLOWANCES : mm**

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Corrosion</td>
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<tr>
<td>Polishing</td>
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<td>0</td>
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</tbody>
</table>

(6) **RADIOGRAPHY & JOINT EFFICIENCY**

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<tr>
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<th>RADIOGRAPHY</th>
<th>JOINT EFFICIENCY</th>
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<tbody>
<tr>
<td>Shell</td>
<td>Spot</td>
<td>0.85</td>
</tr>
<tr>
<td>Head</td>
<td>Full</td>
<td>1.00</td>
</tr>
</tbody>
</table>
VESSEL DESIGN DATA

1. MATERIAL OF CONSTRUCTION:

**Shell side**

Shell  
SA-516 GR. 70 Plt. [UNS:K02700]

Head  
SA-516 GR. 70 Plt. [UNS:K02700]

Body flange  
SA-105 Frg. [UNS:K03504]

Body flange cover  
SA-105 Frg. [UNS:K03504]

Liner

**2. NOZZLE CONNECTIONS:**

**Shell side**

Nozzle neck <= NPS 40  
SA-106 GR. B Smls. Pipe  
[UNS:K03006]

Flange  
SA-105 Frg. [UNS:K03504]

Cover flange  
SA-105 Frg. [UNS:K03504]

Nozzle NPS > 40 & < 200  
SA-106 GR. B Smls. Pipe  
[UNS:K03006]

Flange  
SA-105 Frg. [UNS:K03504]

Cover flange  
SA-105 Frg. [UNS:K03504]

Nozzle neck >= NPS 200  
SA-516 GR. 70 Plt. [UNS:K02700]

Flange  
SA-516 GR. 70 Plt. [UNS:K02700]

Cover flange  
SA-516 GR. 70 Plt. [UNS:K02700]

Pad flange  
SA-516 GR. 70 Plt. [UNS:K02700]

Pad flange cover  
SA-516 GR. 70 Plt. [UNS:K02700]

Manhole flange  
SA-516 GR. 70 Plt. [UNS:K02700]

Manhole cover  
SA-516 GR. 70 Plt. [UNS:K02700]

Reinforcement pad  
SA-516 GR. 70 Plt. [UNS:K02700]

External bolt  
SA-193 GR. B7 Bolt [UNS:G41400]

External gasket  
CAF with suitable binder (3 mm.)

Stiffener  
SA-516 GR. 70 Plt. [UNS:K02700]

Lifting lug  
IS-2062 GR. A Plt.

Support  
IS-2062 GR. A Plt.

Anchor bolt  
Commercial CS Bolt

3. INSULATION & CLADDING:

Mat. / Density / Thk.  
Rockwool (Mineral Fibre) / 136.2 kg/m³ / 40 mm

Mat. / Thk.  
Al. sheet / 1.191 mm
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Item Name</th>
<th>Temp.</th>
<th>Inside pr. +ve</th>
<th>Liquid pr. +ve</th>
<th>Inside pr. -ve</th>
<th>Liquid pr. -ve</th>
<th>Effective pr. +ve</th>
<th>Effective pr. -ve</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bolted Cover (Front)</td>
<td>120</td>
<td>0.12</td>
<td>0.01055</td>
<td>0</td>
<td>0</td>
<td>0.12</td>
<td>0.01055</td>
</tr>
<tr>
<td>2</td>
<td>Shell Flng (Front)</td>
<td>120</td>
<td>0.12</td>
<td>0.01055</td>
<td>0</td>
<td>0</td>
<td>0.12</td>
<td>0.01055</td>
</tr>
<tr>
<td>3</td>
<td>Main Shell</td>
<td>120</td>
<td>0.12</td>
<td>0.01055</td>
<td>0</td>
<td>0</td>
<td>0.12</td>
<td>0.01055</td>
</tr>
<tr>
<td>4</td>
<td>Dished End (Rear)</td>
<td>120</td>
<td>0.12</td>
<td>0.01055</td>
<td>0</td>
<td>0</td>
<td>0.12</td>
<td>0.01055</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Item wise Weight Summary

**Licensee:** CADEM Softwares, 411003  
**Customer:** ABC Company Ltd.  
**Project / Equipment:** Soap Plant / PV-01 - Gas Filter  
**Designed By / Revision and Date:** / R00, 24/Aug/2018 11:17:33

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Item name</th>
<th>Item size</th>
<th>Empty wt kgf</th>
<th>Volume m³</th>
<th>Filled wt kgf</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bolted Cover (Front)</td>
<td>Blind Cover - 1463 OD x 84.304 Thk, RF, 1413 PCD, Tgrv = 1.588</td>
<td>1100.8</td>
<td>0</td>
<td>1100.8</td>
</tr>
<tr>
<td>2</td>
<td>Shell Flng (Front)</td>
<td>Plate Ring - 1463 OD x 1250 ID x 1413 PCD, RF, 119.522 Thk, Tgrv = 1.588</td>
<td>423.7</td>
<td>0</td>
<td>423.7</td>
</tr>
<tr>
<td>3</td>
<td>Gasket Flng (Front)</td>
<td>1381.943 OD x 1250 ID, 3.175 Thk</td>
<td>0.1</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>4</td>
<td>Bolt Flng (Front)</td>
<td>Hex Head Bolt M22 x 240.751 Lg, 56 Nos.</td>
<td>40.57</td>
<td>0</td>
<td>40.57</td>
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<tr>
<td>5</td>
<td>Main Shell</td>
<td>1274 OD x 12 Thk, 1650 Lg</td>
<td>621.4</td>
<td>2.025</td>
<td>2646.3</td>
</tr>
<tr>
<td>6</td>
<td>Dished End (Rear)</td>
<td>Elliptical D/2H = 2.0, 1274 OD x 12 Nom / 10.8 Min Thk, SF = 50</td>
<td>203.2</td>
<td>0.317</td>
<td>520.3</td>
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<tr>
<td>7</td>
<td>Bolting Plate</td>
<td>222 Long x 200 Wide x 16 Thk, 4 Nos.</td>
<td>22.5</td>
<td>0</td>
<td>22.5</td>
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<tr>
<td>8</td>
<td>Gusset Plate</td>
<td>200 Long x 190 Wide x 16 Thk, 8 Nos.</td>
<td>38.51</td>
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<tr>
<td>9</td>
<td>Anchor Bolt</td>
<td>Anchor M20 x 200 Lg, 4 Nos.</td>
<td>1.99</td>
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<tr>
<td>10</td>
<td>Support Pad</td>
<td>275 Long x 272 Wide x 12 Thk, 4 Nos.</td>
<td>28.42</td>
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<td>28.42</td>
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<tr>
<td>11</td>
<td>N 01</td>
<td>ANSI B36.10, 150 NPS Sch.80, 156 Lg</td>
<td>6.697</td>
<td>0.00262</td>
<td>9.32</td>
</tr>
<tr>
<td>12</td>
<td>Flange [N 01]</td>
<td>Weld Neck, ANSI B16.5, RF, 150# for 150 NPS Sch 80 Pipe</td>
<td>8.08</td>
<td>0</td>
<td>8.08</td>
</tr>
<tr>
<td>13</td>
<td>Gasket [N 01]</td>
<td>150 NPS x 150#, 3.175 Thk</td>
<td>0.1</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>14</td>
<td>Counter Flng [N 01]</td>
<td>Weld Neck, ANSI B16.5, RF, 150# for 150 NPS Sch 80 Pipe</td>
<td>8.08</td>
<td>0</td>
<td>8.08</td>
</tr>
<tr>
<td>15</td>
<td>Reinf [N 01]</td>
<td>292.659 OD x 171.275 ID x 12 Thk</td>
<td>4.202</td>
<td>0</td>
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<tr>
<td>16</td>
<td>N 02</td>
<td>ANSI B36.10, 150 NPS Sch.80, 156 Lg</td>
<td>6.697</td>
<td>0.00262</td>
<td>9.32</td>
</tr>
<tr>
<td>17</td>
<td>Flange [N 02]</td>
<td>Weld Neck, ANSI B16.5, RF, 150# for 150 NPS Sch 80 Pipe</td>
<td>8.08</td>
<td>0</td>
<td>8.08</td>
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<tr>
<td>18</td>
<td>Gasket [N 02]</td>
<td>150 NPS x 150#, 3.175 Thk</td>
<td>0.1</td>
<td>0</td>
<td>0.1</td>
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<tr>
<td>19</td>
<td>Counter Flng [N 02]</td>
<td>Weld Neck, ANSI B16.5, RF, 150# for 150 NPS Sch 80 Pipe</td>
<td>8.08</td>
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<tr>
<td>21</td>
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<td>ANSI B36.10, 150 NPS Sch.160, 151 Lg</td>
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<tr>
<td></td>
<td>Description</td>
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<td>Width</td>
<td>Thickness</td>
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<tr>
<td>23</td>
<td>Gasket [N 03]</td>
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<tr>
<td>24</td>
<td>Bolted Cover [N 03]</td>
<td>Blind Cover, ANSI B16.5, RF, 150# for 150 NPS Pipe</td>
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<td>Reinf [N 03]</td>
<td>263.5 OD x 171.275 ID x 12 Thk</td>
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<td>26</td>
<td>Lifting Lugs</td>
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<td>27</td>
<td>Pad (Lifting Lugs)</td>
<td>70 Long x 170 Wide x 8 Thk, 2 Nos.</td>
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<td>28</td>
<td>Insulation</td>
<td>4178.318 W x 3622.804 L, 40 Thk</td>
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<td>29</td>
<td>Cladding</td>
<td>4182.059 W x 3622.804 L, 1.191 Thk</td>
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<td>4.993</td>
</tr>
</tbody>
</table>

Σ 2660.6  Σ 4922.3
1. DESIGN CONDITIONS (Operating Mode, Corroded Condition):
   - Basic wind speed (Section 5.2) $V_b \geq 50$ m/s
   - Expected life of equipment (Section 5.3.1) 25 Years
   - Probability factor (Risk coeff) (Section 5.3.1) $K_1 = 0.902$
   - Terrain category (Section 5.3.2) Category 2
   - Structure class (Section 5.3.2.2) Class B
   - Topography factor (Section 5.3.3) $K_3 = 1.3$
   - Force coefficient (Shape factor) $C_f = 0.8$

3. CALCULATION OF FORCES AND MOMENTS:
   - Equivalent diameter $D_e = 1862$ mm
   - Overall length of equipment $L = 2122.8$ mm
   - Height of C.G. of equipment $H_{cg} = 1738.9$ mm
   - Size and height factor (Section 5.3.2) $K_2 = 0.98$

   Effective transverse cross sectional area
   $$A = D_e \times L = 3952660.7 \text{ mm}^2$$

   Effective wind speed
   $$V_z = K_1 \times K_2 \times K_3 \times V_b = 57.44 \text{ m/s}$$

   Wind pressure
   $$P_z = 6E^{-08} \times V_z^2 = 0.0002 \text{ kgf/mm}^2$$

   Longitudinal force
   $$F = C_f \times A \times P_z = 626.1 \text{ kgf}$$

   Support elevation
   $$H = 474.5 \text{ mm}$$

   Turning moment
   $$M = F \times (H_{cg} - H) = 791596.4 \text{ kgf-mm}$$
1. DESIGN CONDITIONS (Operating Mode, Corroded Condition):

- Weight of equipment (Wo) = 4789.1 kgf
- Importance factor (I) = 1.5
- Soil profile type = Stiff Soil Profile (SD)
- Foundation type = RCC footings + Tie Beams
- Damping factor = 5
- Seismic zone = Zone III

2. CALCULATION OF FORCES AND MOMENTS:

- Elevation of support (H) = 474.5 mm
- Height of C.G. of equipment (Hcg) = 1381.1 mm

Seismic base shear force:

\[
V_b = Ah \times Wo = 0.103 \times 4789.1 = 433.7 \text{ kgf}
\]

Seismic moment of support:

\[
M = Vb \times (Hcg - H) = 433.7 \times (1381.1 - 474.5) = 393227.8 \text{ kgf-mm}
\]
1. DESIGN CONDITIONS (Operating Mode, Corroded Condition):
   - Design pressure: $P = 0.12$ kgf/mm$^2$ g
   - Design temperature: $T = 120$ °C
   - Allowance: $CA = 3$ mm
   - Groove allowance: $Tg = 0$ mm
   - Radiography: Full
   - Joint efficiency: $E = 1$

2. COVER DATA:
   - M.O.C.: SA-105 Frg. [UNS:K03504]
   - Code allw. stress @ design temp.: $Sfo = 14.06$ kgf/mm$^2$
   - Code allw. stress @ atm. temp.: $Sfa = 14.06$ kgf/mm$^2$
   - Young’s modulus: $Ey = 20079.7$ kgf/mm$^2$
   - Self reinforced: False
   - Flange OD: $A = 1463$ mm
   - Thickness provided: $84.3$ mm
   - Thickness available: $81.3$ mm

3. BOLTING DATA:
   - M.O.C.: SA-193 GR. B7 Bolt [UNS:G41400]
   - Code allw. stress @ design temp.: $Sb = 17.58$ kgf/mm$^2$
   - Code allw. stress @ atm. temp.: $Sa = 17.58$ kgf/mm$^2$
   - Bolt PCD: $PCD = 1413$ mm
   - Bolt dia.: $db = 22$ mm
   - No. of bolts: $nb = 56$

4. LINER DATA:
   - M.O.C.: mm
   - Liner ID: mm
   - Liner OD: mm
   - Liner thk.: mm

5. GASKET DATA:
   - M.O.C.: CAF with suitable binder (3 mm.)
   - Gasket seating stress: $y = 1.125$ kgf/mm$^2$
   - Gasket factor: $m = 2$
   - Inside diameter: $Gi = 1256$ mm
   - Outside diameter: $Go = 1381.9$ mm
   - Width of gasket: $N = 62.97$ mm
   - Width of gasket (as per Table 2-5.2): $31.75$ mm
   - Basic gasket seating width (as per Table 2-5.2): $b0 = 31.49$ mm
   - Effective gasket width (as per Table 2-5.2): $b = 14.14$ mm
   - Dia. at load reaction (see Table 2-5.2): $G = 1353.7$ mm
   - Pass partition gasket width: $Wp = 0$ mm
   - Pass partition gasket length: $Lp = 0$ mm
   - Effective pass partition gasket width: $b' = 0$ mm

6. BOLT LOAD CALCULATIONS AS PER APPENDIX 2-5 (b1):
Total joint - contact surface compression load \([Hp]\) 
\[
= 2 \times ( \pi \times b \times G + b' \times Lp ) \times m \times P \\
= 2 \times ( \pi \times 14.14 \times 1353.7 + 0 \times 0 ) \times 2 \times 0.12 \\
= 28863.3 \text{ kgf}
\]
Total hydrostatic end force \([H]\) 
\[
= 0.25 \times \pi \times G^2 \times P \\
= 0.25 \times \pi \times 1353.7^2 \times 0.12 \\
= 172700.1 \text{ kgf}
\]
Minimum required bolt load for operating condition \([Wm1]\) 
\[
= Hp + H \\
= 28863.3 + 172700.1 \\
= 201563.5 \text{ kgf}
\]
7. BOLT LOAD CALCULATIONS AS PER APPENDIX X 2-5 (b2) 
Minimum required bolt load for gasket seating \([Wm2]\) 
\[
= ( \pi \times b \times G + b' \times Lp ) \times y \\
= ( \pi \times 14.14 \times 1353.7 + 0 \times 0 ) \times 1.125 \\
= 67643.1 \text{ kgf}
\]
8. BOLT AREAS AS PER APPENDIX X 2-5 (d) 
Total required cross-sectional area of bolts \([Am]\) 
\[
= \text{MAX} \left[ \frac{Wm2}{Sa}, \frac{Wm1}{Sb} \right] ........... \text{For Internal '+' Pr Design} \\
= \frac{Wm2}{Sa} ........................................... \text{For External Pr & Self Sealing Design} \\
= 11467.6 \text{ mm}^2
\]
Actual bolt area using root diameter \([Ab]\) 
\[
= 15255.5 \text{ mm}^2
\]
Flange design bolt load for the gasket seating \([W]\) 
\[
= 0.5 \times ( Am + Ab ) \times Sa \times 1 ..................... \text{average bolt area} \\
= Ab \times Sa \times 1 ........................................ \text{full bolt area} \\
= 234852.5 \text{ kgf} \left( \text{Avg. bolt area and margin factor of 1} \right)
\]
9. CHECK FOR GASKET CRUSHING 
Minimum gasket width required \([Nmin]\) 
\[
= \frac{Ab \times Sb}{( 2 \times \pi \times y \times G )} \\
= 15255.5 \times 17.58 / ( 2 \times \pi \times 1.125 \times 1353.7 ) \\
= 28.03 \text{ mm}
\]
10. DESIGN CALCULATION AS PER UG 34
Self reinforced \[\text{False}\] 
Factor C is user input \[\text{False}\] 
Factor C taken from fig. UG 34 or user input \[C = 0.3\] 
Factor, 2 \[0.5\] for self reinf. cover, otherwise 1 \[F = 1\]
Required thickness for bolting condition \([t]\) 
\[
= G \times F \times \text{SQRT} \left[ 1.9 \times W \times 0.5 \times ( PCD - G ) / ( Sfa \times E \times G^3 ) \right] \\
= 1353.7 \times 1 \times \text{SQRT} \left[ 1.9 \times 234852.5 \times 0.5 \times ( 1413 - 1353.7 ) / ( 14.06 \times 1 \times 1353.7^3 ) \right] \\
= 26.37 \text{ mm}
\]
Required thickness for operating condition \([t]\) 
\[
= G \times F \times \text{SQRT} \left\{ ( C \times P / ( Sfo \times E ) ) + 1.9 \times Wm1 \times 0.5 \times ( PCD - G ) / ( Sfo \times E \times G^3 ) \right\} \\
= 1353.7 \times 1 \times \text{SQRT} \left\{ ( 0.3 \times 0.12 / ( 14.06 \times 1 ) ) + 1.9 \times 201563.5 \times 0.5 \times ( 1413 - 1353.7 ) / ( 14.06 \times 1 \times 1353.7^3 ) \right\} \\
= 72.72 \text{ mm}
\]
**DESIGN OF FLAT BOLTED HEAD (EXTERNAL)**

**CODE**  
ASME VIII Div.1, 15

### 1. DESIGN CONDITIONS (Operating Mode, Corroded Condition):

- **Design pressure** \( P \): 0.01055 kgf/mm² \( g \)
- **Design temperature** \( T \): 120 °C
- **Allowance** \( CA \): 3 mm
- **Groove allowance** \( Tg \): 0 mm
- **Radiography**: Full
- **Joint efficiency** \( E \): 1

### 2. COVER DATA:

- **M.O.C.**
  - Code: SA-105 Frg. [UNS:K03504]
- **Code allow. stress @ design temp.** \( S_{fo} \): 14.06 kgf/mm²
- **Code allow. stress @ atm. temp.** \( S_{fa} \): 14.06 kgf/mm²
- **Young’s modulus** \( E_y \): 20079.7 kgf/mm²
- **Self reinforced**: False
- **Flange OD** \( A \): 1463 mm
- **Thickness provided**: 84.3 mm
- **Thickness available**: 81.3 mm

### 3. BOLTING DATA:

- **M.O.C.**
  - Code: SA-193 GR. B7 Bolt [UNS:G41400]
- **Code allow. stress @ design temp.** \( S_{b} \): 17.58 kgf/mm²
- **Code allow. stress @ atm. temp.** \( S_{a} \): 17.58 kgf/mm²
- **Bolt PCD**: 1413 mm
- **Bolt dia.**: 22 mm
- **No. of bolts**: 56

### 4. LINER DATA:

- **M.O.C.**
  - Code: CAF with suitable binder (3 mm.)
- **Liner ID**: mm
- **Liner OD**: mm
- **Liner thk.**: mm

### 5. GASKET DATA:

- **M.O.C.**
  - Code: CAF with suitable binder (3 mm.)
- **Gasket seating stress** \( y \): 1.125 kgf/mm²
- **Gasket factor** \( m \): 2
- **Inside diameter** \( G_i \): 1256 mm
- **Outside diameter** \( G_o \): 1381.9 mm
- **Width of gasket** \( N \): 62.97 mm
- **Width of gasket** (as per Table 2-5.2): 31.75 mm
- **Basic gasket seating width** (as per Table 2-5.2): 31.49 mm
- **Effective gasket width** (as per Table 2-5.2): 14.14 mm
- **Dia. at load reaction** (see Table 2-5.2): 1353.7 mm
- **Pass partition gasket width** \( W_{p} \): 0 mm
- **Pass partition gasket length** \( L_{p} \): 0 mm
- **Effective pass partition gasket width** \( b' \): 0 mm

### 6. BOLT LOAD CALCULATIONS AS PER APPENDIX 2-5 (b1):

---

---
Total joint - contact surface compression load \([Hp]\)
\[
= 2 \times ( \pi \times b \times G + b' \times Lp ) \times m \times P
= 2 \times ( \pi \times 14.14 \times 1353.7 + 0 \times 0 ) \times 2 \times 0.01055
= 2536.6 \text{ kgf}
\]

