ASME B31.3 Process Piping

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Piping Development Process
1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test
4. Pressure Design of Metals

- Design Pressure & Temperature
- Quality Factors
- Weld Joint Strength Factor
- Pressure Design of Components
  - Four Methods
  - Straight Pipe
  - Fittings
  - Fabricated Branch Connections
  - Flanges and Blanks
  - Other Components
- Piping Material Specifications

The Material in This Section is Addressed by B31.3 in:

- Chapter II - Design
- Appendix V - Allowable Variations in Elevated Temperature Service
Design Pressure & Temperature

**design pressure:** the pressure at the most severe condition of internal or external pressure and temperature expected during service (301.2)

- The most severe condition is that which results in the greatest required component thickness and the highest component rating.
- The inside pipe in jacketed piping shall be designed for the most severe combination of conditions expected during service.
- Short-term variations may be considered separately. (302.2.4)

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Design Pressure & Temperature

**design pressure:**

- Provisions shall be made to safely contain or relieve any pressure to which the piping may be subjected.
- Sources of pressure to be considered include
  - Ambient influences
  - Pressure oscillations
  - Improper operation
  - Decomposition of fluids
  - Static head
  - Failure of control devices
Design Pressure & Temperature

**design temperature**: the temperature at which, under the coincident pressure, the greatest thickness or highest component rating is required (301.3). For insulated piping:
- May be taken as fluid temperature
- May be based on calculated average wall temperature, or
- May be based on measurements or tests
- Consider heat tracing and other sources of heat

Design Pressure & Temperature

**design temperature**: Uninsulated piping
- fluid temperatures below 150°F (65°C): Shall be taken as fluid temperature, unless solar radiation or other effects make the temperature higher
- fluid temperatures 150°F (65°C) and above:
  - May be taken as fluid temperature
  - May be based on calculated average wall temperature, or
  - Presumptive reductions described in para. 301.3.3 may be used
Design Pressure & Temperature

**design minimum temperature**: the lowest component temperature expected in service

- May be taken as fluid temperature
- May be based on calculated average wall temperature, or
- May be based on measurements or tests

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Design Pressure & Temperature

**allowance for pressure and temperature variation**: The Code allows the design pressure to be set below the most severe coincident pressure and temperature under certain conditions:

- No cast iron or other non-ductile components
- Nominal pressure stresses don’t exceed yield strength at temperature
- Longitudinal stresses are within the allowable
Design Pressure & Temperature

allowance for pressure and temperature variation: more conditions:

- The number of excursions beyond design does not exceed 1000
- The increased pressure does not exceed the test pressure
- With the owners permission can exceed allowable by 33% for no more than 10 hr/event and no more than 100 hr/year
- With the owners permission can exceed allowable by 20% for no more than 50 hr/event and no more than 500 hr/year

Design Pressure & Temperature

allowance for pressure and temperature variation: more conditions:

- Without the owners permission, can exceed allowable by 20% for no more than 50 hr/event and no more than 500 hr/year for self-limiting events such as pressure relieving
- Effects of the variations must be evaluated, e.g. by rules described in Appendix V
- Differential pressure on valve closures should not exceed maximum established by valve manufacturer
Design Pressure & Temperature

Workshop Problem 1: Styrene monomer at ambient temperature.

Pressure switch shuts off positive displacement pump at 630 psi (43 bar)

Determine design pressure, design temperature and relief valve set pressure.

See Page 24 of the supplement.

Design Pressure & Temperature

Workshop Problem 2: If the line in problem 1 is steam cleaned with 50 psi (3.5 bar) steam superheated to 735°F (390°C)

- What should the design pressure be?
- What should the design temperature be?
- What should the relief valve setting be?
Quality Factors

Casting quality factor \( E_c \) (302.3.3)
- Used for cast components not having ratings
- \( E_c = 1.00 \) for gray and malleable iron
- \( E_c \) varies from 0.80 to 1.00 depending on the level of examination
- Table A-1A lists \( E_c \) for specific products

Weld joint quality factor \( E_j \) (302.3.4)
- Table 322.3.4 lists factors used for pipe
- Some factors may be increased when additional examination is performed
- Table A-1B lists \( E_j \) for specific products

Weld Joint Quality Factor \( E_j \)

