Design Conditions

- Code: ASME VIII-1
- Year: 2007
- Addenda: 2009
- MAWP: 300 psi
- MEAWP: 0 psi
- Max. Temp.: 250 °F
- MDMT: -20 °F
- Min. Thk. (UG-16b): 0.0625 in
- Corrosion Allowance: 0 in
- Hydrotest: 390 psi
- Impact Testing: None
- Impact Exemption: UHA-51(d)
- Radiography: None

UG-22 Loadings Considered

- Internal Press.: Yes
- External Press.: No
- Vessel Weight: No
- Weight of Attachments: No
- Attachment of Internals: No
- Attachment of Externals: No
- Cyclic or Dynamic Reactions: No
- Wind Loading: No
- Seismic Loading: No
- Fluid Impact Shock Reactions: No
- Temperature Gradients: No
- Differential Thermal Expansion: No
- Abnormal Pressures: No
- Hydrotest Loads: No

Conclusion: The Hydraulic Manifold Block PVEdwg-4431-6.1 is acceptable for ASME VIII-1 use at 300 psi and 250°F.
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## Revision(s)

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<td>0</td>
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<td>Update Report Captions</td>
<td>13-Dec-11</td>
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Goal:
The Hydraulic Manifold Block PVEdwg-4433-6 will be used under ASME VIII-1 service. This block cannot be calculated to ASME VIII-1 code rules due to the complexity of its geometry. The rules of VIII-2 are used with VIII-1 allowed stresses to determine the acceptability.

Summary Conclusions:

Analysis Software
SolidWorks Simulation 2010 SP4.0

Analysis Type
A static linear elastic study is performed using small displacement theory.

Materials
Material strength properties used in this report are obtained from ASME IID, Table 1A, and are suitable for VIII-1 components. The rules of ASME VIII-2 are used to set the stress limits.

Model and Mesh
The model used in this report represents the full hydraulic manifold block. Pipes are added in to transfer axial loads to the openings and simulate the effect of a closed loop piping system. A 0.125" second order tetrahedral mesh has been applied globally to the entire model. This results in an error of under 5% and is therefore valid. The reported reaction forces match those computed theoretically. The model is in balance and can be used for displacement analysis.

Restraints & Loads
One pipe is fixed; this prevents translation of the model in all three primary planes. The interior cavities and attached pipes are pressurized to 300 psi. When calculated theoretically, the actual reaction forces prove acceptable. The model is in balance and can be used for displacement and stress analysis.

Results
The model has a maximum displacement of 0.0017". The displaced shape of the model is as expected and the magnitude of the displacement is acceptable. The model has a maximum peak stress of 3,043 psi. All stresses in the model are below the primary general membrane stress limit of 20,000 psi and is acceptable for ASME VIII-1 use.

Analysis Conclusion:
The Hydraulic Manifold Block PVEdwg-4431-6.1 is acceptable for ASME VIII-1 use at 300 psi and 250°F.
### Material Stress Limits

**Material Input Chart:**

<table>
<thead>
<tr>
<th>Temperature [ºF]</th>
<th>Material 1</th>
<th>Material 2</th>
<th>Material 3</th>
<th>Material 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Material</strong></td>
<td>SA-479 316</td>
<td>SA-312 TP316</td>
<td>SA-403 316</td>
<td>SA-316</td>
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<tr>
<td><strong>Application</strong></td>
<td>Manifold Block</td>
<td>Attached Pipes</td>
<td>Pipe Caps</td>
<td>Pipe Caps</td>
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<tr>
<td><strong>Sm [psi]</strong></td>
<td>20,000</td>
<td>20,000</td>
<td>20,000</td>
<td>20,000</td>
</tr>
<tr>
<td><strong>Sy [psi]</strong></td>
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<td>24,600</td>
<td>24,600</td>
<td>24,600</td>
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<td><strong>Sya [psi]</strong></td>
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<tr>
<td><strong>Sta [psi]</strong></td>
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<td>75,000</td>
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<tr>
<td><strong>E1</strong></td>
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<td>1.0</td>
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<tr>
<td><strong>E2</strong></td>
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<td>1.0</td>
<td>1.0</td>
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<tr>
<td><strong>E [psi]</strong></td>
<td>27,250,000</td>
<td>27,250,000</td>
<td>27,250,000</td>
<td>27,250,000</td>
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<tr>
<td><strong>v</strong></td>
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<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
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<tr>
<td><strong>Coef</strong></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Pm [psi]</strong></td>
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<tr>
<td><strong>Pl+Pb+Q [psi]</strong></td>
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<td>60,000</td>
<td>60,000</td>
<td>60,000</td>
</tr>
</tbody>
</table>

**Prop. Sources:** ASME II-D 2007 Edition, 2009 Addenda

**Comments:**

1. Sy material property is not required, more conservative Pl+Pb+Q limits might be computed without it.
2. The thermal expansion coefficient is only required for studies including thermal stresses.
3. Refer to VIII-2 5.15 Figure 5.1 and following for the Pm, PI, Q and F stress limits.
4. Refer to VIII-2 5.14 Table 5.6 for the correct application of the calculated stress limits.
5. Use IID tables 5A and 5B for Sm for VIII-2 studies.
6. Use IID tables 1A and 1B for Sm values (S) for VIII-1 studies.
7. Use B31.1 Table A for Sm values for B31.1 studies.
8. Use B31.3 Table A for Sm values for B31.3 studies.
9. 2*Sy Pl+Pb+Q not valid went in creep range.
Assembled Model
Assembled view of (Fig-1) with pipes attached to the block. Refer to PVEdwg-4431-6.1 for dimensional details.