Total hydrostatic end force \([H]\)
\[
= 0.25 \times \pi \times G^2 \times P
= 0.25 \times \pi \times 1353.7^2 \times 0.01055
= 15177.5 \text{ kgf}
\]

Minimum required bolt load for operating condition \([Wm1]\)
\[
= Hp + H
= 2536.6 + 15177.5
= 17714.1 \text{ kgf}
\]

7. BOLT LOAD CALCULATIONS AS PER APPENDIX X 2-5 (b2) :
Minimum required bolt load for gasket seating \([Wm2]\)
\[
= ( \pi \times b \times G + b' \times Lp ) \times y
= ( \pi \times 14.14 \times 1353.7 + 0 \times 0 ) \times 1.125
= 67643.1 \text{ kgf}
\]

8. BOLT AREAS AS PER APPENDIX X 2-5 (d) :
Total required cross-sectional area of bolts \([Am]\)
\[
= \text{MAX} \left[ \frac{Wm2}{Sa}, \frac{Wm1}{Sb} \right] \quad \text{For Internal '+' Pr Design}
= \frac{Wm2}{Sa} \quad \text{For External Pr & Self Sealing Design}
= 3848.4 \text{ mm}^2
\]

Actual bolt area using root diameter \([Ab]\)
\[
= 15255.5 \text{ mm}^2
\]

Flange design bolt load for the gasket seating \([W]\)
\[
= 0.5 \times ( Am + Ab ) \times Sa \times 1 \quad \text{average bolt area}
= Ab \times Sa \times 1 \quad \text{full bolt area}
= 167892.3 \text{ kgf} \quad (\text{Avg. bolt area and margin factor of 1})
\]

9. CHECK FOR GASKET CRUSHING :
Minimum gasket width required \([Nmin]\)
\[
= \frac{Ab \times Sb}{2 \times \pi \times y \times G}
= \frac{15255.5 \times 17.58}{2 \times \pi \times 1.125 \times 1353.7}
= 28.03 \text{ mm}
\]

10. DESIGN CALCULATION AS PER UG 34
Self reinforced \(\text{False}\)
Factor C is user input \(\text{False}\)
Factor C taken from fig. UG 34 or user input \(C = 0.3\)
Factor, 2 \(0.5\) for self reinf. cover, otherwise 1 \(F = 1\)

Required thickness for bolting condition \([t]\)
\[
= G \times F \times \sqrt{\left[ 1.9 \times W x 0.5 \times (PCD - G) / (Sfa \times E \times G^3) \right]} \\
= 1353.7 \times 1 \times \sqrt{\left[ 1.9 \times 167892.3 \times 0.5 \times (1413 - 1353.7) / (14.06 \times 1 \times 1353.7^3) \right]} \\
= 26.37 \text{ mm}
\]

Required thickness for operating condition \([t]\)
\[
= G \times F \times \sqrt{T \left\{ \left[ C \times P / (Sfo \times E) \right] + 1.9 \times Wm1 \times 0.5 \times (PCD - G) / (Sfo \times E \times G^3) \right\} } \\
= 1353.7 \times 1 \times \sqrt{T \left\{ \left[ 0.3 \times 0.01055 / (14.06 \times 1) \right] + 1.9 \times 17714.1 \times 0.5 \times (1413 - 1353.7) / (14.06 \times 1 \times 1353.7^3) \right\} } \\
= 31.77 \text{ mm}
\]
1. DESIGN CONDITIONS (Operating Mode, Corroded Condition):
   - Design pressure \( P \) 0.12 kgf/mm²
   - Design temperature \( T \) 120 °C
   - Allowance \( CA \) 3 mm
   - Groove allowance \( Tg \) 0 mm

2. FLANGE DATA:
   - M.O.C. SA-105 Frg. [UNS:K03504]
   - Code allw. stress @ design temp. \( Sfo \) 14.06 kgf/mm²
   - Code allw. stress @ atm. temp. \( Sfa \) 14.06 kgf/mm²
   - Inside diameter \( B \) 1256 mm
   - Hub length \( h \) 12 mm
   - Thickness (hub end) \( g1 \) 21 mm
   - Thickness (pipe end) \( g0 \) 9 mm
   - Thickness provided 119.5 mm
   - Thickness available 116.5 mm

3. BOLTING DATA:
   - M.O.C. SA-193 GR. B7 Bolt [UNS:G41400]
   - Code allw. stress @ design temp. \( Sb \) 17.58 kgf/mm²
   - Code allw. stress @ atm. temp. \( Sa \) 17.58 kgf/mm²
   - Bolt PCD \( C \) 1413 mm
   - Bolt dia. \( db \) 22 mm
   - No. of bolts \( nb \) 56

4. LINER DATA:
   - M.O.C.
   - Liner ID mm
   - Liner OD mm
   - Liner thk. mm

5. GASKET DATA:
5a. Flange gasket data:
   - M.O.C. CAF with suitable binder (3 mm.)
   - Gasket type Ring Gasket
   - Gasket confinement type Unconfined
   - Flange face type Raised Face
   - Flange gasket surface finish Serrated (Normal)
   - Counter flange face type Raised Face
   - Counter gasket surface finish Serrated (Normal)
   - Applicable gasket sketch in Table 2-5.2 Type 1B
   - Applicable gasket column in Table 2-5.2 1
   - Gasket seating stress (refer to Note 1, Table 2-5.1) \( \gamma \) 1.125 kgf/mm²
   - Gasket factor (from Table 2-5.1) \( m \) 2
   - Inside diameter \( Gi \) 1256 mm
   - Outside diameter \( Go \) 1381.9 mm
   - Width of gasket (as per Table 2-5.2) \( N \) 62.97 mm
5b. Partition groove gasket data (For H.E. body flange):

**M.O.C.**

- Gasket seating stress (refer to Note 1, Table 2-5.1) $\gamma'$: 0 kgf/mm²
- Gasket factor (from Table 2-5.1) $m'$: 0

**Pass partition gasket width**
- $W_p$: 0 mm

**Pass partition gasket length**
- $L_p$: 0 mm

**Effective pass partition gasket width**
- $b'$: 0 mm

### 6. BOLT LOAD CALCULATIONS AS PER APPENDIX X 2-5 (b1)

**Total joint - contact surface compression load** [$H_p$]

$$H_p = 2 \times \left( \pi \times b \times G \times m + b' \times L_p \times m' \right) \times P$$

$$= 2 \times \left( \pi \times 14.14 \times 1353.7 \times 2 + 0 \times 0 \times 0 \right) \times 0.12$$

$$= 28863.3 \text{ kgf}$$

**Total hydrostatic end force** [$H$]

$$H = 0.25 \times \pi \times G^2 \times P$$

$$= 0.25 \times \pi \times 1353.7^2 \times 0.12$$

$$= 172700.1 \text{ kgf}$$

**Minimum required bolt load for operating condition** [$W_{m1a}$]

$$W_{m1a} = H_p + H$$

$$= 28863.3 + 172700.1$$

$$= 201563.5 \text{ kgf}$$

**Minimum required bolt load for operating condition** [$W_{m1b}$]

(from mating flange)

$$W_{m1b} = 201563.5 \text{ kgf}$$

**Governing bolt load for operating condition** [$W_{m1}$]

$$W_{m1} = \max \left[ W_{m1a} , W_{m1b} \right]$$

$$= 201563.5 \text{ kgf}$$

### 7. BOLT LOAD CALCULATION AS PER APPENDIX X 2-5 (b2)

**Minimum required bolt load for gasket seating** [$W_{m2}$]

$$W_{m2} = \left( \pi \times b \times G \times y + b' \times L_p \times y' \right)$$

$$= \left( \pi \times 14.14 \times 1353.7 \times 1.125 + 0 \times 0 \times 0 \right)$$

$$= 67643.1 \text{ kgf}$$

### 8. BOLT AREAS AS PER APPENDIX X 2-5 (d)

**Total required cross-sectional area of bolts** [$A_m$]

$$A_m = \max \left[ W_{m2} / S_a , W_{m1} / S_b \right]$$

For Internal '+' Pr Design

$$= W_{m2} / S_a$$

For External Pr & Self Sealing Design

$$= W_{m1} / S_b$$

$$= 11467.6 \text{ mm}^2$$

**Actual bolt area using root diameter** [$A_b$]

$$A_b = 15255.5 \text{ mm}^2$$

**Flange design bolt load for the gasket seating** [$W$]

$$0.5 \times \left( A_m + Ab \right) \times S_a \times 1$$

**Average bolt area**

$$= A_b \times S_a \times 1$$

**Full bolt area**

$$= 234852.5 \text{ kgf}$$

### 9. CHECK FOR GASKET CRUSHING

**Minimum gasket width required** [$N_{min}$]

$$N_{min} = \frac{A_b \times S_b}{2 \times \pi \times y \times G}$$

$$= 15255.5 \times 17.58 / \left( 2 \times \pi \times 1.125 \times 1353.7 \right)$$

$$= 28.03 \text{ mm}$$

### 10. BOLT SPACING CORRECTION FACTOR

As per Brownell & Young or IS 2825,

$$\text{SQRT} \left[ \text{Bolt spacing} / \left( 2 \times db + t \right) \right]$$

As per TEMA or BS 5500,

$$\text{SQRT} \left[ \text{Bolt spacing} / B_{max} \right]$$
B_{max} = \text{maximum recommended bolt spacing} = 2 \times db + 6 \times t / (m + 0.5)

Code Select, Cf = 1 (\min. equal to 1)

**INTEGRAL FLANGE DESIGN**

### 11. LOADS AND FORCES DURING OPERATING CONDITION AS PER APPENDIX 2-3

**Hydrostatic end force on area inside of flange [HD]**

\[= 0.25 \times \pi \times B^2 \times P\]

\[= 0.25 \times \pi \times 1256^2 \times 0.12\]

\[= 148679.3 \text{ kgf}\]

**Gasket load (difference between flange design bolt load and total hydrostatic end force) [HG]**

\[= W_{m1} - H\]

\[= 201563.5 - 172700.1\]

\[= 28863.3 \text{ kgf}\]

**Difference between total hydrostatic end force and hydrostatic end force on area inside of flange [HT]**

\[= H - HD\]

\[= 172700.1 - 148679.3\]

\[= 24020.9 \text{ kgf}\]

### 12. MOMENT ARMS FOR FLANGE LOADS AS PER TABLE 2-6

**Radial distance from the bolt circle to intersection of hub and back of flange, as per Appendix 2-3 [R]**

\[= 0.5 \times (C - B) - g_1\]

\[= 0.5 \times (1413 - 1256) - 21\]

\[= 57.5 \text{ mm}\]

**Radial distance from the bolt circle to the circle on which HD acts [hD]**

\[= R + 0.5 \times g_1\]

\[= 57.5 + 0.5 \times 21\]

\[= 68 \text{ mm}\]

**Radial distance from gasket load reaction to the bolt circle [hG]**

\[= 0.5 \times (C - G)\]

\[= 0.5 \times (1413 - 1353.7)\]

\[= 29.67 \text{ mm}\]

**Radial distance from the bolt circle to the circle on which HT acts [hT]**

\[= 0.5 \times (R + g_1 + hG)\]

\[= 0.5 \times (57.5 + 21 + 29.67)\]

\[= 54.08 \text{ mm}\]

### 13. FLANGE MOMENTS UNDER OPERATING CONDITION AS PER APPENDIX 2-6

**Component of moment due to HD [MD]**

\[= HD \times hD\]

\[= 148679.3 \times 68\]

\[= 10110190 \text{ kgf-mm}\]

**Component of moment due to HG [MG]**

\[= HG \times hG\]

\[= 28863.3 \times 29.67\]

\[= 856321.7 \text{ kgf-mm}\]

**Component of moment due to HT [MT]**

\[= HT \times hT\]

\[= 24020.9 \times 54.08\]

\[= 1299146.8 \text{ kgf-mm}\]

**Total moment acting on the flange for operating condition [MO]**

\[= MD + MG + MT\]

\[= 10110190 + 856321.7 + 1299146.8\]

\[= 12265658.5 \text{ kgf-mm}\]

### 14. LOADS AND FORCES DURING GASKET SEATING AS PER APPENDIX 2-3

**Gasket load for seating condition [HG]**

\[= W\]

\[= 234852.5 \text{ kgf}\]

### 15. MOMENT UNDER GASKET SEATING AS PER APPENDIX 2-6

**Total moment acting on the flange for gasket seating [MO']**

\[= W \times hG\]

\[= 234852.5 \times 29.67\]

\[= 6967639.1 \text{ kgf-mm}\]

### 16. SHAPE CONSTANTS

\(A / B \quad K \quad 1.165\)
17. STRESS FORMULA FACTORS

Assumed thickness \([t]\) = 106.2 mm

Factor \([\alpha]\) = \(t \times e + 1\)
= 106.2 x 0.00849 + 1
= 1.902

Factor \([\beta]\) = 1.333 x \(t \times e + 1\)
= 1.333 x 106.2 x 0.00849 + 1
= 2.202

Factor \([\gamma]\) = \(\alpha / T\)
= 1.902 / 1.853
= 1.026

Factor \([\delta]\) = \(t^3 / d\)
= 106.2^3 / 290617.3
= 4.12

Factor \([\lambda]\) = \(\gamma + \delta\)
= 1.026 + 4.12
= 5.147

18. FLANGE STRESSES AS PER APPENDIX 2-7 & 2-8

Equivalent moment \([M_{max}]\)
= \(\text{MAX} [ \text{MO} , \text{MO'} \times \text{Sfo} / \text{Sfa} ]\)
= \(\text{MAX} [ 12265658.5 , 6967639.1 \times 14.06 / 14.06 ]\)
= 12265658.5 kgf-mm

Corrected equivalent moment per unit length \([M]\)
= \(\text{Mmax} \times (\text{Cf} / \text{B})\)
= 12265658.5 \times (1 / 1256)
= 9765.7 kgf

Longitudinal hub stress \([SH]\)
= \(f x M / (\lambda \times g1^2)\)
= 4.354 x 9765.7 / (5.147 x 21^2)
= 18.73 kgf/mm² ........................................... < 1.5 x Sfo

Radial flange stress \([SR]\)
= \(\beta x M / (\lambda \times t^2)\)
= 2.202 x 9765.7 / (5.147 x 106.2^2)
= 0.371 kgf/mm² ........................................... < Sfo

Tangential flange stress \([ST]\)
= \( (\text{M} \times \text{Y} / \text{t}^2) - \text{Z} \times \text{SR} \)
= (9765.7 x 12.8 / 106.2^2) - 6.606 x 0.371
= 8.633 kgf/mm² ........................................... < Sfo

Average stress
= \text{MAX} \left[ 0.5 \times \left( \text{SH} + \text{SR} \right) , 0.5 \times \left( \text{SH} + \text{ST} \right) \right]

= \text{MAX} \left[ 0.5 \times \left( 18.73 + 0.371 \right) , 0.5 \times \left( 18.73 + 8.633 \right) \right]

= 13.68 \text{ kgf/mm}^2

\text{19. FLANGE RIGIDITY CHECKING AS PER APPENDIX 2-14}

\text{Modulus of elasticity for flange} \quad E_{fo} \quad 20079.7 \text{ kgf/mm}^2

\text{Rigidity factor} \quad K_I \quad 0.3

\text{Rigidity index} [J]

= 52.14 \times V \times M_{max} / \left( \lambda \times E_{fo} \times g_0^2 \times K_I \times h_0 \right)

= 52.14 \times 0.417 \times 12265658.5 / \left( 5.147 \times 20079.7 \times 9^2 \times 0.3 \times 106.3 \right)

= 0.998

\text{Since } J < 1.0, \text{ design is safe}
1. DESIGN CONDITIONS (Operating Mode, Corroded Condition):
   - Design pressure \( P \): 0.01055 kgf/mm²
   - Design temperature \( T \): 120 °C
   - Allowance CA: 3 mm
   - Groove allowance Tg: 0 mm

2. FLANGE DATA:
   - Code: ASME VIII Div. 1, 15
   - Shell Flng (Front)
   - M.O.C.: SA-105 Frg. [UNS:K03504]
   - Code allowable stress @ design temp. \( S_{fo} \): 14.06 kgf/mm²
   - Code allowable stress @ atm. temp. \( S_{fa} \): 14.06 kgf/mm²
   - Inside diameter \( B \): 1256 mm
   - Hub length \( h \): 12 mm
   - Thickness (hub end) \( g_1 \): 21 mm
   - Thickness (pipe end) \( g_0 \): 9 mm
   - Thickness provided: 119.5 mm
   - Thickness available: 116.5 mm

3. BOLTING DATA:
   - M.O.C.: SA-193 GR. B7 Bolt [UNS:G41400]
   - Code allowable stress @ design temp. \( S_b \): 17.58 kgf/mm²
   - Code allowable stress @ atm. temp. \( S_a \): 17.58 kgf/mm²
   - Bolt PCD \( C \): 1413 mm
   - Bolt dia. \( db \): 22 mm
   - No. of bolts \( nb \): 56

4. LINER DATA:
   - M.O.C.
   - Liner ID: mm
   - Liner OD: mm
   - Liner thk.: mm

5. GASKET DATA:
   5a. Flange gasket data:
   - M.O.C.: CAF with suitable binder (3 mm.)
   - Gasket type: Ring Gasket
   - Gasket confinement type: Unconfined
   - Flange face type: Raised Face
   - Flange gasket surface finish: Serrated (Normal)
   - Counter flange face type: Raised Face
   - Counter gasket surface finish: Serrated (Normal)
   - Applicable gasket sketch in Table 2-5.2: Type 1B
   - Applicable gasket column in Table 2-5.2: 1
   - Gasket seating stress \( \gamma \): 1.125 kgf/mm²
   - Gasket factor \( m \): 2
   - Inside diameter \( Gi \): 1256 mm
   - Outside diameter \( Go \): 1381.9 mm
   - Width of gasket \( N \): 62.97 mm
Width of gasket (as per Table 2-5.2) \( w \) = 62.97 mm

Width of raised face or gasket contact width \( b \) = 31.75 mm

Basic gasket seating width (as per Table 2-5.2) \( b_0 \) = 31.49 mm

Effective gasket width (as per Table 2-5.2) \( b \) = 14.14 mm

Dia. at load reaction (see Table 2-5.2) \( G \) = 1353.7 mm

5b. Partition groove gasket data (For H.E. body flange):

M.O.C. ---

Gasket seating stress (refer to Note 1, Table 2-5.1) \( y' \) = 0 kgf/mm²

Gasket factor (from Table 2-5.1) \( m' \) = 0

Pass partition gasket width \( W_p \) = 0 mm

Pass partition gasket length \( L_p \) = 0 mm

Effective pass partition gasket width \( b' \) = 0 mm

6. BOLT LOAD CALCULATIONS AS PER APPENDIX X 2-5 (b1)

Total joint - contact surface compression load \([H_p]\)
\[
= 2 \times (\pi x b x G x m + b' x L_p x m') x P
\]
\[
= 2536.6 \text{ kgf}
\]

Total hydrostatic end force \([H]\)
\[
= 0.25 x \pi x G^2 x P
\]
\[
= 15177.5 \text{ kgf}
\]

Minimum required bolt load for operating condition \([W_{m1a}]\)
\[
= H_p + H
\]
\[
= 2536.6 + 15177.5
\]
\[
= 17714.1 \text{ kgf}
\]

Minimum required bolt load for operating condition \([W_{m1b}]\)
(from mating flange)
\[
= 17714.1 \text{ kgf}
\]

Governing bolt load for operating condition \([W_{m1}]\)
\[
= \text{MAX} [W_{m1a}, W_{m1b}]
\]
\[
= \text{MAX} [17714.1, 17714.1]
\]
\[
= 17714.1 \text{ kgf}
\]

7. BOLT LOAD CALCULATION AS PER APPENDIX X 2-5 (b2)

Minimum required bolt load for gasket seating \([W_{m2}]\)
\[
= (\pi x b x G x y + b' x L_p x y')
\]
\[
= 67643.1 \text{ kgf}
\]

8. BOLT AREAS AS PER APPENDIX X 2-5 (d)

Total required cross-sectional area of bolts \([A_m]\)
\[
= \text{MAX} [W_{m2} / S_a, W_{m1} / S_b] \text{......... For Internal '++- Pr Design}
\]
\[
= W_{m2} / S_a \text{........................................... For External Pr & Self Sealing Design}
\]
\[
= 3848.4 \text{ mm²}
\]

Actual bolt area using root diameter \([A_b]\)
\[
= 15255.5 \text{ mm²}
\]

Flange design bolt load for the gasket seating \([W]\)
\[
= 0.5 x (A_m + Ab) x S_a x 1 \text{............ average bolt area}
\]
\[
= Ab x S_a x 1 \text{...........................................full bolt area}
\]
\[
= 167892.3 \text{ kgf} \text{ (Avg. bolt area and margin factor of 1)}
\]

9. CHECK FOR GASKET CRUSHING

Minimum gasket width required \([N_{min}]\)
\[
= Ab x S_b / (2 \times \pi x y x G)
\]
\[
= 15255.5 \times 17.58 / (2 \times \pi x 1.125 x 1353.7)
\]
\[
= 28.03 \text{ mm}
\]