<table>
<thead>
<tr>
<th>Type of Weld</th>
<th>Factor ( (\text{Table 302.2.4}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>None (seamless)</td>
<td>1.00</td>
</tr>
<tr>
<td>Electric Resistance Weld</td>
<td>0.85</td>
</tr>
<tr>
<td>Furnace Butt Weld</td>
<td>0.60</td>
</tr>
<tr>
<td>Single Fusion Weld</td>
<td>0.80 to 1.00*</td>
</tr>
<tr>
<td>Double Fusion Weld</td>
<td>0.85 to 1.00*</td>
</tr>
<tr>
<td>API 5L SAW, GMAW</td>
<td>0.95</td>
</tr>
</tbody>
</table>

*Depending on level of examination
Weld Joint Strength Factor

Weld joint strength reduction factor $W_{(302.3.5)}$

- Used to account for the long-term (creep) strength of welds that may be lower than the base material
- In the absence of more applicable data, $W$ shall be:
  - 1.00 for all materials 950°F (510°C) and below
  - 0.50 for all materials at 1500°F (815°C)
  - Linearly interpolated for intermediate temperatures
- $W$ values are based on testing of selected low alloys, stainless steels, and nickel alloys

Pressure Design of Components

- Four Methods for Pressure Design
- Straight Pipe
- Fittings
  - Pipe Bends
  - Miter Bends
  - Reducers
- Fabricated Branch Connections
- Flanges and Blanks
- Other Components
Four Methods for Pressure Design

- Calculations in accordance with Code formula
- Ratings given in a component standard
- Ratings same as straight seamless pipe
- Qualification by calculation plus experience, analysis or test

Straight Pipe

Total thickness required is the sum of:

1. Pressure design thickness
2. Manufacturing tolerance (usually 12.5% of the nominal wall thickness)
3. Corrosion (or erosion) allowance
4. Mechanical allowances, e.g. threading
**Straight Pipe**

**Threading allowance — nominal thread depth described in ASME B1.20.1**

<table>
<thead>
<tr>
<th>NPS</th>
<th>Depth (in.)</th>
<th>Depth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>½ &amp; ¾</td>
<td>0.057</td>
<td>1.45</td>
</tr>
<tr>
<td>1 thru 2</td>
<td>0.069</td>
<td>1.77</td>
</tr>
</tbody>
</table>

\[
t = \frac{PD}{2(SEW + PY)}
\]

Where:
- \( t \) = pressure design thickness
- \( P \) = design pressure
- \( D \) = outside diameter of pipe
- \( S \) = stress value for material from Appendix A
- \( E \) = quality factor
- \( W \) = weld joint strength reduction factor
- \( Y \) = coefficient (function of material and temperature), usually 0.4
## Coefficient Y

<table>
<thead>
<tr>
<th>Material Type</th>
<th>≤900°F ≤482°C</th>
<th>950°F 510°C</th>
<th>1000°F 538°C</th>
<th>1050°F 566°C</th>
<th>1100°F 593°C</th>
<th>≥1150°F ≥621°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferritic Steels</td>
<td>0.4</td>
<td>0.5</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Austenitic Steels</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.5</td>
<td>0.7</td>
</tr>
<tr>
<td>Other Ductile Metals</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Cast Iron</td>
<td>0.0</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

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## Straight Pipe Wall Thickness

**Workshop:** What is the required nominal pipe wall thickness for the following case:

- Styrene monomer service
- ASTM A53 Gr B ERW carbon steel pipe
- Design pressure and temperature from Problems 1 and 2, page 24 of the supplement.
- $S = 20,000$ psi (138 MPa) - verify
- Corrosion allowance = 1/8" (3.2 mm)
- Socket welding thru NPS 1½
- Buttwelding NPS 2 and larger

See Supplement starting on page 31.
## Pipe Wall Thicknesses

<table>
<thead>
<tr>
<th>Carbon Steel</th>
<th>Also for Carbon Steel</th>
<th>Stainless Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>STD WT</td>
<td>Sch 10</td>
<td>Sch 5S</td>
</tr>
<tr>
<td>XS WT</td>
<td>Sch 20</td>
<td>Sch 10S</td>
</tr>
<tr>
<td>XXS WT</td>
<td>Sch 30</td>
<td>Sch 40S</td>
</tr>
<tr>
<td></td>
<td>Sch 40</td>
<td>Sch 80S</td>
</tr>
<tr>
<td></td>
<td>Sch 60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sch 80</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sch 160</td>
<td></td>
</tr>
</tbody>
</table>