Exploded Model
Exploded view of the hydraulic manifold block. A complete solid model matching the hydraulic manifold block geometry is used in the analysis. A fixed pipe is modeled in as a method of restraint. Capped pipes are attached to each of the openings to transmit axial loads generated in a closed loop system. Stresses in the attached pipes are not analyzed and are outside the scope of this report.
Mesh Plot
View of the mesh applied to the model. A 0.125" size with second order tetrahedral solid elements is been applied.

Mesh Rotated Close-up
A close-up of the mesh rotated to show the opposite side of the model. All components are treated as bonded connections and are meshed as a single body.
Mesh Error Plot
A view of the error plot with the mesh overlaid.
No general areas observe error in excess of 5%. The error plot justifies the mesh selected. The model may be used for further analysis.

Mesh Error Close-up
A close-up of the manifold line in area.
Note that error in excess of 5% is limited to locations of discontinuity.
Fixed Restraint
A fixed restraint is applied to the end face of the "line in" pipe. Applying the restraint to the pipe end allows the Hydraulic Manifold Block to deform as it would in reality.

Fixed Restraint Close-up
A close-up of (Fig-7). The fixed restraint prevents translation of the model in the X, Y and Z directions. The model is fully restrained from rigid body motion in all three directions.
Internal Pressure
300 psi is applied to all internal faces of the manifold and attached pipes.

Internal Pressure (Sectioned View)
A sectioned view of (Fig-9).
300 \text{ P [psi]} - \text{Pressure}

\textbf{X Axis:} reaction forces on the YZ plane caused by loads in the X direction

\[ 3.356 \text{ XArea [in}^2\text{]} - \text{Pressurized area on YZ plane} \]
\[ 0.0 \text{ XForce [lbs]} - \text{Added force in the X direction} \]
\[ 1006.700 \text{ XReaction [lbs]} - \text{Reaction force in X direction reported by FEA program} \]

\[ T_{\text{ReactionX [lbs]}} = \text{XArea} \times P + \text{XForce} \]
\[ = 3.356 \times 300 + 0 = 1,007 \]

\[ \text{Theoretical X reaction force} \]

\textbf{Y Axis:} reaction forces on the XZ plane caused by loads in the Y direction

\[ 0.000 \text{ YArea [in}^2\text{]} - \text{Pressurized area on XZ plane} \]
\[ 0.0 \text{ YForce [lbs]} - \text{Added force in the Y direction} \]
\[ 0.093 \text{ YReaction [lbs]} - \text{Reaction force in Y direction reported by FEA program} \]

\[ T_{\text{ReactionY [lbs]}} = \text{YArea} \times P + \text{YForce} \]
\[ = 0 \times 300 + 0 = 0 \]

\[ \text{Theoretical Y reaction force} \]

\textbf{Z Axis:} reaction forces on the XY plane caused by loads in the Z direction

\[ 0.000 \text{ ZArea [in}^2\text{]} - \text{Pressurized area on XY plane} \]
\[ 0.0 \text{ ZForce [lbs]} - \text{Added force in the Z direction} \]
\[ -0.210 \text{ ZReaction [lbs]} - \text{Reaction force in Z direction reported by FEA program} \]

\[ T_{\text{ReactionZ [lbs]}} = \text{ZArea} \times P + \text{ZForce} \]
\[ = 0 \times 300 + 0 = 0 \]

\[ \text{Theoretical Z reaction force} \]

\textbf{Resultant of reaction forces in X, Y and Z:}

\[ T_{\text{Resultant [lbs]}} = \sqrt{T_{\text{ReactionX}}^2 + T_{\text{ReactionY}}^2 + T_{\text{ReactionZ}}^2} \]
\[ = \sqrt{1007^2 + 0^2 + 0^2} = 1,007 \]

\[ \text{Theoretical resultant} \]

\[ \text{Resultant [lbs]} = \sqrt{X_{\text{Reaction}}^2 + Y_{\text{Reaction}}^2 + Z_{\text{Reaction}}^2} \]
\[ = \sqrt{1006.7^2 + 0.093^2 + (-0.21)^2} = 1,007 \]

\[ \text{Actual resultant} \]

\[ \text{Error [%]} = 100 \times \frac{T_{\text{Resultant}} - \text{Resultant}}{\text{Resultant}} \]
\[ = 100 \times \frac{1007 - 1007}{1007} = 0.0 \]

\[ \text{Error should be less than 2%} \]

\[ \text{CheckError} = \text{ABS}(0) < 2 \]
\[ = \text{Acceptable} \]
The manifold block expands radially outward and elongates axially away from the fixed restraint. The direction of displacement is as expected. The magnitude of displacement is acceptable.

**Displacement Plot**
A view of the displacement plot with superimposed original geometry, results are magnified 5000 times. The maximum displacement in the model is 0.00017".

**Displacement Plot (Rotated)**
The manifold block expands radially outward and elongates axially away from the fixed restraint. The direction of displacement is as expected. The magnitude of displacement is acceptable.
The maximum peak stress in the model is 3,034 psi and occurs on the inside corner of the middle port as shown.

von Mises Stress Plot
A view of the von Mises stress plot. All areas in the model are below the primary general membrane limit of 20,000 psi for SA-479 316 and are acceptable.

von Mises Stress Plot (Rotated)
The maximum peak stress in the model is 3,034 psi and occurs on the inside corner of the middle port as shown.
von Mises Stress Plot (With Mesh)
A view of the von Mises stress plot with the mesh overlaid.

von Mises Stress Plot (Close-up With Mesh)
A close-up of (Fig-16). This shows the von Mises stress with the mesh overlaid at the maximum peak stress location. The stresses in this region are acceptable and no further analysis is necessary.