10. BOLT SPACING CORRECTION FACTOR

As per Brownell & Young or IS 2825,
\[
= \text{SQRT} [\text{Bolt spacing} / (2 x db + t)]
\]

As per TEMA or BS 5500,
\[
= \text{SQRT} [\text{Bolt spacing} / B_{max}] \text{................. where,}
Bmax = maximum recommended bolt spacing = 2 x db + 6 x t / ( m + 0.5 )

Code Select, Cf = 1 ( min. equal to 1 )

11. LOADS AND FORCES DURING OPERATING CONDITION AS PER APPENDIX 2-3

Hydrostatic end force on area inside of flange [HD]
= 0.25 x π x B² x P
= 0.25 x π x 1256² x 0.01055
= 13066.4 kgf

Difference between total hydrostatic end force and hydrostatic end force on area inside of flange [HT]
= H - HD
= 15177.5 - 13066.4
= 2111 kgf

12. MOMENT ARMS FOR FLANGE LOADS AS PER APPENDIX TABLE 2-6

Radial distance from the bolt circle to intersection of hub and back of flange, as per Appendix 2-3 [R]
= 0.5 x ( C - B ) - g1
= 0.5 x ( 1413 - 1256 ) - 21
= 57.5 mm

Radial distance from the bolt circle to the circle on which HD acts [hD]
= R + 0.5 x g1
= 57.5 + 0.5 x 21
= 68 mm

Radial distance from gasket load reaction to the bolt circle [hG]
= 0.5 x ( C - G )
= 0.5 x ( 1413 - 1353.7 )
= 29.67 mm

Radial distance from the bolt circle to the circle on which HT acts [hT]
= 0.5 x ( R + g1 + hG )
= 0.5 x ( 57.5 + 21 + 29.67 )
= 54.08 mm

13. FLANGE MOMENTS UNDER OPERATING CONDITION AS PER APPENDIX 2-6

Component of moment due to HD [MD]
= HD x ( hD - hG )
= 13066.4 x ( 68 - 29.67 )
= 500860.4 kgf-mm

Component of moment due to HT [MT]
= HT x ( hT - hG )
= 2111 x ( 54.08 - 29.67 )
= 51542.9 kgf-mm

Total moment acting on the flange for operating condition [MO]
= MD + MT
= 500860.4 + 51542.9
= 552403.2 kgf-mm

14. LOADS AND FORCES DURING GASKET SEATING AS PER APPENDIX 2-3

Gasket load for seating condition [HG]
= W
= 167892.3 kgf

15. MOMENT UNDER GASKET SEATING AS PER APPENDIX 2-6

Total moment acting on the flange for gasket seating [MO’]
= W x hG
= 167892.3 x 29.67
= 4981054.6 kgf-mm

16. SHAPE CONSTANTS

\[
\begin{array}{ccc}
\text{A} / \text{B} & \text{K} & 1.165 \\
\text{T} & 1.853 \\
\text{Z} & 6.606 \\
\text{Y} & 12.8 \\
\text{U} & 14.06 \\
\text{h0} & \text{106.3} \\
\text{F} / \text{h0} & \text{0.00849}
\end{array}
\]
17. STRESS FORMULA FACTORS

Assumed thickness \([t]\) = 70.88 mm
Factor \([\alpha]\) = \(txe + 1\)
= 70.88 x 0.00849 + 1
= 1.602
Factor \([\beta]\) = 1.333 x \(txe + 1\)
= 1.333 x 70.88 x 0.00849 + 1
= 1.803
Factor \([\gamma]\) = \(\alpha\) / T
= 1.602 / 1.853
= 0.865
Factor \([\delta]\) = \(t^3 / d\)
= 70.88^3 / 290617.3
= 1.225
Factor \([\lambda]\) = \(\gamma + \delta\)
= 0.865 + 1.225
= 2.09

18. FLANGE STRESSES AS PER APPENDIX 2-7 & 2-8

Equivalent moment \([M_{\text{max}}]\)
= MAX \([ MO , MO' x Sfo / Sfa ]\)
= MAX \([ 552403.2 , 4981054.6 x 14.06 / 14.06 ]\)
= 4981054.6 kgf-mm
Corrected equivalent moment per unit length \([M]\)
= \(M_{\text{max}} x ( C_f / B )\)
= 4981054.6 x ( 1 / 1256 )
= 3965.8 kgf
Longitudinal hub stress \([SH]\)
= \(f x M / ( \delta x g_1^2 )\)
= 4.354 x 3965.8 / ( 2.09 x 21^2 )
= 18.74 kgf/mm²
Radial flange stress \([SR]\)
= \(\beta x M / ( \lambda x t^2 )\)
= 1.602 x 3965.8 / ( 2.09 x 70.88^2 )
= 0.681 kgf/mm²
Tangential flange stress \([ST]\)
= \( ( M x Y / t^2 ) - Z x SR\)
= ( 3965.8 x 12.8 / 70.88^2 ) - 6.606 x 0.681
= 5.603 kgf/mm²
Average stress
= MAX \([ 0.5 x ( SH + SR ) , 0.5 x ( SH + ST ) ]\)
= MAX \([ 0.5 x ( 18.74 + 0.681 ) , 0.5 x ( 18.74 + 5.603 ) ]\)
= 12.17 kgf/mm²

19. FLANGE RIGIDITY CHECKING AS PER APPENDIX AS PER 2-14

Modulus of elasticity for flange \(E_{fo}\)
= 20079.7 kgf/mm²
Rigidity factor \(K_I\)
= 0.3
Rigidity index \( J \)
\[ J = \frac{52.14 \times V \times M_{\text{max}}}{\lambda \times E_{\text{fracture}} \times g_0^2 \times K_I \times h_0} \]
\[ J = 52.14 \times 0.417 \times 4981054.6 / (2.09 \times 20079.7 \times 9^2 \times 0.3 \times 106.3) \]
\[ J = 0.998 \]
Since \( J < 1.0 \), design is safe
1. DESIGN CONDITIONS (Operating Mode, Corroded Condition)

Thickness of shell under internal pressure \[ t_i \] = \( \frac{\pi x R}{S \times E - 0.6 \times \pi} \)
= \( \frac{0.12 \times 628}{14.06 \times 0.85 - 0.6 \times 0.12} \)
= 6.343 mm

3. DESIGN CALCULATION OF SHELL THICKNESS UNDER EXTERNAL PRESSURE AS PER UG-28

Allowable external pressure \[ P_a \] = \( 4 \times \frac{B}{3 \times (OD / te)} \)
= \( 4 \times \frac{2.302}{3 \times 282.7} \)
= 0.01086 kgf/mm²

Since \( P_a > P_e \), design is safe.

Since available thickness is more than design thickness, design is safe.
DESIGN CONDITIONS (Operating Mode, Corroded Condition):

1. Design Calculation as per UG 32 d / Appendix 1-4 (c):
   
   Factor \( K \) = 1
   
   Thickness for internal pressure \( t \) = \( K \times \pi \times ID / (2 \times S \times E - 0.2 \times \pi) \)
   
   = 1 \times 0.12 \times 1256 / (2 \times 14.06 \times 1 - 0.2 \times 0.12)
   
   = 5.364 mm
   
2. Design Calculation as per UG 33 d:
   
   Thickness for equivalent internal pressure \( t \) = \( K \times 1.67 \times Pe \times ID / (2 \times S \times 1.0 - 0.2 \times 1.67 \times Pe) \)
   
   = 1 \times 1.67 \times 0.01055 \times 1256 / (2 \times 14.06 \times 1.0 - 0.2 \times 1.67 \times 0.01055)
   
   = 0.787 mm
   
   Factor \( Ko \) = 0.88
   
   Assumed head thickness, \( te \) = 3.211 mm
   
   Factor \( A \) = 0.125 \times te / (Ko \times OD)
   
   = 0.125 \times 3.211 / (0.88 \times 1274)
   
   = 0.0036
   
   Factor with reference to chart (CS-2) \( B \) = 3.777 kgf/mm²
   
   Allowable external pressure \( Pa \) = \( B / (Ko \times OD / te) \)
   
   = 3.777 \times 3.211 / (0.88 \times 1274)
   
   = 0.01082 kgf/mm²
   
   Since \( Pa > Pe \), design is safe
Since available thickness is more than design thickness, design is safe.
1. LUG DATA :
   M.O.C
   No. of support N 4
   Base plate width b_1 222 mm
   Base plate depth L_b 200 mm
   Thickness of base plate t_b 16 mm
   Allowable bending stress S_b 22.15 kgf/mm²

2. BOLT DATA :
   M.O.C
   No. of bolt / lug N_b 1
   Bolt diameter d_b 20 mm
   PCD D 1598 mm
   Diameter of bolt hole 24 mm
   Allowable tensile stress F_s 10.69 kgf/mm²

3. GUSSET DATA :
   Thickness t_g 16 mm
   Height h 190 mm
   Gusset angle θ 51.71°
   Gusset depth at top L_c 50 mm
   Number of gussets n 2
   Distance between gussets b 180 mm

4. SHELL DATA :
   Material SA-516 GR. 70 Plt. [UNS:K02700]
   OD diameter OD 1274 mm
   Inside diameter ID 1256 mm
   Thickness available t_s 9 mm

5. PAD DATA :
   Material SA-516 GR. 70 Plt. [UNS:K02700]
   Thickness t_p 12 mm
   Width W 275 mm
   Length L 272 mm

6. LOAD AND MOMENT (Wind) :
   Max. overturning moment M 791596.4 kgf-mm
   Design weight of vessel W_t 2415.5 kgf

7. DESIGN OF ANCHOR BOLTS :
   Total uplift force on bolts [T]
   = \left[ 4 \times \frac{M}{(D \times N)} \right] - \frac{W_t}{N}
   = \left[ 4 \times \frac{791596.4}{(1598 \times 4)} \right] - 2415.5 / 4
   = -108.5 \text{ kgf}
   Required area of bolts [A_m]
   = \text{MAX} \left[ \left( \frac{T}{F_s} \right), 0 \right]
   = \text{MAX} \left[ (-108.5 / 10.69), 0 \right]
Available area of bolts \([Ab]\)
\[= Ar \times Nb \] ................................................................. where, \(Ar = 217.1 \text{ mm}^2\), is root area of bolt
\[= 217.1 \times 1\]
\[= 217.1 \text{ mm}^2\]

Since \(Ab > Am\), bolts provided are sufficient

**8. GUSSET DESIGN:**

Reaction force at each support \([Q]\)
\[= \left[\frac{4 \times M}{(D \times N)}\right] + \frac{Wt}{N}\]
\[= \left[\frac{4 \times 791596.4}{(1598 \times 4)}\right] + \frac{2415.5}{4}\]
\[= 1099.2 \text{ kgf}\]

Maximum axial force in gusset \([P1]\)
\[= \frac{Q}{n}\]
\[= \frac{1099.2}{2}\]
\[= 549.6 \text{ kgf}\]

Allowable compr. stress in gusset \([Sg]\)
\[= \frac{18000}{\left[1 + 12 \times \left(h'/tg\right)^2 / 18000\right]} \] ................................. where, \(h' = 242.1 \text{ mm}\)
\[= \frac{18000}{\left[1 + 12 \times \left(242.1 / 16\right)^2 / 18000\right]}\]
\[= 15616.8 \text{ psi}\]
\[= 10.98 \text{ kgf/mm}^2\]

Required thickness of gusset \([tg']\)
\[= \frac{2 \times P1 \times (3 \times a - Lb)}{\left[\frac{5g \times Lb^2 \times (\sin \theta)^2}{Sg \times Lb^2 \times (\sin \theta)^2}\right]}\]
\[= \frac{2 \times 549.6 \times (3 \times 150 - 200)}{\left[\frac{10.98 \times (200)^2 \times (\sin 51.71)^2}{Sg \times Lb^2 \times (\sin \theta)^2}\right]}\]
\[= 1.016 \text{ mm}\]

**9. BASE PLATE DESIGN:**

Bending moment \([Mb]\)
\[= \frac{Q \times b1}{6}\]
\[= 1099.2 \times 222 / 6\]
\[= 40671.8 \text{ kgf-mm}\]

Bearing pressure \([bp]\)
\[= \frac{Q}{(w \times b1)} \] ................................................................. where, \(w = 120 \text{ mm}\)
\[= \frac{1099.2}{(120 \times 222)}\]
\[= 0.04126 \text{ kgf/mm}^2\]

Bending moment due to bearing pressure \([Mb']\)
\[= \frac{bp \times b^2}{10}\]
\[= 0.04126 \times 180^2 / 10\]
\[= 133.7 \text{ kgf-mm}\]

Required thickness of base plate between chairs \([tb']\)
\[= SQRT\{6 \times MAX\{Mb, Mb'\} / [(Lb - db) \times Sb]\}\]
\[= SQRT\{6 \times MAX\{40671.8, 133.7\} / [(200 - 20) \times 22.15]\}\]
\[= 7.912 \text{ mm}\]

**10. CHECK FOR COMPRESSION PLATE:**

Equivalent radial load \([r]\)
\[= \frac{Q \times a}{(n \times h)}\]
\[= \frac{1099.2 \times 150}{(2 \times 190)}\]
\[= 433.9 \text{ kgf}\]

Angle between supports \([\alpha]\)
\[= \frac{2 \times \pi}{N}\]
\[= \frac{2 \times \pi}{4}\]
\[= 1.571 \text{ rad}\]

Internal bending moment coefficient \([Kr]\)
\[
= 0.5 \times \left[ \frac{1}{0.5 \times \alpha} - \cot(0.5 \times \alpha) \right] \\
= 0.5 \times \left[ \frac{1}{0.5 \times 1.571} - \cot(0.5 \times 1.571) \right] \\
= 0.137
\]

Internal bending moment \([M_c]\)
\[
= 0.5 \times K_r \times f \times OD \\
= 0.5 \times 0.137 \times 433.9 \times 1274 \\
= 37761.8 \text{ kgf-mm}
\]

Bending stress induced \([f_b]\)
\[
= \frac{M_o}{Z_c} \\
= \frac{37761.8}{13224.4} \\
= 2.855 \text{ kgf/mm}^2
\]

Since, induced stress \(f_b < \) allow. stress \(S_b\) in shell material, design is safe.
LUG SUPPORT DESIGN

1. LUG DATA:
   M.O.C: IS-2062 GR. A Plt.
   No. of support: N = 4
   Base plate width: b1 = 222 mm
   Base plate depth: Lb = 200 mm
   Thickness of base plate: tb = 16 mm
   Allowable bending stress: Sb = 22.15 kgf/mm²

2. BOLT DATA:
   M.O.C: Commercial CS Bolt
   No. of bolt / lug: Nb = 1
   Bolt diameter: db = 20 mm
   PCD: D = 1598 mm
   Diameter of bolt hole: 24 mm
   Allowable tensile stress: Fs = 10.69 kgf/mm²

3. GUSSET DATA:
   Thickness: tg = 16 mm
   Height: h = 190 mm
   Gusset angle: θ = 51.71
   Gusset depth at top: Lc = 50 mm
   Number of gussets: n = 2
   Distance between gussets: b = 180 mm

4. SHELL DATA:
   Material: SA-516 GR. 70 Plt. [UNS:K02700]
   OD diameter: OD = 1274 mm
   Inside diameter: ID = 1256 mm
   Thickness available: ts = 9 mm

5. PAD DATA:
   Material: SA-516 GR. 70 Plt. [UNS:K02700]
   Thickness: tp = 12 mm
   Width: W = 275 mm
   Length: L = 272 mm

6. LOAD AND MOMENT (Seismic):
   Max. overturning moment: M = 393227.8 kgf-mm
   Design weight of vessel: Wt = 4789.1 kgf

7. DESIGN OF ANCHOR BOLTS:
   Total uplift force on bolts [T] = [ 4 x M / (D x N) ] - Wt / N
   = [ 4 x 393227.8 / (1598 x 4) ] - 4789.1 / 4
   = -951.2 kgf
   Required area of bolts [Am] = MAX [ (T / Fs), 0 ]
   = MAX [(-951.2 / 10.69), 0 ]
Available area of bolts \([A_b]\)

\[= A_r \times N_b \]

where, \(A_r = 217.1 \text{ mm}^2\), is root area of bolt

\[= 217.1 \times 1\]

\[= 217.1 \text{ mm}^2\]

Since \(A_b > A_m\), bolts provided are sufficient

**8. GUSSET DESIGN:**

Reaction force at each support \([Q]\)

\[= \left[ 4 \times \frac{M}{(D \times N)} \right] + \frac{W_t}{N} \]

\[= \left[ 4 \times 393227.8 / (1598 \times 4) \right] + 4789.1 / 4 \]

\[= 1443.3 \text{ kgf}\]

Maximum axial force in gusset \([P_1]\)

\[= \frac{Q}{n} \]

\[= 1443.3 / 2 \]

\[= 721.7 \text{ kgf}\]

Allowable compr. stress in gusset \([S_g]\)

\[= \frac{18000}{\left[ 1 + 12 \times \left( \frac{h'}{tg} \right)^2 / 18000 \right]} \]

where, \(h' = 242.1 \text{ mm}\)

\[= \frac{18000}{\left[ 1 + 12 \times \left( \frac{242.1}{16} \right)^2 / 18000 \right]} \]

\[= \frac{15616.8}{10.98} \text{ psi}\]

\[= 1.334 \text{ mm}\]

**9. BASE PLATE DESIGN:**

Bending moment \([M_b]\)

\[= \frac{Q \times b_1}{6} \]

\[= 1443.3 \times 222 / 6 \]

\[= 53403.7 \text{ kgf-mm}\]

Bearing pressure \([b_p]\)

\[= \frac{Q}{(w \times b_1)} \]

where, \(w = 120 \text{ mm}\)

\[= 1443.3 / (120 \times 222) \]

\[= 0.05418 \text{ kgf/mm}^2\]

Bending moment due to bearing pressure \([M_{b'}]\)

\[= b_p \times b^2 / 10 \]

\[= 0.05418 \times 180^2 / 10 \]

\[= 175.5 \text{ kgf-mm}\]

Required thickness of base plate between chairs \([t_b']\)

\[= \sqrt{6 \times \text{MAX}[M_b, M_{b'}] / [(L_b - d_b) \times S_b]} \]

\[= \sqrt{6 \times \text{MAX}[53403.7, 175.5] / [(200 - 20) \times 22.15]} \]

\[= 9.067 \text{ mm}\]

**10. CHECK FOR COMPRESSION PLATE:**

Equivalent radial load \([f]\)

\[= \frac{Q \times a}{(n \times h)} \]

\[= 1443.3 \times 150 / (2 \times 190) \]

\[= 569.7 \text{ kgf}\]

Angle between supports \([\alpha]\)

\[= 2 \times \pi / N \]

\[= 2 \times \pi / 4 \]

\[= 1.571 \text{ rad}\]

Internal bending moment coefficient \([K_r]\)
\[
= 0.5 \times \left[ \frac{1}{0.5 \times \alpha} - \cot(0.5 \times \alpha) \right] \\
= 0.5 \times \left[ \frac{1}{0.5 \times 1.571} - \cot(0.5 \times 1.571) \right] \\
= 0.137 \\
\]

Internal bending moment [Mc]
\[
= 0.5 \times K_r \times f \times OD \\
= 0.5 \times 0.137 \times 569.7 \times 1274 \\
= 49582.7 \text{ kgf-mm} \\
\]

Bending stress induced [fb]
\[
= \frac{M_o}{Z_c} \\
= \frac{49582.7}{13224.4} \\
= 3.749 \text{ kgf/mm}^2 \\
\]

Since, induced stress \( fb \) < allow. stress \( S_b \) in shell material, design is safe.
DESIGN CONDITIONS
Design pressure (internal) \( P_i \) 0.12 kgf/mm²
Design pressure (external) \( P_e \) 0.01055 kgf/mm²
Design temperature \( T \) 120 °C

NOZZLE DATA
M.O.C. SA-106 GR. B Smls. Pipe [UNS:K03006]
Allowable stress @ design temperature \( S_n \) 12.02 kgf/mm²
Outside diameter \( OD \) 168.3 mm
Inside diameter \( ID \) 152.3 mm
Maximum chord length \( D \) 152.3 mm
Neck thickness (provided) \( t_{np} \) 10.97 mm
Internal allowance, corrosion + polishing \( CAI \) 3 mm
External allowance, corrosion + polishing \( CAE \) 0
Neck thickness \( t_{np} - CAI - CAE \) \( t_n \) 7.973 mm
Max. under tolerance on thickness \( Alw \) 1.372 mm
Available neck thickness \( tc \) 6.601 mm
Nozzle projection outward \( Lo \) 150 mm
Total length of nozzle \( L \) 156 mm
Connection type Pipe Nozzle
Application type Process Opening
Reinforcement calculation method Isolated Opening
Design as large opening False

SHELL DATA (Main Shell)
M.O.C. SA-516 GR. 70 Plt. [UNS:K02700]
Allowable stress @ design temperature \( S_v \) 14.06 kgf/mm²
Inside radius \( R \) 628 mm
Thickness \( t \) 9 mm
Min. thickness for external pressure \( tr2 \) 4.506 mm

WELD DATA
Nozzle outside weld \( W_1 \) 10.86 mm

CALCULATION OF NOZZLE NECK THICKNESS AS PER UG-45
Neck thickness for internal pressure, \([t_{a_1}]\)
Formula in Appendix 1-1, \([t_{a_1}]\)
\[\frac{0.5 \times P_i \times OD}{Sn 	imes E + 0.4 \times P_i}\]
\[= \frac{0.5 \times 0.12 \times 168.3}{12.02 \times 1.0 + 0.4 \times 0.12}\]
\[= 0.836 \text{ mm}\]

Neck thickness for external pressure, \([t_{a_2}]\)
Neck thickness for external pressure as per UG-28
Assumed neck thickness, \([t_{a_2}]\) = 0.552 mm
\[L / OD = 0.891\]
\[OD / t_{a_2} = 304.7\]
Factor A = 0.00028
Factor B = 2.99 kgf/mm²
Allowable external pressure, [Pa]
\[ = 4 \times \frac{B}{(3 \times \text{OD} / \text{ta}_2)} \]
\[ = 4 \times 2.99 / (3 \times 304.7) \]
\[ = 0.01309 \text{ kgf/mm}^2 \text{ g} \]

Shell thickness for internal pressure as per UG-37 & UG-27, \([\text{tr}_1 = \text{tb}_1]\)
\[ = \frac{\pi \times R}{(Sv \times E - 0.6 \times \pi)} \]
\[ = 0.12 \times 628 / (14.06 \times 1.0 - 0.6 \times 0.12) \]
\[ = 5.387 \text{ mm} \]

Shell thickness considering internal pressure equal to external pressure as per UG-27, \([\text{tb}_2]\)
\[ = \frac{P_e \times R}{(Sv \times E - 0.6 \times P_e)} \]
\[ = 0.01055 \times 628 / (14.06 \times 1.0 - 0.6 \times 0.01055) \]
\[ = 0.471 \text{ mm} \]

Nozzle minimum thickness required as per Table UG-45, \([\text{tb}_3]\)
\[ = 6.223 \text{ mm} \]

Minimum thickness of vessel wall required as per UG-16(b), \([\text{t_min}]\)
\[ = 1.6 \text{ mm} \]

Neck thk as per UG-45, \([\text{t}_{\text{UG_45}}]\)
Thickness, \([\text{ta}]\)
\[ = \text{MAX} \{ \text{ta}_1, \text{ta}_2, \text{t_min} \} \]
\[ = \text{MAX} \{ 0.836, 0.552, 1.6 \} \]
\[ = 1.6 \text{ mm} \]

Thickness, \([\text{tb}]\)
\[ = \text{MIN} \{ \text{tb}_3, \text{MAX} (\text{tb}_1, \text{tb}_2, \text{t_min}) \} \]
\[ = \text{MIN} \{ 6.223, \text{MAX} (5.387, 5.387, 1.6) \} \]
\[ = 5.387 \text{ mm} \]

Thickness, \([\text{t}_{\text{UG_45}}]\)
\[ = \text{MAX} \{ \text{ta}, \text{tb} \} \text{ .......... for Process Nozzle} \]
\[ = \text{ta} \text{ ......................... for Access Opening} \]
\[ = 5.387 \text{ mm ......................... Process Opening} \]

Since available neck thickness, \(\text{tc} >= \text{t}_{\text{UG_45}}\), selected neck thickness is adequate.
DESIGN CONDITIONS
Design pressure (internal) \( P_i \) 0.12 kgf/mm²
Design pressure (external) \( P_e \) 0.01055 kgf/mm²
Design temperature \( T \) 120 °C

NOZZLE DATA
M.O.C. SA-106 GR. B Smls. Pipe [UNS:K03006]
Allowable stress @ design temperature \( S_n \) 12.02 kgf/mm²
Outside diameter \( OD \) 168.3 mm
Inside diameter \( ID \) 152.3 mm
Maximum chord length \( D \) 152.3 mm
Neck thickness (provided) \( t_{np} \) 10.97 mm
Internal allowance, corrosion + polishing \( CAI \) 3 mm
External allowance, corrosion + polishing \( CAE \) 0
Neck thickness (\( t_{np} - CAI - CAE \)) \( tn \) 7.973 mm
Max. under tolerance on thickness \( Alw \) 1.372 mm
Available neck thickness (\( tn - Alw \)) \( tc \) 6.601 mm
Nozzle projection outward (from vessel outer face) \( Lo \) 150 mm
Total length of nozzle (\( Lo + tvp + Addn for curvature \)) \( L \) 156 mm
Connection type Pipe Nozzle
Application type Process Opening
Reinforcement calculation method Isolated Opening
Design as large opening False

SHELL DATA (Main Shell)
M.O.C. SA-516 GR. 70 Plt. [UNS:K02700]
Allowable stress @ design temperature \( S_v \) 14.06 kgf/mm²
Inside radius \( R \) 628 mm
Thickness \( t \) 9 mm
Min. thickness for external pressure \( tr2 \) 4.506 mm

WELD DATA
Nozzle outside weld \( W_1 \) 10.86 mm

CALCULATION OF NOZZLE NECK THICKNESS AS PER UG-45
Neck thickness for internal pressure, \( [ta_1] \)
Formula in Appendix 1-1, \( [ta_1] \)
\[
= \left( 0.5 \times P_i \times OD \right) \times \left( \frac{Sn \times E + 0.4 \times P_i}{12.02 \times 1.0 + 0.4 \times 0.12} \right)
\]
\[
= 0.836 \text{ mm}
\]
Neck thickness for external pressure, \( [ta_2] \)
Neck thickness for external pressure as per UG-28
Assumed neck thickness, \( [ta_2] = 0.552 \text{ mm} \)
\[
L / OD = 0.891
\]
\[
OD / ta_2 = 304.7
\]
Factor A = 0.00028
Factor B = 2.99 kgf/mm²
Allowable external pressure, \( [\text{Pa}] \)
\[
= 4 \times \frac{B}{(3 \times \text{OD} / \text{ta}_2)} \\
= 4 \times 2.99 / (3 \times 304.7) \\
= 0.01309 \text{ kgf/mm}^2 \text{ g}
\]

Shell thickness for internal pressure as per UG-37 & UG-27, \( [\text{tr}_1 = \text{tb}_1] \)
\[
= \frac{\pi \times R}{(Sv \times E - 0.6 \times \pi)} \\
= 0.12 \times 628 / (14.06 \times 1.0 - 0.6 \times 0.12) \\
= 5.387 \text{ mm}
\]

Shell thickness considering internal pressure equal to external pressure as per UG-27, \( [\text{tb}_2] \)
\[
= \frac{P_e \times R}{(Sv \times E - 0.6 \times P_e)} \\
= 0.01055 \times 628 / (14.06 \times 1.0 - 0.6 \times 0.01055) \\
= 0.471 \text{ mm}
\]

Nozzle minimum thickness required as per Table UG-45, \( [\text{tb}_3] \)
\[
= 6.223 \text{ mm}
\]

Minimum thickness of vessel wall required as per UG-16(b), \( [\text{t}_{\text{min}}] \)
\[
= 1.6 \text{ mm}
\]

Neck thk as per UG-45, \( [\text{t}_{\text{UG-45}}] \)

Thickness, \( [\text{ta}] \)
\[
= \text{MAX} \left( \text{ta}_1, \text{ta}_2, \text{t}_{\text{min}} \right) \\
= \text{MAX} \left[ 0.836, 0.552, 1.6 \right] \\
= 1.6 \text{ mm}
\]

Thickness, \( [\text{tb}] \)
\[
= \text{MIN} \left( \text{tb}_3, \text{MAX} \left( \text{tb}_1, \text{tb}_2, \text{t}_{\text{min}} \right) \right) \\
= \text{MIN} \left[ 6.223, \text{MAX} \left( 5.387, 5.387, 1.6 \right) \right] \\
= 5.387 \text{ mm}
\]

Thickness, \( [\text{t}_{\text{UG-45}}] \)
\[
= \text{MAX} \left( \text{ta}, \text{tb} \right) \text{ .................. for Process Nozzle} \\
= \text{ta} \text{ ................................ for Access Opening} \\
= 5.387 \text{ mm} \text{ ...................... Process Opening}
\]

Since available neck thickness, \( \text{tc} \geq \text{t}_{\text{UG-45}} \), selected neck thickness is adequate.
DESIGN CONDITIONS

Design pressure (internal) $P_i = 0.12 \text{ kgf/mm}^2$ g
Design pressure (external) $P_e = 0.01055 \text{ kgf/mm}^2$ g
Design temperature $T = 120 ^\circ \text{C}$

NOZZLE DATA

M.O.C. SA-106 GR. B Smls. Pipe [UNS:K03006]
Allowable stress @ design temperature $S_n = 12.02 \text{ kgf/mm}^2$
Outside diameter $OD = 168.3 \text{ mm}$
Inside diameter $ID = 137.7 \text{ mm}$
Maximum chord length $D = 137.7 \text{ mm}$

Neck thickness (provided) $t_{np} = 18.26 \text{ mm}$
Internal allowance, corrosion + polishing $CAI = 3 \text{ mm}$
External allowance, corrosion + polishing $CAE = 0$
Neck thickness ($t_{np} - CAI - CAE$) $tn = 15.26 \text{ mm}$
Max. under tolerance on thickness $Alw = 2.283 \text{ mm}$
Available neck thickness ($t_n - Alw$) $tc = 12.98 \text{ mm}$
Nozzle projection outward (from vessel outer face) $Lo = 150 \text{ mm}$
Nozzle projection inward (from vessel inner face) $Li = 0 \text{ mm}$
Total length of nozzle ($L = Lo + Li + tvp + Addn for curvature$) $L = 151 \text{ mm}$
Connection type Pipe Nozzle
Application type Process Opening
Reinforcement calculation method Isolated Opening
Design as large opening False

HEAD DATA (Dished End (Rear))

Allowable stress @ design temperature $S_v = 14.06 \text{ kgf/mm}^2$
Inside diameter of head @ head skirt $Dsf = 1256 \text{ mm}$
$D/2H$ for Ellipsoidal head 2
Factor from Table UG-37 $K_1 = 0.9$
Inside diameter of equivalent sphere, $K_1 \times Dsk \times 2$ $ID_1 = 2260.8 \text{ mm}$
Thickness $t = 7.8 \text{ mm}$
Min. thickness for external pressure $tr_2 = 3.211 \text{ mm}$

WELD DATA

Nozzle outside weld $W_1 = 11.88 \text{ mm}$

CALCULATION OF NOZZLE NECK THICKNESS AS PER UG-45

Neck thickness for internal pressure, $[ta_1]$
Formula in Appendix 1-1, $[ta_1]$
$= (0.5 \times P_i \times OD) / (S_n \times E + 0.4 \times P_i) = (0.5 \times 0.12 \times 168.3) / (12.02 \times 1.0 + 0.4 \times 0.12) = 0.836 \text{ mm}$

Neck thickness for external pressure, $[ta_2]$
Neck thickness for external pressure as per UG-28
Assumed neck thickness, \([ta_2]\) = 0.538 mm

\[ L / OD = 0.891 \]

\[ OD / ta_2 = 312.9 \]

Factor A = 0.00027

Factor B = 2.878 kgf/mm²

Allowable external pressure, \([Pa]\) = 4 \times B / (3 \times OD / ta_2)

= 4 \times 2.878 / (3 \times 312.9)

= 0.01226 kgf/mm²

Head thickness for internal pressure as per UG-37 & UG-27(d), \([tr1 = tb_1]\) = 0.5 \times Pi \times ID1 / (2 \times S\nu \times E - 0.2 \times Pi)

= 0.5 \times 0.12 \times 2260.8 / (2 \times 14.06 \times 1.0 - 0.2 \times 0.12)

= 4.828 mm

Head thickness considering internal pressure equal to external pressure per UG-27(d), \([tb_2]\) = 0.5 \times Pe \times ID1 / (2 \times S\nu \times E - 0.2 \times Pe)

= 0.5 \times 0.01055 \times 2260.8 / (2 \times 14.06 \times 1.0 - 0.2 \times 0.01055)

= 0.424 mm

Nozzle minimum thickness required as per Table UG-45, \([tb_3]\) = 6.223 mm

Minimum thickness of vessel wall required as per UG-16(b), \([t_{min}]\) = 1.6 mm

Neck thk as per UG-45, \([t_{UG-45}]\)

Thickness, \([ta]\) = MAX [ta_1, ta_2, t_{min}]

= MAX [0.836, 0.538, 1.6]

= 1.6 mm

Thickness, \([tb]\) = MIN [tb_3, MAX (tb_1, tb_2, t_{min})]

= MIN [6.223, MAX (4.828, 0.424, 1.6)]

= 4.828 mm

Thickness, \([t_{UG-45}]\) = MAX [ta, tb] for Process Nozzle

= ta for Access Opening

= 4.828 mm Process Opening

Since available neck thickness, \(tc >= t_{UG-45}\), selected neck thickness is adequate.
DESIGN OF LIFTING LUG

1. LIFTING LUG DATA:

Material: IS-2062 GR. A Plt.
Length of lug (LL): 70 mm
Width of lug (A): 120 mm
Thickness of lug plate (TL): 14 mm
Straight length (B1): 10 mm
Radius at tip (R3): 35 mm
Pin Hole diameter (D1): 40 mm
Lug to vessel weld size (W1): 6.216 mm
Min yield stress (Sy): 24.61 kgf/mm²
Allowable tensile stress (2/3 x Sy) (St): 16.4 kgf/mm²
Allowable bending stress (1.5 x St) (Sb): 22.15 kgf/mm²
Allowable shear stress (0.6 x St) (Ss): 9.843 kgf/mm²

2. DESIGN LOADS:

Total design lift weight (Wt): 2660.6 kgf
Number of lifting lugs (N): 2
Jirk load factor (j): 1.5

3. CALCULATION OF REFERENCE DIMENSIONS:

Dimension [L1] = LL - B1 - R3 = 70 - 10 - 35 = 25 mm
Dimension [L2] = L1 / SIN (θ1) = 25 / SIN (0.395) = 65 mm
Dimension [LT] = LL - R3 = 70 - 35 = 35 mm
Angle [θ2] = ASIN (R3 / L2) = ASIN (35 / 65) = 0.569 radians
Angle [θ1] = ATAN (2 x L1 / A) = ATAN (2 x 25 / 120) = 0.395 radians

4. DESIGN OF LUG PLATE:

Effective design load on each lug (P) = j x Wt / N = 1.5 x 2660.6 / 2 = 1998.1 kgf
Required min. thickness of lug plate for shear (t2) = P / [(R3 - 0.5 x D1) x Ss] = 1998.1 / [(35 - 0.5 x 40) x 9.843] = 13.53 mm
Required min. thickness of lug plate for bending (t1) = Required min. thickness of lug plate for tension (t3)
= 6 \times P \times LT / ( A^2 \times Sb )
= 6 \times 1998.1 \times 35 / ( 120^2 \times 22.15 )
= 1.316 \text{ mm}

= P / ( ( 2 \times L3 - D1 ) \times ss )
= 1998.1 / ( ( 2 \times 42.62 - 40 ) \times 16.4 )
= 2.692 \text{ mm}

5. CALCULATION OF STRESSES IN LUG PLATE WELDS:

Bending stress in weld [ f1 ]
= 6 \times P \times LT / [ 2 \times LL^2 ]
= 6 \times 1998.1 \times 35 / ( 2 \times 70^2 )
= 42.82 \text{ kgf/mm}

Max. shear stress in weld [ f2 ]
= P / [ 2 \times A ]
= 1998.1 / ( 2 \times 120 )
= 8.326 \text{ kgf/mm}

Min. Size of lug plate weld [ w1 ]
= \text{MAX} ( f1 , 2 \times f2 ) / ( 0.707 \times Ss )
= \text{MAX} ( 42.82 , 2 \times 8.326 ) / ( 0.707 \times 9.843 )
= 6.153 \text{ mm}
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<th>Weight ( kgf )</th>
<th>Wind Shear ( kgf )</th>
<th>Wind Moment ( kgf-m )</th>
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Customer: ABC Company Ltd.
Project: Soap Plant
Location: Vapi Site
Plant: Refrigeration Plant

**Equipment Information:**
- **Design Code:** ASME VIII Div.1, 15
- **Equipment Name:** PV-01 - Gas Filter
- **Equipment Type:** Pressure Vessel
- **Equipment Class:** N.A.
- **Equipment Category:** N.A.
- **Reference Drawing No:** ---
- **Service:** Other Service
- **Support Type:** Lug Supports

**Design & Reviewal:**
- **Designed By:**
- **Design Date:** 24/Aug/2018 11:17:33
- **Checked By:**
- **Approved By:**
- **Revision:** R00

**Inspection & Approval:**
- **Inspection Agency:** ---
- **Reviewed By:** ---

**Equipment Data:**
- **Front end:** Flat End
- **Front end flanged:** True
- **Rear end:** Dished End
- **Rear end flanged:** False
- **Shell ID:** 1250 mm
- **Shell OD:** 1274 mm
- **Length, Shell (W.L. to W.L) / Overall:** 1650 / 2122.8 mm

**Other Data:**
- **Fabricated weight (corr / uncorr):** 2415.5 / 2660.6 kgf
- **Empty weight + external weights (corr / uncorr):** 2415.5 / 2660.6 kgf
- **Estimated operating weight (corr / uncorr):** 4789.1 / 5009.7 kgf
- **Estimated hydrotest weight (corr / uncorr):** 4701.6 / 4922.3 kgf


Licensee: CADEM Softwares, 411003
Customer: ABC Company Ltd.
Project / Equipment: Soap Plant / PV-01 - Gas Filter
Designed By / Revision and Date: R00, 24/Aug/2018 11:17:33

VESSEL DESIGN DATA

(1) PROCESS DETAILS:

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<thead>
<tr>
<th>MEDIA</th>
<th>DENSITY kg/ m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating</td>
<td>1000</td>
</tr>
<tr>
<td>Design1</td>
<td>1000</td>
</tr>
<tr>
<td>Startup</td>
<td></td>
</tr>
<tr>
<td>Shutdown</td>
<td></td>
</tr>
<tr>
<td>Upset</td>
<td></td>
</tr>
<tr>
<td>Hydrotest</td>
<td>1000</td>
</tr>
<tr>
<td>Pneumatic</td>
<td>1.2</td>
</tr>
</tbody>
</table>

(2) PR.: kgf/mm² g

<table>
<thead>
<tr>
<th>Based on</th>
<th>INT.</th>
<th>EXT.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>Design1</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>Design2</td>
<td></td>
<td></td>
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<td>Startup</td>
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<tr>
<td>Shutdown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrotest</td>
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<td>0.195</td>
</tr>
<tr>
<td>Pneumatic</td>
<td>0.165</td>
<td>0.165</td>
</tr>
</tbody>
</table>

(3) TEST PR.: kgf/mm² g

<table>
<thead>
<tr>
<th>Based on</th>
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<th>MAX.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating</td>
<td>25</td>
<td>120</td>
</tr>
<tr>
<td>Design1</td>
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<td>150</td>
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<tr>
<td>Design2</td>
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<td></td>
</tr>
<tr>
<td>Startup</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shutdown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrotest</td>
<td>21.67</td>
<td>45</td>
</tr>
<tr>
<td>Pneumatic</td>
<td>21.67</td>
<td>45</td>
</tr>
</tbody>
</table>

(4) TEMPERATURE: °C

<table>
<thead>
<tr>
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<th>MIN.</th>
<th>MAX.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating</td>
<td>25</td>
<td>120</td>
</tr>
<tr>
<td>Design1</td>
<td>15</td>
<td>150</td>
</tr>
<tr>
<td>Design2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Startup</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shutdown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrotest</td>
<td>21.67</td>
<td>45</td>
</tr>
<tr>
<td>Pneumatic</td>
<td>21.67</td>
<td>45</td>
</tr>
</tbody>
</table>

(5) ALLOWANCES: mm

| Corrosion | 3 | 0 |
| Polishing | 0 | 0 |

(6) RADIOGRAPHY & JOINT EFFICIENCY:

<table>
<thead>
<tr>
<th>Shell</th>
<th>Spotted</th>
<th>Joint Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>Full</td>
<td>0.85</td>
</tr>
</tbody>
</table>


VESSEL DESIGN DATA
1. MATERIAL OF CONSTRUCTION:

Shell side
- Shell: SA-516 GR. 70 Plt. [UNS:K02700]
- Head: SA-516 GR. 70 Plt. [UNS:K02700]
- Body flange: SA-105 Frg. [UNS:K03504]
- Body flange cover: SA-105 Frg. [UNS:K03504]
- Liner:

Nozzle connections:
- Nozzle neck <= NPS 40: SA-106 GR. B Smls. Pipe [UNS:K03006]
- Flange: SA-105 Frg. [UNS:K03504]
- Cover flange: SA-105 Frg. [UNS:K03504]
- Nozzle NPS > 40 & < 200: SA-106 GR. B Smls. Pipe [UNS:K03006]
- Flange: SA-105 Frg. [UNS:K03504]
- Cover flange: SA-105 Frg. [UNS:K03504]
- Nozzle neck >= NPS 200: SA-516 GR. 70 Plt. [UNS:K02700]
- Flange: SA-516 GR. 70 Plt. [UNS:K02700]
- Cover flange: SA-516 GR. 70 Plt. [UNS:K02700]
- Pad flange: SA-516 GR. 70 Plt. [UNS:K02700]
- Pad flange cover: SA-516 GR. 70 Plt. [UNS:K02700]
- Manhole flange: SA-516 GR. 70 Plt. [UNS:K02700]
- Manhole cover: SA-516 GR. 70 Plt. [UNS:K02700]
- Reinforcement pad: SA-516 GR. 70 Plt. [UNS:K02700]
- External bolt: SA-193 GR. B7 Bolt [UNS:G41400]
- External gasket: CAF with suitable binder (3 mm.)
- Stiffener: SA-516 GR. 70 Plt. [UNS:K02700]
- Lifting lug: IS-2062 GR. A Plt.
- Support: IS-2062 GR. A Plt.
- Anchor bolt: Commercial CS Bolt

2. INSULATION & CLADDING:
- Mat. / Density / Thk.: Rockwool (Mineral Fibre) / 136.2 kg/m³ / 40 mm
- Mat. / Thk.: Al. sheet / 1.191 mm
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>+ve</td>
<td>-ve</td>
<td>+ve</td>
</tr>
<tr>
<td>1</td>
<td>Bolted Cover (Front)</td>
<td>150</td>
<td>0.15</td>
<td>0.01055</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Shell Flng (Front)</td>
<td>150</td>
<td>0.15</td>
<td>0.01055</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Main Shell</td>
<td>150</td>
<td>0.15</td>
<td>0.01055</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Dished End (Rear)</td>
<td>150</td>
<td>0.15</td>
<td>0.01055</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ITEM WISE WEIGHT SUMMARY

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Item name</th>
<th>Item size</th>
<th>Empty wt kgf</th>
<th>Volume m³</th>
<th>Filled wt kgf</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bolted Cover (Front)</td>
<td>Blind Cover - 1463 OD x 84.304 Thk, RF, 1413 PCD, Tgrv = 1.588</td>
<td>1100.8</td>
<td>0</td>
<td>1100.8</td>
</tr>
<tr>
<td>2</td>
<td>Shell Flng (Front)</td>
<td>Plate Ring - 1463 OD x 1250 ID x 1413 PCD, RF, 119.522 Thk, Tgrv = 1.588</td>
<td>423.7</td>
<td>0</td>
<td>423.7</td>
</tr>
<tr>
<td>3</td>
<td>Gasket Flng (Front)</td>
<td>Hex Head Bolt M22 x 240.751 Lg, 56 Nos.</td>
<td>40.57</td>
<td>0</td>
<td>40.57</td>
</tr>
<tr>
<td>4</td>
<td>Bolt Flng (Front)</td>
<td>1274 OD x 12 Thk, 1650 Lg</td>
<td>621.4</td>
<td>2.025</td>
<td>2646.3</td>
</tr>
<tr>
<td>5</td>
<td>Main Shell</td>
<td>Elliptical D/2H = 2.0, 1274 OD x 12 Nom / 10.8 Mln Thk, SF = 50</td>
<td>203.2</td>
<td>0.317</td>
<td>520.3</td>
</tr>
<tr>
<td>6</td>
<td>Dished End (Rear)</td>
<td>222 Long x 200 Wide x 16 Thk, 4 Nos.</td>
<td>22.5</td>
<td>0</td>
<td>22.5</td>
</tr>
<tr>
<td>7</td>
<td>Bolting Plate</td>
<td>200 Long x 190 Wide x 16 Thk, 8 Nos.</td>
<td>38.51</td>
<td>0</td>
<td>38.51</td>
</tr>
<tr>
<td>8</td>
<td>Gusset Plate</td>
<td>Anchor M20 x 200 Lg, 4 Nos.</td>
<td>1.99</td>
<td>0</td>
<td>1.99</td>
</tr>
<tr>
<td>9</td>
<td>Anchor Bolt</td>
<td>275 Long x 272 Wide x 12 Thk, 4 Nos.</td>
<td>28.42</td>
<td>0</td>
<td>28.42</td>
</tr>
<tr>
<td>10</td>
<td>Support Pad</td>
<td>ANSIB36.10, 150 NPS Sch.80, 156 Lg</td>
<td>6.697</td>
<td>0.00262</td>
<td>9.32</td>
</tr>
<tr>
<td>11</td>
<td>Flange [N 01]</td>
<td>Weld Neck, ANSI B16.5, RF, 150# for 150 NPS Sch 80 Pipe</td>
<td>8.08</td>
<td>0</td>
<td>8.08</td>
</tr>
<tr>
<td>12</td>
<td>Gasket [N 01]</td>
<td>150 NPS x 150#, 3.175 Thk</td>
<td>0.1</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>13</td>
<td>Counter Flng [N 01]</td>
<td>Weld Neck, ANSI B16.5, RF, 150# for 150 NPS Sch 80 Pipe</td>
<td>8.08</td>
<td>0</td>
<td>8.08</td>
</tr>
<tr>
<td>14</td>
<td>Reinf [N 01]</td>
<td>292.659 OD x 171.275 ID x 12 Thk</td>
<td>4.202</td>
<td>0</td>
<td>4.202</td>
</tr>
<tr>
<td>15</td>
<td>Flange [N 02]</td>
<td>ANSIB36.10, 150 NPS Sch.80, 156 Lg</td>
<td>6.697</td>
<td>0.00262</td>
<td>9.32</td>
</tr>
<tr>
<td>16</td>
<td>Gasket [N 02]</td>
<td>Weld Neck, ANSI B16.5, RF, 150# for 150 NPS Sch 80 Pipe</td>
<td>8.08</td>
<td>0</td>
<td>8.08</td>
</tr>
<tr>
<td>17</td>
<td>Counter Flng [N 02]</td>
<td>150 NPS x 150#, 3.175 Thk</td>
<td>0.1</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>18</td>
<td>Reinf [N 02]</td>
<td>Weld Neck, ANSI B16.5, RF, 150# for 150 NPS Sch 80 Pipe</td>
<td>8.08</td>
<td>0</td>
<td>8.08</td>
</tr>
<tr>
<td>19</td>
<td>Flange [N 03]</td>
<td>292.659 OD x 171.275 ID x 12 Thk</td>
<td>4.202</td>
<td>0</td>
<td>4.202</td>
</tr>
<tr>
<td>20</td>
<td>Flange [N 03]</td>
<td>ANSIB36.10, 150 NPS Sch.160, 151 Lg</td>
<td>10.29</td>
<td>0.00206</td>
<td>12.35</td>
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<tr>
<td></td>
<td>Description</td>
<td>Dimensions</td>
<td>Width</td>
<td>Length</td>
<td>Thickness</td>
</tr>
<tr>
<td>---</td>
<td>------------------------------</td>
<td>------------------------------</td>
<td>-------</td>
<td>--------</td>
<td>-----------</td>
</tr>
<tr>
<td>23</td>
<td>Gasket [N 03]</td>
<td>150 NPS x 150#, 3.175 Thk</td>
<td>0.1</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>24</td>
<td>Bolted Cover [N 03]</td>
<td>Blind Cover, ANSI B16.5, RF, 150# for 150 NPS Pipe</td>
<td>11.56</td>
<td>0</td>
<td>11.56</td>
</tr>
<tr>
<td>25</td>
<td>Reinf [N 03]</td>
<td>263.5 OD x 171.275 ID x 12 Thk</td>
<td>2.992</td>
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<tr>
<td>26</td>
<td>Lifting Lugs</td>
<td>120 Long x 70 Wide x 14 Thk, 2 Nos.</td>
<td>1.862</td>
<td>0</td>
<td>1.862</td>
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<tr>
<td>27</td>
<td>Pad (Lifting Lugs)</td>
<td>70 Long x 170 Wide x 8 Thk, 2 Nos.</td>
<td>1.507</td>
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</tr>
<tr>
<td>28</td>
<td>Insulation</td>
<td>4178.318 W x 3622.804 L, 40 Thk</td>
<td>82.44</td>
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</tr>
<tr>
<td>29</td>
<td>Cladding</td>
<td>4182.059 W x 3622.804 L, 1.191 Thk</td>
<td>4.993</td>
<td>0</td>
<td>4.993</td>
</tr>
</tbody>
</table>

\[ \sum 2660.6 \quad \sum 4922.3 \]
**Wind Load Calculation**

**1. Design Conditions (Design Mode 1, Corroded Condition):**

- **Basic wind speed (Section 5.2):** \( V_b \) = 50 m/s
- **Expected life of equipment (Section 5.3.1):** 25 Years
- **Probability factor (Risk coeff) (Section 5.3.1):** \( K_1 \) = 0.902
- **Terrain category (Section 5.3.2):** Category 2
- **Structure class (Section 5.3.2.2):** Class B
- **Topography factor (Section 5.3.3):** \( K_3 \) = 1.3
- **Force coefficient (Shape factor):** \( C_f \) = 0.8

**2. Calculation of Forces and Moments:**

- **Equivalent diameter:** \( D_e \) = 1862 mm
- **Overall length of equipment:** \( L \) = 2122.8 mm
- **Height of C.G. of equipment:** \( H_{cg} \) = 1738.9 mm
- **Size and height factor (Section 5.3.2):** \( K_2 \) = 0.98

**Equations:**

- Effective transverse cross-sectional area:
  \[ A = D_e \times L \]

- Effective wind speed:
  \[ V_z = K_1 \times K_2 \times K_3 \times V_b \]
  \( V_z = 57.44 \text{ m/s} \)

- Wind pressure:
  \[ P_z = 6 \times 10^{-8} \times V_z^2 \]
  \( P_z = 0.0002 \text{ kgf/mm}^2 \)

- Longitudinal force:
  \[ F = C_f \times A \times P_z \]
  \( F = 626.1 \text{ kgf} \)

- Support elevation:
  \( H = 474.5 \text{ mm} \)

- Turning moment:
  \[ M = F \times (H_{cg} - H) \]
  \( M = 791596.4 \text{ kgf-mm} \)
SEISMIC LOAD CALCULATION

1. DESIGN CONDITIONS (Design Mode 1, Corroded Condition):

- Weight of equipment \( Wo \): 4789.1 kgf
- Importance factor \( I \): 1.5
- Soil profile type: Stiff Soil Profile (SD)
- Foundation type: RCC footings + Tie Beams
- Damping factor: 5
- Seismic zone: Zone III
- Seismic zone factor \( Z \): 0.16
- Response reduction factor \( R \): 2.9
- Spectral accelerations coeff. \( Sa / g \): 2.5, Use max value
- Damping correction factor \( Cf \): 1

\[
\text{Seismic coefficient} = 0.5 \times Z \times I \times Cf \times \left( \frac{Sa}{g} \right) \times \left( \frac{1}{R} \right) \\
= 0.5 \times 0.16 \times 1.5 \times 1 \times 2.5 \times \left( \frac{1}{2.9} \right) \\
= 0.103
\]

2. CALCULATION OF FORCES AND MOMENTS:

- Elevation of support \( H \): 474.5 mm
- Height of C.G. of equipment \( Hcg \): 1381.1 mm

\[
\text{Seismic base shear force} = Ah \times Wo \\
= 0.103 \times 4789.1 \\
= 433.7 \text{ kgf}
\]

\[
\text{Seismic moment of support} = Vb \times (Hcg - H) \\
= 433.7 \times (1381.1 - 474.5) \\
= 393227.8 \text{ kgf-mm}
\]
1. DESIGN CONDITIONS (Design Mode 1, Corroded Condition):
   - Design pressure: \( P = 0.15 \text{ kgf/mm}^2 \)
   - Design temperature: \( T = 150 \, ^\circ\text{C} \)
   - Allowance: \( CA = 3 \text{ mm} \)
   - Groove allowance: \( Tg = 0 \text{ mm} \)
   - Radiography: Full
   - Joint efficiency: \( E = 1 \)

2. COVER DATA:
   - M.O.C.: SA-105 Frg. [UNS:K03504]
   - Code allw. stress @ design temp.: \( Sfo = 14.06 \text{ kgf/mm}^2 \)
   - Code allw. stress @ atm. temp.: \( Sfa = 14.06 \text{ kgf/mm}^2 \)
   - Young’s modulus: \( Ey = 19888.4 \text{ kgf/mm}^2 \)
   - Self reinforced: False
   - Flange OD: \( A = 1463 \text{ mm} \)
   - Thickness provided: \( 84.3 \text{ mm} \)
   - Thickness available: \( 81.3 \text{ mm} \)

3. BOLTING DATA:
   - M.O.C.: SA-193 GR. B7 Bolt [UNS:G41400]
   - Code allw. stress @ design temp.: \( Sb = 17.58 \text{ kgf/mm}^2 \)
   - Code allw. stress @ atm. temp.: \( Sa = 17.58 \text{ kgf/mm}^2 \)
   - Bolt PCD: \( PCD = 1413 \text{ mm} \)
   - Bolt dia.: \( db = 22 \text{ mm} \)
   - No. of bolts: \( nb = 56 \)

4. LINER DATA:
   - M.O.C.: CAF with suitable binder (3 mm.)
   - Liner ID: \( \text{mm} \)
   - Liner OD: \( \text{mm} \)
   - Liner thk.: \( \text{mm} \)

5. GASKET DATA:
   - M.O.C.: CAF with suitable binder (3 mm.)
   - Gasket seating stress: \( y = 1.125 \text{ kgf/mm}^2 \)
   - Gasket factor: \( m = 2 \)
   - Inside diameter: \( Gi = 1256 \text{ mm} \)
   - Outside diameter: \( Go = 1381.9 \text{ mm} \)
   - Width of gasket: \( N = 62.97 \text{ mm} \)
   - Width of gasket: \( b_0 = 31.75 \text{ mm} \)
   - Basic gasket seating width: \( b_0 = 31.49 \text{ mm} \)
   - Effective gasket width: \( b = 14.14 \text{ mm} \)
   - Dia. at load reaction: \( G = 1353.7 \text{ mm} \)
   - Pass partition gasket width: \( Wp = 0 \text{ mm} \)
   - Pass partition gasket length: \( Lp = 0 \text{ mm} \)
   - Effective pass partition gasket width: \( b' = 0 \text{ mm} \)

6. BOLT LOAD CALCULATIONS AS PER APPENDIX 2-5 (b1):
Total joint - contact surface compression load \([Hp]\)
\[
= 2 \times ( \pi \times b \times G + b' \times Lp ) \times m \times P
\]
\[
= 2 \times ( \pi \times 14.14 \times 1353.7 + 0 \times 0 ) \times 2 \times 0.15
\]
\[
= 36079.2 \text{ kgf}
\]

Total hydrostatic end force \([H]\)
\[
= 0.25 \times \pi \times G^2 \times P
\]
\[
= 0.25 \times \pi \times 1353.7^2 \times 0.15
\]
\[
= 215875.2 \text{ kgf}
\]
Minimum required bolt load for operating condition \([Wm1]\)
\[
= Hp + H
\]
\[
= 36079.2 + 215875.2
\]
\[
= 251954.3 \text{ kgf}
\]

7. BOLT LOAD CALCULATIONS AS PER APPENDIX X 2-5 (b2) :
Minimum required bolt load for gasket seating \([Wm2]\)
\[
= ( \pi \times b \times G + b' \times Lp ) \times y
\]
\[
= ( \pi \times 14.14 \times 1353.7 + 0 \times 0 ) \times 1.125
\]
\[
= 67643.1 \text{ kgf}
\]

8. BOLT AREAS AS PER APPENDIX X 2-5 (d) :
Total required cross-sectional area of bolts \([Am]\)
\[
= \text{MAX} \left[ \frac{Wm2}{Sa}, \frac{Wm1}{Sb} \right] \quad \text{For Internal '+' Pr Design}
\]
\[
= \frac{Wm2}{Sa} \quad \text{For External Pr & Self Sealing Design}
\]
\[
= 14334.5 \text{ mm}^2
\]
Actual bolt area using root diameter \([Ab]\)
\[
= 15255.5 \text{ mm}^2
\]
Flange design bolt load for the gasket seating \([W]\)
\[
= 0.5 \times ( Am + Ab ) \times Sa \times 1 \quad \text{average bolt area}
\]
\[
= Ab \times Sa \times 1 \quad \text{full bolt area}
\]
\[
= 260047.9 \text{ kgf} \quad \text{(Avg. bolt area and margin factor of 1)}
\]

9. CHECK FOR GASKET CRUSHING :
Minimum gasket width required \([Nmin]\)
\[
= \frac{Ab \times Sb}{( 2 \times \pi \times y \times G )}
\]
\[
= 15255.5 \times 17.58 / ( 2 \times \pi \times 1.125 \times 1353.7 )
\]
\[
= 28.03 \text{ mm}
\]

10. DESIGN CALCULATION AS PER UG 34

Self reinforced \[
\text{False}
\]
Factor C is user input \[
\text{False}
\]
Factor C taken from fig. UG 34 or user input \[
C = 0.3
\]
Factor, 2 for self reinf. cover, otherwise 1 \[
F = 1
\]
Required thickness for bolting condition \([t]\)
\[
= G \times F \times \sqrt{ \frac{1.9 \times W}{( Sfa \times E \times G^3 )} }
\]
\[
= 1353.7 \times 1 \times \sqrt{ \frac{1.9 \times 260047.9 \times 0.5 \times ( 1413 - 1353.7 )}{( 14.06 \times 1 \times 1353.7^3 )} }
\]
\[
= 27.75 \text{ mm}
\]
Required thickness for operating condition \([t]\)
\[
= G \times F \times \sqrt{ \left[ \frac{C \times P}{( Sfo \times E )} \right] + 1.9 \times Wm1 \times 0.5 \times ( PCD - G )/( Sfo \times E \times G^3 )}
\]
\[
= 1353.7 \times 1 \times \sqrt{ \left[ \frac{0.3 \times 0.15}{( 14.06 \times 1 )} \right] + 1.9 \times 251954.3 \times 0.5 \times ( 1413 - 1353.7 )/( 14.06 \times 1 \times 1353.7^3 )}
\]
\[
= 81.3 \text{ mm}
\]

Self reinforced \[
\text{False}
\]
Factor C is user input \[
\text{False}
\]
Factor C taken from fig. UG 34 or user input \[
C = 0.3
\]
Factor, 2 for self reinf. cover, otherwise 1 \[
F = 1
\]
Required thickness for bolting condition \([t]\)
\[
= G \times F \times \sqrt{ \frac{1.9 \times W}{( Sfa \times E \times G^3 )} }
\]
\[
= 1353.7 \times 1 \times \sqrt{ \frac{1.9 \times 260047.9 \times 0.5 \times ( 1413 - 1353.7 )}{( 14.06 \times 1 \times 1353.7^3 )} }
\]
\[
= 27.75 \text{ mm}
\]
Required thickness for operating condition \([t]\)
\[
= G \times F \times \sqrt{ \left[ \frac{C \times P}{( Sfo \times E )} \right] + 1.9 \times Wm1 \times 0.5 \times ( PCD - G )/( Sfo \times E \times G^3 )}
\]
\[
= 1353.7 \times 1 \times \sqrt{ \left[ \frac{0.3 \times 0.15}{( 14.06 \times 1 )} \right] + 1.9 \times 251954.3 \times 0.5 \times ( 1413 - 1353.7 )/( 14.06 \times 1 \times 1353.7^3 )}
\]
\[
= 81.3 \text{ mm}
\]
**1. DESIGN CONDITIONS (Design Mode 1, Corroded Condition):**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design pressure P</td>
<td>0.01055 kgf/mm² g</td>
</tr>
<tr>
<td>Design temperature T</td>
<td>150 °C</td>
</tr>
<tr>
<td>Allowance CA</td>
<td>3 mm</td>
</tr>
<tr>
<td>Groove allowance Tg</td>
<td>0 mm</td>
</tr>
<tr>
<td>Radiography</td>
<td>Full</td>
</tr>
<tr>
<td>Joint efficiency E</td>
<td>1</td>
</tr>
</tbody>
</table>

**2. COVER DATA:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.O.C.</td>
<td>SA-105 Frg. [UNS:K03504]</td>
</tr>
<tr>
<td>Code allw. stress @ design temp. Sfo</td>
<td>14.06 kgf/mm²</td>
</tr>
<tr>
<td>Code allw. stress @ atm. temp. Sfa</td>
<td>14.06 kgf/mm²</td>
</tr>
<tr>
<td>Young’s modulus Ey</td>
<td>19888.4 kgf/mm²</td>
</tr>
<tr>
<td>Self reinforced</td>
<td>False</td>
</tr>
<tr>
<td>Flange OD A</td>
<td>1463 mm</td>
</tr>
<tr>
<td>Thickness provided</td>
<td>84.3 mm</td>
</tr>
<tr>
<td>Thickness available</td>
<td>81.3 mm</td>
</tr>
</tbody>
</table>

**3. BOLTING DATA:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.O.C.</td>
<td>SA-193 GR. B7 Bolt [UNS:G41400]</td>
</tr>
<tr>
<td>Code allw. stress @ design temp. Sb</td>
<td>17.58 kgf/mm²</td>
</tr>
<tr>
<td>Code allw. stress @ atm. temp. Sa</td>
<td>17.58 kgf/mm²</td>
</tr>
<tr>
<td>Bolt PCD</td>
<td>1413 mm</td>
</tr>
<tr>
<td>Bolt dia. db</td>
<td>22 mm</td>
</tr>
<tr>
<td>No. of bolts nb</td>
<td>56</td>
</tr>
</tbody>
</table>

**4. LINER DATA:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.O.C.</td>
<td></td>
</tr>
<tr>
<td>Liner ID</td>
<td>mm</td>
</tr>
<tr>
<td>Liner OD</td>
<td>mm</td>
</tr>
<tr>
<td>Liner thk.</td>
<td>mm</td>
</tr>
</tbody>
</table>

**5. GASKET DATA:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.O.C.</td>
<td>CAF with suitable binder (3 mm.)</td>
</tr>
<tr>
<td>Gasket seating stress y</td>
<td>1.125 kgf/mm²</td>
</tr>
<tr>
<td>Gasket factor m</td>
<td>2</td>
</tr>
<tr>
<td>Inside diameter Gi</td>
<td>1256 mm</td>
</tr>
<tr>
<td>Outside diameter Go</td>
<td>1381.9 mm</td>
</tr>
<tr>
<td>Width of gasket N</td>
<td>62.97 mm</td>
</tr>
<tr>
<td>Width of gasket (as per Table 2.5.2)</td>
<td>31.75 mm</td>
</tr>
<tr>
<td>Basic gasket seating width (as per Table 2.5.2) b0</td>
<td>31.49 mm</td>
</tr>
<tr>
<td>Effective gasket width (as per Table 2.5.2) b</td>
<td>14.14 mm</td>
</tr>
<tr>
<td>Dia. at load reaction (see Table 2.5.2) G</td>
<td>1353.7 mm</td>
</tr>
<tr>
<td>Pass partition gasket width Wp</td>
<td>0 mm</td>
</tr>
<tr>
<td>Pass partition gasket length Lp</td>
<td>0 mm</td>
</tr>
<tr>
<td>Effective pass partition gasket width b'</td>
<td>0 mm</td>
</tr>
</tbody>
</table>

**6. BOLT LOAD CALCULATIONS AS PER APPENDIX X 2-5 (b1):**
Total joint - contact surface compression load \([Hp]\)
\[
= 2 \times ( \pi \times b \times G + b' \times Lp ) \times m \times P
\]
\[
= 2 \times ( \pi \times 14.14 \times 1353.7 + 0 \times 0 ) \times 2 \times 0.01055
\]
\[
= 2536.7 \text{ kgf}
\]
Total hydrostatic end force \([H]\)
\[
= 0.25 \times \pi \times G^2 \times P
\]
\[
= 0.25 \times \pi \times 1353.7^2 \times 0.01055
\]
\[
= 15177.9 \text{ kgf}
\]
Minimum required bolt load for operating condition \([Wm1]\)
\[
= Hp + H
\]
\[
= 2536.7 + 15177.9
\]
\[
= 17714.6 \text{ kgf}
\]

7. BOLT LOAD CALCULATIONS AS PER APPENDIX X 2-5 (b2):
Minimum required bolt load for gasket seating \([Wm2]\)
\[
= ( \pi \times b \times G + b' \times Lp ) \times y
\]
\[
= ( \pi \times 14.14 \times 1353.7 + 0 \times 0 ) \times 1.125
\]
\[
= 67643.1 \text{ kgf}
\]

8. BOLT AREAS AS PER APPENDIX X 2-5 (d):
Total required cross-sectional area of bolts \([Am]\)
\[
= \text{MAX} \left[ \frac{Wm2}{Sa} , \frac{Wm1}{Sb} \right] \text{ ....... For Internal '+' Pr Design}
\]
\[
= \frac{Wm2}{Sa} \text{ ......................... For External Pr & Self Sealing Design}
\]
\[
= 3848.4 \text{ mm}^2
\]
Actual bolt area using root diameter \([Ab]\)
\[
= 15255.5 \text{ mm}^2
\]
Flange design bolt load for the gasket seating \([W]\)
\[
= 0.5 \times ( A_m + A_b ) \times Sa \times 1 \text{ ................. average bolt area}
\]
\[
= Ab \times Sa \times 1 \text{ ...........................................full bolt area}
\]
\[
= 167892.3 \text{ kgf} \text{ ( Avg. bolt area and margin factor of 1 )}
\]

9. CHECK FOR GASKET CRUSHING:
Minimum gasket width required \([Nmin]\)
\[
= \frac{Ab \times Sb}{(2 \times \pi \times y \times G)}
\]
\[
= 15255.5 \times 17.58 / (2 \times \pi \times 1.125 \times 1353.7)
\]
\[
= 28.03 \text{ mm}
\]

10. DESIGN CALCULATION AS PER UG 34
Self reinforced \(\text{False}\)
Factor C is user input \(\text{False}\)
Factor C taken from fig. UG 34 or user input
\[
C \quad 0.3
\]
Factor, \(F \quad 0.5\) for self reinf. cover, otherwise \(1\)
\[
F \quad 1
\]
Required thickness for bolting condition \([t]\)
\[
= G \times F \times \sqrt{ \left[ 1.9 \times W \times 0.5 \times ( PCD - G ) / ( Sfa \times E \times G^3 ) \right] + 1.9 \times 167892.3 \times 0.5 \times ( 1413 - 1353.7 ) / ( 14.06 \times 1 \times 1353.7^3 )}
\]
\[
= 27.75 \text{ mm}
\]
Required thickness for operating condition \([t]\)
\[
= G \times F \times \sqrt{\left[ C \times P / ( Sfo \times E ) + 1.9 \times Wm1 \times 0.5 \times ( PCD - G ) / ( Sfo \times E \times G^3 ) \right] + 1.9 \times 17714.6 \times 0.5 \times ( 1413 - 1353.7 ) / ( 14.06 \times 1 \times 1353.7^3 )}
\]
\[
= 34.04 \text{ mm}
\]
**FLANGE DESIGN (INTERNAL)**

**CODE**

- **ASME VIII Div.1, 15**

### 1. DESIGN CONDITIONS (Design Mode 1, Corroded Condition):

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design pressure</td>
<td>0.15 kgf/mm² g</td>
</tr>
<tr>
<td>Design temperature</td>
<td>150 °C</td>
</tr>
<tr>
<td>Allowance</td>
<td>3 mm</td>
</tr>
<tr>
<td>Groove allowance</td>
<td>0 mm</td>
</tr>
</tbody>
</table>

### 2. FLANGE DATA:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.O.C.</td>
<td>SA-105 Frg. [UNS:K03504]</td>
</tr>
<tr>
<td>Code allw. stress @ design temp.</td>
<td>Sfo 14.06 kgf/mm²</td>
</tr>
<tr>
<td>Code allw. stress @ atm. temp.</td>
<td>Sfa 14.06 kgf/mm²</td>
</tr>
<tr>
<td>Inside diameter</td>
<td>B 1256 mm</td>
</tr>
<tr>
<td>Hub length</td>
<td>h 12 mm</td>
</tr>
<tr>
<td>Thickness (hub end)</td>
<td>g₁ 21 mm</td>
</tr>
<tr>
<td>Thickness (pipe end)</td>
<td>g₀ 9 mm</td>
</tr>
<tr>
<td>Thickness provided</td>
<td>119.5 mm</td>
</tr>
<tr>
<td>Thickness available</td>
<td>116.5 mm</td>
</tr>
</tbody>
</table>

### 3. BOLTING DATA:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.O.C.</td>
<td>SA-193 GR. B7 Bolt [UNS:G41400]</td>
</tr>
<tr>
<td>Code allw. stress @ design temp.</td>
<td>Sb 17.58 kgf/mm²</td>
</tr>
<tr>
<td>Code allw. stress @ atm. temp.</td>
<td>Sa 17.58 kgf/mm²</td>
</tr>
<tr>
<td>Bolt PCD</td>
<td>C 1413 mm</td>
</tr>
<tr>
<td>Bolt dia.</td>
<td>db 22 mm</td>
</tr>
<tr>
<td>No. of bolts</td>
<td>nb 56</td>
</tr>
</tbody>
</table>

### 4. LINER DATA:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.O.C.</td>
<td>mm</td>
</tr>
<tr>
<td>Liner ID</td>
<td>mm</td>
</tr>
<tr>
<td>Liner OD</td>
<td>mm</td>
</tr>
<tr>
<td>Liner thk.</td>
<td>mm</td>
</tr>
</tbody>
</table>

### 5. GASKET DATA:

#### 5a. Flange gasket data:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.O.C.</td>
<td>CAF with suitable binder (3 mm.)</td>
</tr>
<tr>
<td>Gasket type</td>
<td>Ring Gasket</td>
</tr>
<tr>
<td>Gasket confinement type</td>
<td>Unconfined</td>
</tr>
<tr>
<td>Flange face type</td>
<td>Raised Face</td>
</tr>
<tr>
<td>Flange gasket surface finish</td>
<td>Serrated (Normal)</td>
</tr>
<tr>
<td>Counter flange face type</td>
<td>Raised Face</td>
</tr>
<tr>
<td>Counter gasket surface finish</td>
<td>Serrated (Normal)</td>
</tr>
<tr>
<td>Applicable gasket sketch in Table 2-5.2</td>
<td>Type 1B</td>
</tr>
<tr>
<td>Applicable gasket column in Table 2-5.2</td>
<td>1</td>
</tr>
<tr>
<td>Gasket seating stress (refer to Note 1, Table 2-5.1)</td>
<td>γ 1.125 kgf/mm²</td>
</tr>
<tr>
<td>Gasket factor (from Table 2-5.1)</td>
<td>m 2</td>
</tr>
<tr>
<td>Inside diameter</td>
<td>Gi 1256 mm</td>
</tr>
<tr>
<td>Outside diameter</td>
<td>Go 1381.9 mm</td>
</tr>
<tr>
<td>Width of gasket</td>
<td>N 62.97 mm</td>
</tr>
</tbody>
</table>
5b. Partition groove gasket data (For H.E. body flange):

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.O.C.</td>
<td>--</td>
</tr>
<tr>
<td>Gasket seating stress</td>
<td>0 kgf/mm²</td>
</tr>
<tr>
<td>Gasket factor</td>
<td>0</td>
</tr>
<tr>
<td>Pass partition gasket width</td>
<td>0 mm</td>
</tr>
<tr>
<td>Pass partition gasket length</td>
<td>0 mm</td>
</tr>
<tr>
<td>Effective pass partition gasket width</td>
<td>0 mm</td>
</tr>
</tbody>
</table>

6. BOLT LOAD CALCULATIONS AS PER APPENDIX 2-5 (b1)

Total joint - contact surface compression load \( [H_p] \):
\[
2 \times \left( \pi \times b \times G \times m + b' \times L_p \times m' \right) \times P
\]
\[
= 36079.2 \text{ kgf}
\]
Total hydrostatic end force \( [H] \):
\[
0.25 \times \pi \times G^2 \times P
\]
\[
= 215875.2 \text{ kgf}
\]
Minimum required bolt load for operating condition \([W_{m1a}]\):
\[
H_p + H
\]
\[
= 36079.2 + 215875.2
\]
\[
= 251954.3 \text{ kgf}
\]
Minimum required bolt load for operating condition \([W_{m1b}]\):
\[
\text{from mating flange}
\]
\[
= 251954.3 \text{ kgf}
\]
Governing bolt load for operating condition \([W_m]\):
\[
\text{MAX} \left[ W_{m1a}, W_{m1b} \right]
\]
\[
= 251954.3 \text{ kgf}
\]

7. BOLT LOAD CALCULATIONS AS PER APPENDIX 2-5 (b2)

Minimum required bolt load for gasket seating \([W_{m2}]\):
\[
\left( \pi \times b \times G \times y + b' \times L_p \times y' \right)
\]
\[
= 67643.1 \text{ kgf}
\]

8. BOLT AREAS AS PER APPENDIX 2-5 (d)

Total required cross-sectional area of bolts \([A_m]\):
\[
\text{MAX} \left[ W_{m2} / S_a, W_{m1} / S_b \right] \text{ ........ For Internal '+' Pr Design}
\]
\[
= W_{m1} / S_b \text{ .................. For External Pr & Self Sealing Design}
\]
\[
= 14334.5 \text{ mm}^2
\]
Actual bolt area using root diameter \([A_b]\):
\[
= 15255.5 \text{ mm}^2
\]
Flange design bolt load for the gasket seating \([W]\):
\[
0.5 \times ( A_m + A_b ) \times S_a \times 1 \text{ .................... average bolt area}
\]
\[
= Ab \times Sa \times 1 \text{ ......................................full bolt area}
\]
\[
= 260047.9 \text{ kgf} \text{ (Avg. bolt area and margin factor of 1 )}
\]

9. CHECK FOR GASKET CRUSHING

Minimum gasket width required \([N_{min}]\):
\[
= Ab \times Sb / ( 2 \times \pi \times y \times G )
\]
\[
= 28.03 \text{ mm}
\]

10. BOLT SPACING CORRECTION FACTOR

As per Brownell & Young or IS 2825,
\[
= \text{SQRT} \left[ \text{Bolt spacing} / ( 2 \times db + t ) \right]
\]
As per TEMA or BS 5500,
\[
= \text{SQRT} \left[ \text{Bolt spacing} / B_{max} \right] \text{ ................. where,}
\]
B_{\text{max}} = \text{maximum recommended bolt spacing} = 2 \times d_b + 6 \times t / (m + 0.5)

\text{Code Select, } Cf = 1 \text{ (min. equal to 1)}

\textbf{11. LOADS AND FORCES DURING OPERATING CONDITION AS PER APPENDIX 2-3}

Hydrostatic end force on area inside of flange [HD]

\[ = 0.25 \pi \times B^2 \times P \]
\[ = 0.25 \pi \times 1256^2 \times 0.15 \]
\[ = 185849.1 \text{ kgf} \]

Gasket load (difference between flange design bolt load and total hydrostatic end force) [HG]

\[ = W_{\text{m1}} - H \]
\[ = 251954.3 - 215875.2 \]
\[ = 36079.2 \text{ kgf} \]

Difference between total hydrostatic end force and hydrostatic end force on area inside of flange [HT]

\[ = H - HD \]
\[ = 215875.2 - 185849.1 \]
\[ = 30026.1 \text{ kgf} \]

\textbf{12. MOMENT ARMS FOR FLANGE LOADS AS PER TABLE 2-6}

Radial distance from the bolt circle to intersection of hub and back of flange, as per Appendix 2-3 [R]

\[ = 0.5 \times (C - B) - g_1 \]
\[ = 0.5 \times (1413 - 1256) - 21 \]
\[ = 57.5 \text{ mm} \]

Radial distance from the bolt circle to the circle on which HD acts [hD]

\[ = R + 0.5 \times g_1 \]
\[ = 57.5 + 0.5 \times 21 \]
\[ = 68 \text{ mm} \]

Radial distance from gasket load reaction to the bolt circle [hG]

\[ = 0.5 \times (C - G) \]
\[ = 0.5 \times (1413 - 1353.7) \]
\[ = 29.67 \text{ mm} \]

Radial distance from the bolt circle to the circle on which HT acts [hT]

\[ = 0.5 \times (R + g_1 + hG) \]
\[ = 0.5 \times (57.5 + 21 + 29.67) \]
\[ = 54.08 \text{ mm} \]

\textbf{13. FLANGE MOMENTS UNDER OPERATING CONDITION AS PER APPENDIX 2-6}

Component of moment due to HD [MD]

\[ = HD \times hD \]
\[ = 185849.1 \times 68 \]
\[ = 12637737.5 \text{ kgf-mm} \]

Component of moment due to HG [MG]

\[ = HG \times hG \]
\[ = 36079.2 \times 29.67 \]
\[ = 1070402.1 \text{ kgf-mm} \]

Component of moment due to HT [MT]

\[ = HT \times hT \]
\[ = 30026.1 \times 54.08 \]
\[ = 1623933.5 \text{ kgf-mm} \]

Total moment acting on the flange for operating condition [MO]

\[ = MD + MG + MT \]
\[ = 12637737.5 + 1070402.1 + 1623933.5 \]
\[ = 15332073.2 \text{ kgf-mm} \]

\textbf{14. LOADS AND FORCES DURING GASKET SEATING AS PER APPENDIX 2-3}

Gasket load for seating condition [HG]

\[ = W \]
\[ = 260047.9 \text{ kgf} \]

\textbf{15. MOMENT UNDER GASKET SEATING AS PER APPENDIX 2-6}

Total moment acting on the flange for gasket seating [MO']

\[ = W \times hG \]
\[ = 260047.9 \times 29.67 \]
\[ = 7715141.1 \text{ kgf-mm} \]

\textbf{16. SHAPE CONSTANTS}

\[ A / B \quad K \quad 1.165 \]
17. STRESS FORMULA FACTORS

Assumed thickness \([t]\) = 116.5 mm

Factor \([\alpha]\) = \[t x e + 1\] = 116.5 x 0.00849 + 1 = 1.99

Factor \([\beta]\) = \[1.333 x t x e + 1\] = 1.333 x 116.5 x 0.00849 + 1 = 2.319

Factor \([\gamma]\) = \[\alpha / T\] = 1.99 / 1.853 = 1.074

Factor \([\delta]\) = \[t^3 / d\] = \[116.5^3 / 290617.3\] = 5.444

Factor \([\lambda]\) = \[\gamma + \delta\] = 1.074 + 5.444 = 6.518

18. FLANGE STRESSES AS PER APPENDIX 2-7 & 2-8

Equivalent moment \([M_{\text{max}}]\) = MAX \[ MO , MO' x Sfo / Sfa \] = MAX \[ 15332073.2 , 7715141.1 x 14.06 / 14.06 \] = 15332073.2 kgf-mm

Corrected equivalent moment per unit length \([M]\) = \[M_{\text{max}} x ( C_f / B )\] = 15332073.2 x ( 1 / 1256 ) = 12207.1 kgf

Longitudinal hub stress \([SH]\) = \[f x M / ( \lambda x g1^2 )\] = \[4.354 x 12207.1 / ( 6.518 x 21^2 )\] = \[18.49 \text{ kgf/mm}^2\] < \[1.5 x Sfo\]

Radial flange stress \([SR]\) = \[\beta x M / ( \lambda x t^2 )\] = \[2.319 x 12207.1 / ( 6.518 x 116.5^2 )\] = \[0.32 \text{ kgf/mm}^2\] < \[Sfo\]

Tangential flange stress \([ST]\) = \[( M x Y / t^2 ) - Z x SR\] = \[( 12207.1 x 12.8 / 116.5^2 ) - 6.606 x 0.32\] = \[9.391 \text{ kgf/mm}^2\] < \[Sfo\]

Average stress
\begin{align*}
&= \text{MAX}[0.5x(\text{SH} + \text{SR}), 0.5x(\text{SH} + \text{ST})] \\
&= \text{MAX}[0.5x(18.49 + 0.32), 0.5x(18.49 + 9.391)] \\
&= 13.94 \text{ kgf/mm}^2 \quad \text{......................... < } S_fo
\end{align*}

**19. FLANGE RIGIDITY CHECKING AS PER APPENDIX 2-14**

| Modulus of elasticity for flange | E_fo | 19888.4 kgf/mm² |
| Rigidity factor | K_I | 0.3 |

Rigidity index [J]
\[
J = 52.14 \times V \times M_{\text{max}} / (\lambda \times E_fo \times g_0^2 \times K_I \times h_0) \\
= 52.14 \times 0.417 \times 15332073.2 / (6.518 \times 19888.4 \times 9^2 \times 0.3 \times 106.3) \\
= 0.995
\]

Since J < 1.0, design is safe
1. DESIGN CONDITIONS (Design Mode 1, Corroded Condition):

- Design pressure: \( P = 0.01055 \text{ kgf/mm}^2 \)
- Design temperature: \( T = 150 \text{ °C} \)
- Allowance: \( CA = 3 \text{ mm} \)
- Groove allowance: \( Tg = 0 \text{ mm} \)

2. FLANGE DATA:

- M.O.C.: SA-105 Frg. [UNS:K03504]
- Code allowed stress @ design temp.: \( Sfo = 14.06 \text{ kgf/mm}^2 \)
- Code allowed stress @ atm. temp.: \( Sfa = 14.06 \text{ kgf/mm}^2 \)
- Inside diameter: \( B = 1256 \text{ mm} \)
- Hub length: \( h = 12 \text{ mm} \)
- Thickness (hub end): \( g1 = 21 \text{ mm} \)
- Thickness (pipe end): \( g0 = 9 \text{ mm} \)
- Thickness provided: \( 119.5 \text{ mm} \)
- Thickness available: \( 116.5 \text{ mm} \)

3. BOLTING DATA:

- M.O.C.: SA-193 GR. B7 Bolt [UNS:G41400]
- Code allowed stress @ design temp.: \( Sb = 17.58 \text{ kgf/mm}^2 \)
- Code allowed stress @ atm. temp.: \( Sa = 17.58 \text{ kgf/mm}^2 \)
- Bolt PCD: \( C = 1413 \text{ mm} \)
- Bolt dia.: \( db = 22 \text{ mm} \)
- No. of bolts: \( nb = 56 \)

4. LINER DATA:

- M.O.C.: mm
- Liner ID: mm
- Liner OD: mm
- Liner thk.: mm

5. GASKET DATA:

5a. Flange gasket data:

- M.O.C.: CAF with suitable binder (3 mm.)
- Gasket type: Ring Gasket
- Gasket confinement type: Unconfined
- Flange face type: Raised Face
- Flange gasket surface finish: Serrated (Normal)
- Counter flange face type: Raised Face
- Counter gasket surface finish: Serrated (Normal)
- Applicable gasket sketch in Table 2-5.2: Type 1B
- Applicable gasket column in Table 2-5.2: 1
- Gasket seating stress (refer to Note 1, Table 2-5.1): \( \gamma = 1.125 \text{ kgf/mm}^2 \)
- Gasket factor (from Table 2-5.1): \( m = 2 \)
- Inside diameter: \( Gi = 1256 \text{ mm} \)
- Outside diameter: \( Go = 1381.9 \text{ mm} \)
- Width of gasket (as per Table 2-5.2): \( N = 62.97 \text{ mm} \)
5b. Partition groove gasket data (For H.E. body flange):

M.O.C.
Gasket seating stress (refer to Note 1, Table 2-5.1) $y'$ $0$ kgf/mm²
Gasket factor (from Table 2-5.1) $m'$ $0$
Pass partition gasket width $W_p$ $0$ mm
Pass partition gasket length $L_p$ $0$ mm
Effective pass partition gasket width $b'$ $0$ mm

6. BOLT LOAD CALCULATIONS AS PER APPENDIX 2-5 (b1)
Total joint - contact surface compression load [$H_p$]
$$= 2 \times ( \pi \times b \times G \times m + b' \times L_p \times m') \times P$$
$$= 2536.7 \text{ kgf}$$
Total hydrostatic end force [$H$]
$$= 0.25 \times \pi \times G^2 \times P$$
$$= 15177.9 \text{ kgf}$$
Minimum required bolt load for operating condition [$W_{m1a}$]
$$= H_p + H$$
$$= 2536.7 + 15177.9$$
$$= 17714.6 \text{ kgf}$$
Minimum required bolt load for operating condition [$W_{m1b}$]
(from mating flange)
$$= 17714.6 \text{ kgf}$$
Governing bolt load for operating condition [$W_{m1}$]
$$= \text{MAX} \left[ W_{m1a}, W_{m1b} \right]$$
$$= \text{MAX} \left[ 17714.6, 17714.6 \right]$$
$$= 17714.6 \text{ kgf}$$

7. BOLT LOAD CALCULATIONS AS PER APPENDIX 2-5 (b2)
Minimum required bolt load for gasket seating [$W_m2$]
$$= ( \pi \times b \times G \times y + b' \times L_p \times y')$$
$$= 67643.1 \text{ kgf}$$

8. BOLT AREAS AS PER APPENDIX 2-5 (d)
Total required cross-sectional area of bolts [$A_m$]
$$= \text{MAX} \left[ W_m2 / S_a, W_{m1} / S_b \right] \text{ For Internal '+' Pr Design}$$
$$= W_m2 / S_a \text{................................. For External Pr & Self Sealing Design}$$
$$= 3848.4 \text{ mm}^2$$
Actual bolt area using root diameter [$A_b$]
$$= 15255.5 \text{ mm}^2$$
Flange design bolt load for the gasket seating [$W$]
$$= 0.5 \times ( A_m + A_b ) \times S_a \times 1 \text{......................... average bolt area}$$
$$= A_b \times S_a \times 1 \text{.................................full bolt area}$$
$$= 167892.3 \text{ kgf} \text{(Avg, bolt area and margin factor of 1)}$$

9. CHECK FOR GASKET CRUSHING
Minimum gasket width required [$N_{min}$]
$$= A_b \times S_b / ( 2 \times \pi \times y \times G )$$
$$= 15255.5 \times 17.58 / ( 2 \times \pi \times 1.125 \times 1353.7 )$$
$$= 28.03 \text{ mm}$$

10. BOLT SPACING CORRECTION FACTOR
As per Brownell & Young or IS 2825,
$$= \text{SQRT} \left[ \text{Bolt spacing} / ( 2 \times \pi \times d_b + t ) \right]$$
As per TEMA or BS 5500,
$$= \text{SQRT} \left[ \text{Bolt spacing} / 8 \times \pi \times d_b \right]$$
where,
Bmax = maximum recommended bolt spacing = 2 x db + 6 x t / ( m + 0.5 )

Code Select, Cf = 1 (min. equal to 1)

11. LOADS AND FORCES DURING OPERATING CONDITION AS PER APPENDIX 2-3

Hydrostatic end force on area inside of flange [HD]
= 0.25 x π x B² x P
= 0.25 x π x 1256² x 0.01055
= 13066.8 kgf

Difference between total hydrostatic end force and hydrostatic end force on area inside of flange [HT]
= H - HD
= 15177.9 - 13066.8
= 2111.1 kgf

12. MOMENT ARMS FOR FLANGE LOADS AS PER APPENDIX TABLE 2-6

Radial distance from the bolt circle to intersection of hub and back of flange, as per Appendix 2-3 [R]
= 0.5 x ( C - B ) - g1
= 0.5 x ( 1413 - 1256 ) - 21
= 57.5 mm

Radial distance from the bolt circle to the circle on which HD acts [hD]
= R + 0.5 x g1
= 57.5 + 0.5 x 21
= 68 mm

Radial distance from gasket load reaction to the bolt circle [hG]
= 0.5 x ( C - G )
= 0.5 x ( 1413 - 1353.7 )
= 29.67 mm

Radial distance from the bolt circle to the circle on which HT acts [hT]
= 0.5 x ( R + g1 + hG )
= 0.5 x ( 57.5 + 21 + 29.67 )
= 54.08 mm

13. FLANGE MOMENTS UNDER OPERATING CONDITION AS PER APPENDIX 2-6

Component of moment due to HD [MD]
= HD x ( hD - hG )
= 13066.8 x ( 68 - 29.67 )
= 500874.5 kgf-mm

Component of moment due to HT [MT]
= HT x ( hT - hG )
= 2111.1 x ( 54.08 - 29.67 )
= 51544.3 kgf-mm

Total moment acting on the flange for operating condition [MO]
= MD + MT
= 500874.5 + 51544.3
= 552418.8 kgf-mm

14. LOADS AND FORCES DURING GASKET SEATING AS PER APPENDIX 2-3

Gasket load for seating condition [HG]
= W
= 167892.3 kgf

15. MOMENT UNDER GASKET SEATING AS PER APPENDIX 2-6

Total moment acting on the flange for gasket seating [MO']
= W x hG
= 167892.3 x 29.67
= 4981054.6 kgf-mm

16. SHAPE CONSTANTS

A / B
K 1.165
T 1.853
Z 6.606
Y 12.8
U 14.06

h0 106.3

F / h0 e 0.00849
17. STRESS FORMULA FACTORS

Assumed thickness \([t]\)

Factor \([\alpha]\) = \(t \times e + 1\)

\[= 71.38 \times 0.00849 + 1\]

\[= 1.606\]

Factor \([\beta]\) = \(1.333 \times t \times e + 1\)

\[= 1.333 \times 71.38 \times 0.00849 + 1\]

\[= 1.808\]

Factor \([\gamma]\) = \(\frac{\alpha}{T}\)

\[= \frac{1.606}{1.853}\]

\[= 0.867\]

Factor \([\delta]\) = \(t^3 / d\)

\[= \frac{71.38^3}{290617.3}\]

\[= 1.251\]

Factor \([\lambda]\) = \(\gamma + \delta\)

\[= 0.867 + 1.251\]

\[= 2.118\]

18. FLANGE STRESSES AS PER APPENDIX 2-7 & 2-8

Equivalent moment \([M_{\text{max}}]\)

\[= \text{MAX} \left[ M_O, M_O' \times S_{fi} / S_{fa} \right]\]

\[= \text{MAX} \left[ 552418.8, 4981054.6 \times 14.06 / 14.06 \right]\]

\[= 4981054.6 \text{ kgf-mm}\]

Corrected equivalent moment per unit length \([M]\)

\[= M_{\text{max}} \times \left( \frac{C_f}{B} \right)\]

\[= 4981054.6 \times \left( \frac{1}{1256} \right)\]

\[= 3965.8 \text{ kgf}\]

Longitudinal hub stress \([SH]\)

\[= f \times \frac{M}{(\lambda \times g_1^2)}\]

\[= 4.354 \times 3965.8 / (2.118 \times 21^2)\]

\[= 18.49 \text{ kgf/mm}^2\] \(< 1.5 \times S_{fo}\]

Radial flange stress \([SR]\)

\[= \beta \times \frac{M}{(\lambda \times t^2)}\]

\[= 1.606 \times 3965.8 / (2.118 \times 71.38^2)\]

\[= 0.665 \text{ kgf/mm}^2\] \(< S_{fo}\]

Tangential flange stress \([ST]\)

\[= (M \times Y / t^2) - Z \times \Delta R\]

\[= (3965.8 \times 12.8 / 71.38^2) - 6.606 \times 0.665\]

\[= 5.571 \text{ kgf/mm}^2\] \(< S_{fo}\]

Average stress

\[= \text{MAX} \left[ 0.5 \times (SH + SR), 0.5 \times (SH + ST) \right]\]

\[= \text{MAX} \left[ 0.5 \times (18.49 + 0.665), 0.5 \times (18.49 + 5.571) \right]\]

\[= 12.03 \text{ kgf/mm}^2\] \(< S_{fo}\]

19. FLANGE RIGIDITY CHECKING AS PER APPENDIX 2-14

Modulus of elasticity for flange \(E_{fo}\)

\[= 19888.4 \text{ kgf/mm}^2\]

Rigidity factor \(K_I\)

\[= 0.3\]
Rigidity index \([J]\) 
\[= 52.14 \times \frac{V \times M_{\text{max}}}{(\gamma \times E_{f0} \times \sigma_0^2 \times K_{I} \times h_{0})}\] 
\[= 52.14 \times \frac{0.417 \times 4981054.6}{(2.118 \times 19888.4 \times 9^2 \times 0.3 \times 106.3)}\] 
\[= 0.994\] 
Since \(J < 1.0\), design is safe
DESIGN CONDITIONS (Design Mode 1, Corroded Condition)

Thickness of shell under internal pressure \( (t_i) \) = \( \frac{\pi R}{S \times E - 0.6 \times \pi} \)
= \( 0.15 \times 628 / (14.06 \times 0.85 - 0.6 \times 0.15) \)
= 7.941 mm

DESIGN CALCULATION AS PER UG-27

Thickness of shell under internal pressure \( (t_i) \) = \( \frac{\pi R}{S \times E - 0.6 \times \pi} \)
= \( 0.15 \times 628 / (14.06 \times 0.85 - 0.6 \times 0.15) \)
= 7.941 mm

DESIGN CALCULATION OF SHELL THICKNESS UNDER EXTERNAL PRESSURE AS PER UG-28

Allowable external pressure \( (Pa) \) = \( 4 \times B / (3 \times (OD / te)) \)
= \( 4 \times 2.298 / (3 \times 282.7) \)
= 0.01084 kgf/mm² g

Since \( Pa > Pe \), design is safe.
Since available thickness is more than design thickness, design is safe.
1. DESIGN CONDITIONS (Design Mode 1, Corroded Condition):

2. DESIGN CALCULATION AS PER UG 32 d / APPENDIX 1-4 (c):

- Factor \( K \) = 1

- Thickness for internal pressure \( t \)
  
  \[
  t = \frac{K \times P_i \times ID}{2 \times S \times E - 0.2 \times P_i} 
  \]

  \[
  = 1 \times 0.15 \times 1256 / (2 \times 14.06 \times 1 - 0.2 \times 0.15) 
  \]

  \[
  = 6.706 \text{ mm} 
  \]

3. DESIGN CALCULATION AS PER UG 33 d:

- Thickness for equivalent internal pressure \( t \)
  
  \[
  t = \frac{K \times P_e \times ID}{2 \times S \times 1.0 - 0.2 \times P_e} 
  \]

  \[
  = 1 \times 1.67 \times 0.01055 \times 1256 / (2 \times 14.06 \times 1.0 - 0.2 \times 1.67 \times 0.01055) 
  \]

  \[
  = 0.787 \text{ mm} 
  \]

- Factor \( K_o \) = 0.88

- Assumed head thickness, \( t_e \)
  
  \[
  t_e = 3.211 \text{ mm} 
  \]

- Factor \( A \)
  
  \[
  A = 0.125 \times t_e / (K_o \times OD) 
  \]

  \[
  = 0.125 \times 3.211 / (0.88 \times 1274) 
  \]

  \[
  = 0.00036 
  \]

- Factor with reference to chart (CS-2) \( B \)
  
  \[
  B = 3.771 \text{ kgf/mm}^2 
  \]

- Allowable external pressure \( P_a \)
  
  \[
  P_a = B / (K_o \times OD / t_e) 
  \]

  \[
  = 3.771 \times 3.211 / (0.88 \times 1274) 
  \]

  \[
  = 0.0108 \text{ kgf/mm}^2 
  \]

Since \( P_a > P_e \), design is safe.
Since available thickness is more than design thickness, design is safe.
1. **LUG DATA:**
   - **M.O.C:** IS-2062 GR. A Plt.
   - **No. of support:** N 4
   - **Base plate width:** b1 222 mm
   - **Base plate depth:** Lb 200 mm
   - **Thickness of base plate:** tb 16 mm
   - **Allowable bending stress:** Sb 22.15 kgf/mm²

2. **BOLT DATA:**
   - **M.O.C:** Commercial CS Bolt
   - **No. of bolt / lug:** Nb 1
   - **Bolt diameter:** db 20 mm
   - **PCD:** D 1598 mm
   - **Diameter of bolt hole:** 24 mm
   - **Allowable tensile stress:** Fs 10.69 kgf/mm²

3. **GUSSET DATA:**
   - **Thickness:** tg 16 mm
   - **Height:** h 190 mm
   - **Gusset angle:** θ 51.71
   - **Gusset depth at top:** Lc 50 mm
   - **Number of gussets:** n 2
   - **Distance between gussets:** b 180 mm

4. **SHELL DATA:**
   - **Material:** SA-516 GR. 70 Plt. [UNS:K02700]
   - **OD diameter:** OD 1274 mm
   - **Inside diameter:** ID 1256 mm
   - **Thickness available:** ts 9 mm

5. **PAD DATA:**
   - **Material:** SA-516 GR. 70 Plt. [UNS:K02700]
   - **Thickness:** tp 12 mm
   - **Width:** W 275 mm
   - **Length:** L 272 mm

6. **LOAD AND MOMENT (Wind):**
   - **Max. overturning moment:** M 791596.4 kgf-mm
   - **Design weight of vessel:** Wt 2415.5 kgf

7. **DESIGN OF ANCHOR BOLTS:**
   - **Total uplift force on bolts [T]**
     = \[ 4 \times \frac{M}{(D \times N)} \] - Wt / N
     = \[ 4 \times \frac{791596.4}{(1598 \times 4)} \] - 2415.5 / 4
     = -108.5 kgf
   - **Required area of bolts [Am]**
     = \[ \text{MAX} \left\{ \frac{T}{Fs}, 0 \right\} \]
     = \[ \text{MAX} \left\{ \frac{-108.5}{10.69}, 0 \right\} \]
Available area of bolts \( Ab \)

\[ Ab = Ar \times Nb \]

where, \( Ar = 217.1 \text{ mm}^2 \), is root area of bolt

\[ = 217.1 \times 1 \]

\[ = 217.1 \text{ mm}^2 \]

Since \( Ab > Am \), bolts provided are sufficient

8. GUSSET DESIGN:

Reaction force at each support \( [Q] \)

\[ [ 4 \times M / \left( D \times N \right) ] + Wt / N \]

\[ = [ 4 \times 791596.4 / \left( 1598 \times 4 \right) ] + 2415.5 / 4 \]

\[ = 1099.2 \text{ kgf} \]

Maximum axial force in gusset \( [P1] \)

\[ = Q / n \]

\[ = 1099.2 / 2 \]

\[ = 549.6 \text{ kgf} \]

Allowable compr. stress in gusset \( [Sg] \)

\[ = 18000 / \left[ 1 + 12 \times \left( h'/tg \right)^2 / 18000 \right] \]

\[ = 18000 / \left[ 1 + 12 \times \left( 242.1 / 16 \right)^2 / 18000 \right] \]

\[ = 15616.8 \text{ psi} \]

\[ = 10.98 \text{ kgf/mm}^2 \]

Required thickness of gusset \( [tg'] \)

\[ = 2 \times P1 \times \left( 3 \times a - Lb \right) / \left[ Sg \times Lb^2 \times \left( \sin \theta \right)^2 \right] \]

\[ = 2 \times 549.6 \times \left( 3 \times 150 - 200 \right) / \left[ 10.98 \times (200)^2 \times \left( \sin 51.71 \right)^2 \right] \]

\[ = 1.016 \text{ mm} \]

9. BASE PLATE DESIGN:

Bending moment \( [Mb] \)

\[ = Q \times b1 / 6 \]

\[ = 1099.2 \times 222 / 6 \]

\[ = 40671.8 \text{ kgf-mm} \]

Bearing pressure \( [bp] \)

\[ = Q / \left( w \times b1 \right) \]

\[ = 1099.2 / \left( 120 \times 222 \right) \]

\[ = 0.04126 \text{ kgf/mm}^2 \]

Bending moment due to bearing pressure \( [Mb'] \)

\[ = bp \times b^2 / 10 \]

\[ = 0.04126 \times 180^2 / 10 \]

\[ = 133.7 \text{ kgf-mm} \]

Required thickness of base plate between chairs \( [tb'] \)

\[ = SQRT \left\{ 6 \times MAX \left[ Mb, Mb' \right] / \left[ (Lb - db) \times Sb \right] \right\} \]

\[ = SQRT \left\{ 6 \times MAX \left[ 40671.8, 133.7 \right] / \left[ (200 - 20) \times 22.15 \right] \right\} \]

\[ = 7.912 \text{ mm} \]

10. CHECK FOR COMPRESSION PLATE:

Equivalent radial load \( [r] \)

\[ = Q \times a / \left( n \times h \right) \]

\[ = 1099.2 \times 150 / \left( 2 \times 190 \right) \]

\[ = 433.9 \text{ kgf} \]

Angle between supports \( [\alpha] \)

\[ = 2 \times \pi / N \]

\[ = 2 \times \pi / 4 \]

\[ = 1.571 \text{ rad} \]

Internal bending moment coefficient \( [Kr] \)
\[
= 0.5 \times \left[ \frac{1}{0.5 \times \alpha} \right] - \cot \left( 0.5 \times \alpha \right)
\]
\[
= 0.5 \times \left[ \frac{1}{0.5 \times 1.571} \right] - \cot \left( 0.5 \times 1.571 \right)
\]
\[
= 0.137
\]

Internal bending moment [Mc]
\[
= 0.5 \times Kr \times f \times OD
\]
\[
= 0.5 \times 0.137 \times 433.9 \times 1274
\]
\[
= 37761.8 \text{ kgf-mm}
\]

Bending stress induced [fb]
\[
= \frac{Mo}{Z_c}
\]
\[
= \frac{37761.8}{13224.4}
\]
\[
= 2.855 \text{ kgf/mm}^2
\]

Since, induced stress fb < allow. stress Sb in shell material, design is safe.
1. LUG DATA:
   M.O.C IS-2062 GR. A Plt.
   No. of support N 4
   Base plate width b1 222 mm
   Base plate depth Lb 200 mm
   Thickness of base plate tb 16 mm
   Allowable bending stress Sb 22.15 kgf/mm²

2. BOLT DATA:
   M.O.C Commercial CS Bolt
   No. of bolt / lug Nb 1
   Bolt diameter db 20 mm
   PCD D 1598 mm
   Diameter of bolt hole 24 mm
   Allowable tensile stress Fs 10.69 kgf/mm²

3. GUSSET DATA:
   Thickness tg 16 mm
   Height h 190 mm
   Gusset angle θ 51.71
   Gusset depth at top Lc 50 mm
   Number of gussets n 2
   Distance between gussets b 180 mm

4. SHELL DATA:
   Material SA-516 GR. 70 Plt. [UNS:K02700]
   OD diameter OD 1274 mm
   Inside diameter ID 1256 mm
   Thickness available ts 9 mm

5. PAD DATA:
   Material SA-516 GR. 70 Plt. [UNS:K02700]
   Thickness tp 12 mm
   Width W 275 mm
   Length L 272 mm

6. LOAD AND MOMENT (Seismic):
   Max. overturning moment M 393227.8 kgf-mm
   Design weight of vessel Wt 4789.1 kgf

7. DESIGN OF ANCHOR BOLTS:
   Total uplift force on bolts [T] = [ 4 x M / ( D x N ) ] - Wt / N
   = [ 4 x 393227.8 / ( 1598 x 4 ) ] - 4789.1 / 4
   = -951.2 kgf
   Required area of bolts [Am]
   = MAX [ ( T / Fs ) , 0 ]
   = MAX [ ( -951.2 / 10.69 ) , 0 ]
Available area of bolts [Ab]
= Ar x Nb ........................................................................................................... where, Ar = 217.1 mm², is root area of bolt
= 217.1 x 1
= 217.1 mm²

Since Ab > Am, bolts provided are sufficient

8. GUSSET DESIGN:
Reaction force at each support [Q]
= [ 4 x M / ( D x N ) ] + Wt / N 
= [ 4 x 393227.8 / ( 1598 x 4 ) ] + 4789.1 / 4 
= 1443.3 kgf

Maximum axial force in gusset [P1]
= Q / n 
= 1443.3 / 2 
= 721.7 kgf

Allowable compr. stress in gusset [Sg]
= 18000 / [ 1 + 12 x ( h' / tg ) ² / 18000 ] ................................................. where, h’ = 242.1 mm 
= 18000 / [ 1 + 12 x ( 242.1 / 16 ) ² / 18000 ]
= 15616.8 psi
= 10.98 kgf/mm²

Required thickness of gusset [tg’]
= 2 x P1 x ( 3 x a - Lb ) / [ Sg x Lb ² x ( sin θ ) ² ] 
= 2 x 721.7 x ( 3 x 150 - 200 ) / [ 10.98 x ( 200 ) ² x ( sin 51.71 ) ² ]
= 1.334 mm

9. BASE PLATE DESIGN:
Bending moment [Mb]
= Q x b1 / 6 
= 1443.3 x 222 / 6 
= 53403.7 kgf-mm

Bearing pressure [bp]
= Q / ( w x b1 ) ........................................................................................................... where, w = 120 mm
= 1443.3 / ( 120 x 222 ) 
= 0.05418 kgf/mm²

Bending moment due to bearing pressure [Mb’]
= bp x b ² / 10 
= 0.05418 x 180 ² / 10 
= 175.5 kgf-mm

Required thickness of base plate between chairs [tb’]
= SQRT { 6 x MAX [ Mb , Mb’ ] / [ ( Lb - db ) x Sb ] } 
= SQRT { 6 x MAX [ 53403.7 , 175.5 ] / [ ( 200 - 20 ) x 22.15 ] } 
= 9.067 mm

10. CHECK FOR COMPRESSION PLATE:
Equivalent radial load [f]
= Q x a / ( n x h ) 
= 1443.3 x 150 / ( 2 x 190 ) 
= 569.7 kgf

Angle between supports [α]
= 2 x π / N 
= 2 x π / 4 
= 1.571 rad

Internal bending moment coefficient [Kr]
= 0.5 \times \left[ \frac{1}{(0.5 \times \alpha)} - \cot \left( 0.5 \times \alpha \right) \right]
= 0.5 \times \left[ \frac{1}{(0.5 \times 1.571)} - \cot \left( 0.5 \times 1.571 \right) \right]
= 0.137

Internal bending moment [Mc]

= 0.5 \times K_r \times f \times OD
= 0.5 \times 0.137 \times 569.7 \times 1274
= 49582.7 \ kgf-mm

Bending stress induced [fb]

= \frac{M_o}{Z_c}
= \frac{49582.7}{13224.4}
= 3.749 \ kgf/mm^2

Since, induced stress fb < allow. stress Sb in shell material, design is safe.
DESIGN CONDITIONS
Design pressure (internal) \( P_i \) 0.15 kgf/mm²
design pressure (external) \( P_e \) 0.01055 kgf/mm²
design temperature \( T \) 150 °C

NOZZLE DATA
M.O.C. SA-106 GR. B Smls. Pipe [UNS:K03006]
allowable stress @ design temperature \( S_n \) 12.02 kgf/mm²
outside diameter \( O_D \) 168.3 mm
inside diameter \( I_D \) 152.3 mm
maximum chord length \( D \) 152.3 mm
neck thickness (provided) \( t_{np} \) 10.97 mm
internal allowance, corrosion + polishing \( C_{AI} \) 3 mm
external allowance, corrosion + polishing \( C_{AE} \) 0
neck thickness \( t \) 7.973 mm
max. under tolerance on thickness \( A_{lw} \) 1.372 mm
available neck thickness \( t - A_{lw} \) 6.601 mm
nozzle projection outward \( L_{o} \) 150 mm
total length of nozzle \( L \) 156 mm
connection type pipe nozzle
application type process opening
reinforcement calculation method isolated opening
design as large opening false
M.O.C. SA-516 GR. 70 Plt. [UNS:K02700]
allowable stress @ design temperature \( S_v \) 14.06 kgf/mm²
inside radius \( R \) 628 mm
thickness \( t \) 9 mm
min. thickness for external pressure \( t_{r2} \) 4.506 mm

WELD DATA
Nozzle outside weld \( W_1 \) 10.86 mm

CALCULATION OF NOZZLE NECK THICKNESS AS PER UG-45
Neck thickness for internal pressure \( , [t_{a1}] \)
Formula in Appendix 1-1, \( [t_{a1}] \)
\[ = \frac{(0.5 \times P_i \times O_D)}{(S_n \times E + 0.4 \times P_i)} \]
\[ = \frac{(0.5 \times 0.15 \times 168.3)}{(12.02 \times 1.0 + 0.4 \times 0.15)} \]
\[ = 1.045 \text{ mm} \]
Neck thickness for external pressure \( , [t_{a2}] \)
Neck thickness for external pressure as per UG-28
Assumed neck thickness \( , [t_{a2}] \) = 0.552 mm
\( L / O_D = 0.891 \)
\( O_D / t_{a2} = 304.7 \)
Factor \( A = 0.00028 \)
Factor \( B = 2.985 \text{ kgf/mm}^2 \)
Allowable external pressure, \([\text{Pa}]\)
\[
= 4 \times \frac{B}{(3 \times \text{OD} / \text{ta}_2)}
\]
\[
= 4 \times \frac{2.985}{(3 \times 304.7)}
\]
\[
= 0.01306 \text{ kgf/mm}^2\ g
\]

Shell thickness for internal pressure as per UG-37 & UG-27, \([\text{tr}_1 = \text{tb}_1]\)
\[
= \pi x R / (Sv x E - 0.6 x \pi)
\]
\[
= 0.15 \times 628 / (14.06 x 1.0 - 0.6 x 0.15)
\]
\[
= 6.742 \text{ mm}
\]

Shell thickness considering internal pressure equal to external pressure as per UG-27, \([\text{tb}_2]\)
\[
= Pe x R / (Sv x E - 0.6 x Pe)
\]
\[
= 0.01055 \times 628 / (14.06 x 1.0 - 0.6 x 0.01055)
\]
\[
= 0.471 \text{ mm}
\]

Nozzle minimum thickness required as per Table UG-45, \([\text{tb}_3]\)
\[
= 6.223 \text{ mm}
\]

Minimum thickness of vessel wall required as per UG-16(b), \([\text{t}_\text{min}]\)
\[
= 1.6 \text{ mm}
\]

Neck thickness as per UG-45, \([\text{t}_\text{UG}_45]\)

- **Thickness, \([\text{ta}]\)**
  \[
  = \text{MAX} [\text{ta}_1 , \text{ta}_2 , \text{t}_\text{min}]
  \]
  \[
  = \text{MAX} [1.045 \text{, } 0.552 \text{, } 1.6]
  \]
  \[
  = 1.6 \text{ mm}
  \]

- **Thickness, \([\text{tb}]\)**
  \[
  = \text{MIN} [\text{tb}_3 \times \text{MAX} (\text{tb}_1 \text{, } \text{tb}_2 \text{, } \text{t}_\text{min})]
  \]
  \[
  = \text{MIN} [6.223 \times \text{MAX} (6.742 \text{, } 6.223 \text{, } 1.6)]
  \]
  \[
  = 6.223 \text{ mm}
  \]

- **Thickness, \([\text{t}_\text{UG}_45]\)**
  \[
  = \text{MAX} [\text{ta} \text{, } \text{tb}] \text{......... for Process Nozzle}
  \]
  \[
  = \text{ta} \text{ .............. for Access Opening}
  \]
  \[
  = 6.223 \text{ mm} \text{ .............. Process Opening}
  \]

Since available neck thickness, \(tc \geq t_{\text{UG}_45}\), selected neck thickness is adequate.
**DESIGN CONDITIONS**

Design pressure (internal) \( P_i \) 0.15 kgf/mm² g
Design pressure (external) \( P_e \) 0.01055 kgf/mm² g
Design temperature \( T \) 150 °C

**NOZZLE DATA**

M.O.C. SA-106 GR. B Smls. Pipe [UNS:K03006]
Allowable stress @ design temperature \( S_n \) 12.02 kgf/mm²
Outside diameter \( OD \) 168.3 mm
Inside diameter \( ID \) 152.3 mm
Maximum chord length \( D \) 152.3 mm
Neck thickness (provided) \( t_{np} \) 10.97 mm
Internal allowance, corrosion + polishing \( CAI \) 3 mm
External allowance, corrosion + polishing \( CAE \) 0
Neck thickness (\( t_{np} - CAI - CAE \)) \( t_n \) 7.973 mm
Max. under tolerance on thickness \( Alw \) 1.372 mm
Available neck thickness (\( t_n - Alw \)) \( tc \) 6.601 mm
Nozzle projection outward (from vessel outer face) \( Lo \) 150 mm
Total length of nozzle (\( Lo + tvp + Addn for curvature \)) \( L \) 156 mm
Connection type Pipe Nozzle
Application type Process Opening
Reinforcement calculation method Isolated Opening
Design as large opening False

**SHELL DATA (Main Shell)**

M.O.C. SA-516 GR. 70 Plt. [UNS:K02700]
Allowable stress @ design temperature \( S_v \) 14.06 kgf/mm²
Inside radius \( R \) 628 mm
Thickness \( t \) 9 mm
Min. thickness for external pressure \( tr2 \) 4.506 mm

**WELD DATA**

Nozzle outside weld \( W_1 \) 10.86 mm

**CALCULATION OF NOZZLE NECK THICKNESS AS PER UG-45**

Neck thickness for internal pressure, \([t_{a_1}]\)

Formula in Appendix 1-1, \([t_{a_1}]\)

\[
= \left( 0.5 \times P_i \times OD \right) / \left( S_n \times E + 0.4 \times P_i \right) \\
= \left( 0.5 \times 0.15 \times 168.3 \right) / \left( 12.02 \times 1.0 + 0.4 \times 0.15 \right) \\
= 1.045 \text{ mm}
\]

Neck thickness for external pressure, \([t_{a_2}]\)

Neck thickness for external pressure as per UG-28

Assumed neck thickness, \([t_{a_2}] = 0.552 \text{ mm}\)

L / OD = 0.891
OD / \( t_{a_2} = 304.7 \)
Factor A = 0.00028
Factor B = 2.985 kgf/mm²
Allowable external pressure, \([\text{Pa}]\) 
\[= 4 \times \frac{B}{(3 \times \text{OD} / \text{ta}_2)}\]  
\[= 4 \times \frac{2.985}{(3 \times 304.7)}\]  
\[= 0.01306 \text{ kgf/mm}^2\]  

Shell thickness for internal pressure as per UG-37 & UG-27, \([\text{tr}_1 = \text{tb}_1]\) 
\[= \frac{\pi \times R}{(S_v \times E - 0.6 \times \pi)}\]  
\[= \frac{0.15 \times 628}{(14.06 \times 1.0 - 0.6 \times 0.15)}\]  
\[= 6.742 \text{ mm}\]  

Shell thickness considering internal pressure equal to external pressure as per UG-27, \([\text{tb}_2]\) 
\[= \frac{\pi \times R}{(S_v \times E - 0.6 \times \pi \times \text{Pe})}\]  
\[= \frac{0.01055 \times 628}{(14.06 \times 1.0 - 0.6 \times 0.01055)}\]  
\[= 0.471 \text{ mm}\]  

Nozzle minimum thickness required as per Table UG-45, \([\text{tb}_3]\) 
\[= 6.223 \text{ mm}\]  

Minimum thickness of vessel wall required as per UG-16(b), \([\text{t}_{\text{min}}]\) 
\[= 1.6 \text{ mm}\]  

Neck thk as per UG-45, \([\text{t}_{\text{UG-45}}]\) 
Thickness, \([\text{ta}]\) 
\[= \max \{\text{ta}_1, \text{ta}_2, \text{t}_{\text{min}}\}\]  
\[= \max \{1.045, 0.552, 1.6\}\]  
\[= 1.6 \text{ mm}\]  

Thickness, \([\text{tb}]\) 
\[= \min \{\text{tb}_3, \max \{\text{tb}_1, \text{tb}_2, \text{t}_{\text{min}}\}\}\]  
\[= \min \{6.223, \max \{6.742, 6.223, 1.6\}\}\]  
\[= 6.223 \text{ mm}\]  

Thickness, \([\text{t}_{\text{UG-45}}]\) 
\[= \max \{\text{ta}, \text{tb}\}\]  
\[= \text{ta}\]  
\[\text{for Process Nozzle}\]  
\[\text{ta}\]  
\[\text{for Access Opening}\]  
\[= 6.223 \text{ mm}\]  

Since available neck thickness, \(t_{c} >= t_{\text{UG-45}}\), selected neck thickness is adequate.
**DESIGN CONDITIONS**

Design pressure (internal) \( \Pi \) 0.15 kgf/mm\(^2\) g

Design pressure (external) \( \Pi_e \) 0.01055 kgf/mm\(^2\) g

Design temperature \( T \) 150 °C

**NOZZLE DATA**

M.O.C. SA-106 GR. B Smls. Pipe [UNS:K03006]

Allowable stress @ design temperature \( S_n \) 12.02 kgf/mm\(^2\)

Outside diameter \( OD \) 168.3 mm

Inside diameter \( ID \) 137.7 mm

Maximum chord length \( D \) 137.7 mm

Neck thickness (provided) \( \text{tnp} \) 18.26 mm

Internal allowance, corrosion + polishing \( CAI \) 3 mm

External allowance, corrosion + polishing \( CAE \) 0 mm

Neck thickness (\( \text{tnp} - CAI - CAE \)) \( t_n \) 15.26 mm

Max. under tolerance on thickness \( Alw \) 2.283 mm

Available neck thickness (\( \text{tnp} - Alw \)) \( tc \) 12.98 mm

Nozzle projection outward (from vessel outer face) \( Lo \) 150 mm

Nozzle projection inward (from vessel inner face) \( Li \) 0 mm

Total length of nozzle (\( Lo + Li + tvp + Addn \) for curvature) \( L \) 151 mm

Connection type Pipe Nozzle

Application type Process Opening

Reinforcement calculation method Isolated Opening

Design as large opening False

**HEAD DATA (Dished End (Rear))**

Allowable stress @ design temperature \( S_v \) 14.06 kgf/mm\(^2\)

Inside diameter of head @ head skirt \( D_{sf} \) 1256 mm

\( D / 2 \) for Ellipsoidal head 2

Factor from Table UG-37 \( K_1 \) 0.9

Inside diameter of equivalent sphere, \( K_1 \times D_{sk} \times 2 \) \( ID_{1} \) 2260.8 mm

Thickness \( t \) 7.8 mm

Min. thickness for external pressure \( tr_{2} \) 3.211 mm

**WELD DATA**

Nozzle outside weld \( W_1 \) 11.88 mm

**CALCULATION OF NOZZLE NECK THICKNESS AS PER UG-45**

Neck thickness for internal pressure, \([ta_1]\)

Formula in Appendix 1-1, \([ta_1]\)

\[
= \left( 0.5 \times \Pi \times OD \right) / \left( S_n \times E + 0.4 \times Pi \right)
\]

\[
= \left( 0.5 \times 0.15 \times 168.3 \right) / \left( 12.02 \times 1.0 + 0.4 \times 0.15 \right)
\]

\[
= 1.045 \text{ mm}
\]

Neck thickness for external pressure, \([ta_2]\)

Neck thickness for external pressure as per UG-28
Assumed neck thickness, \( [ta_2] = 0.538 \text{ mm} \)
L / OD = 0.891
OD / ta_2 = 312.9
Factor A = 0.00027
Factor B = 2.872 kgf/mm²
Allowable external pressure, \([Pa]\) = 4 x B / ( 3 x OD / ta_2 )
= 4 x 2.872 / ( 3 x 312.9 )
= 0.01224 kgf/mm²

Head thickness for internal pressure as per UG-37 & UG-27(d), \([tr1 = tb_1]\)
= 0.5 x Pi x ID1 / ( 2 x Sv x E - 0.2 x Pi )
= 0.5 x 0.15 x 2260.8 / ( 2 x 14.06 x 1.0 - 0.2 x 0.15 )
= 6.036 mm

Head thickness considering internal pressure equal to external pressure per UG-27(d), \([tb_2]\)
= 0.5 x Pe x ID1 / ( 2 x Sv x E - 0.2 x Pe )
= 0.5 x 0.01055 x 2260.8 / ( 2 x 14.06 x 1.0 - 0.2 x 0.01055 )
= 0.424 mm

Nozzle minimum thickness required as per Table UG-45, \([tb_3]\)
= 6.223 mm

Minimum thickness of vessel wall required as per UG-16(b), \([t_{min}]\)
= 1.6 mm

Neck thk as per UG-45, \([tUG_45]\)
Thickness, \([ta]\)
= MAX [ ta_1, ta_2, t_{min} ]
= MAX [ 1.045, 0.538, 1.6 ]
= 1.6 mm

Thickness, \([tb]\)
= MIN [ tb_3, MAX ( tb_1, tb_2, t_{min} ) ]
= MIN [ 6.223, MAX ( 6.036, 0.424, 1.6 ) ]
= 6.036 mm

Thickness, \([tUG_45]\)
= MAX [ ta, tb ] ............... for Process Nozzle
= ta ........................................ for Access Opening
= 6.036 mm ............................... Process Opening

Since available neck thickness, tc >= tUG_45, selected neck thickness is adequate.
1. LIFTING LUG DATA:

Material: IS-2062 GR. A Plt.
Length of lug (LL): 70 mm
Width of lug (A): 120 mm
Thickness of lug plate (TL): 14 mm
Straight length (B1): 10 mm
Radius at tip (R3): 35 mm
Pin Hole diameter (D1): 40 mm
Lug to vessel weld size (W1): 6.216 mm
Min yield stress (Sy): 24.61 kgf/mm²
Allowable tensile stress (2/3 x Sy): (St) 16.4 kgf/mm²
Allowable bending stress (1.5 x St): (Sb) 22.15 kgf/mm²
Allowable shear stress (0.6 x St): (Ss) 9.843 kgf/mm²

2. DESIGN LOADS:

Total design lift weight (Wt): 2660.6 kgf
Number of lifting lugs (N): 2
Jirk load factor (j): 1.5

3. CALCULATION OF REFERENCE DIMENSIONS:

Dimension [L1] = LL - B1 - R3
= 70 - 10 - 35
= 25 mm
Dimension [L2] = L1 / SIN (θ1)
= 25 / SIN (0.395)

Dimension [LT] = LL - R3
= 70 - 35
= 35 mm

Angle [θ2] = ASIN (R3 / L2)
= ASIN (35 / 65)
= 0.569 radians

Angle [θ1] = ATAN (2 x L1 / A)
= ATAN (2 x 25 / 120)
= 0.395 radians

Dimension [L3] = R3 / SIN (θ3)
= 35 / SIN (0.963)
= 42.62 mm

4. DESIGN OF LUG PLATE:

Effective design load on each lug (P) = j x Wt / N
= 1.5 x 2660.6 / 2
= 1998.1 kgf

Required min. thickness of lug plate for shear (t2) = P / [(R3 - 0.5 x D1) x Ss]
= 1998.1 / [(35 - 0.5 x 40) x 9.843]
= 13.53 mm

Required min. thickness of lug plate for bending (t1) = Required min. thickness of lug plate for tension (t3)
5. CALCULATION OF STRESSES IN LUG PLATE WELDS:

Bending stress in weld \([ f_1 ]\)

\[
= 6 \times P \times LT / \left( A_x^2 \times S_b \right)
\]

\[
= 6 \times 1998.1 \times 35 / ( 120^2 \times 22.15 )
\]

\[
= 1.316 \text{ mm}
\]

Max. shear stress in weld \([ f_2 ]\)

\[
= P / [ ( 2 \times L3 - D1 ) \times ss ]
\]

\[
= 1998.1 / [ ( 2 \times 42.62 - 40 ) \times 16.4 ]
\]

\[
= 2.692 \text{ mm}
\]

Min. Size of lug plate weld \([ w_1 ]\)

\[
= \text{MAX} \left( f_1, 2 \times f_2 \right) / ( 0.707 \times S_s )
\]

\[
= \text{MAX} \left( 42.82, 2 \times 8.326 \right) / ( 0.707 \times 9.843 )
\]

\[
= 6.153 \text{ mm}
\]
### FOUNDATION LOAD DATA

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<th>Weight (kgf)</th>
<th>Shear (kgf)</th>
<th>Moment (kgf-m)</th>
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