### Pipe Wall Thicknesses

- STD WT and Sch 40 are the same NPS 1/8 through 10
- STD WT is 3/8” (9.52 mm) NPS 12 and larger
- XS WT and Sch 80 are the same NPS 1/8 through 8
- XS WT is 1/2” (12.70 mm) NPS 8 and larger
- Sch 40S is the same as STD WT
- Sch 80S is the same as XS WT
Fittings

- **Listed Fittings** – Can be used within their pressure-temperature ratings
- **Unlisted Fittings** – Must have pressure-temperature ratings that conform with para. 304
  - Rules for specific geometries in paras. 304.2 through 304.6
  - Rules for other geometries in para. 304.7

B16.3 – Malleable Iron Threaded Fittings
(US Customary Units)
Fittings - Listed Fitting Example

B16.3 – Malleable Iron Threaded Fittings
(Metric Units)

B16.9 – Wrought Steel Buttweld Fittings

The allowable pressure ratings for fittings designed in accordance with this standard may be calculated as for straight seamless pipe of equivalent material...in accordance with the rules established in the applicable sections of ASME B31...Pipe size, wall thickness...and material identity on the fittings are in lieu of pressure rating markings.
Design temperature and other service conditions shall be limited as provided by the applicable piping code or regulation for the material of construction of the fittings. Within these limits the maximum allowable pressure of a fitting shall be that computed for straight seamless pipe of equivalent material.

The schedule of pipe corresponding to each Class of fitting for rating purposes is shown:

<table>
<thead>
<tr>
<th>Class</th>
<th>Thd/SW</th>
<th>Sch No.</th>
<th>Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>Thd</td>
<td>80</td>
<td>XS</td>
</tr>
<tr>
<td>3000</td>
<td>Thd</td>
<td>160</td>
<td>---</td>
</tr>
<tr>
<td>6000</td>
<td>Thd</td>
<td>---</td>
<td>Xxs</td>
</tr>
<tr>
<td>3000</td>
<td>SW</td>
<td>80</td>
<td>XS</td>
</tr>
<tr>
<td>6000</td>
<td>SW</td>
<td>160</td>
<td>---</td>
</tr>
<tr>
<td>9000</td>
<td>SW</td>
<td>---</td>
<td>Xxs</td>
</tr>
</tbody>
</table>
Pipe Bends

\[ t = \frac{PD}{2 \left( \frac{SEW}{I} + PY \right)} \]

Where:

\[ I = \frac{4(R_1/D) - 1}{4(R_1/D) - 2} \]

- at the intrados

\[ I = \frac{4(R_1/D) + 1}{4(R_1/D) + 2} \]

- at the extrados

\[ I = 1.0 \]

- at the side centerline

\[ R_1 = \text{Bend radius} \]

Miter Bends

\[ P_m = \left[ \frac{SEW(T-c)}{r_2} \right] \times GF \]

Where:

\[ r_2 = \text{mean radius of pipe} \]

\[ GF = \text{factor based on the miter angle (}\alpha\text{) and bend radius} \]
Reducers

May be designed in accordance with rules in ASME B&PV Code, Section VIII, Division 1 for conical or toriconical sections.

Fabricated Branch Connections

Typical Welded Branch Connections [Fig.328.5.4]

Unreinforced

Reinforced

Lateral (angular branch)
Flanges and Blanks

- **Listed Flanges & Blanks** – Can be used within their pressure-temperature ratings
- **Unlisted Flanges & Blanks** – Must have pressure-temperature ratings that conform with
  - Rules for specific geometries in paras. 304.5
  - Rules for other geometries in para. 304.7
Flanges and Blanks

Listed Flange Example: B16.5 – Pipe Flanges and Flanged Fittings

Flanges and Blanks

Listed Blank Example:
B16.48 – Steel Line Blanks

- Ratings the same as for flanges of corresponding material
- Blank thicknesses were determined in accordance with B31.3 rules
Flanges and Blanks

Unlisted Flanges & Banks:

- Flanges may be designed in accordance with ASME B&PV Code, Section VIII, Division 1, Appendix 2 with B31.3 allowable stresses
- Blanks may be designed in accordance with para. 304.5.3

Other Components [304.7.2]

Components for which there are no specific rules require:

- Calculations consistent with the design criteria of B31.3, and
- Substantiation of the calculations by
  - Extensive successful experience
  - Experimental stress analysis
  - Proof test, or
  - Finite element stress analysis
- Documentation available for owner’s approval
- Interpolation between sizes & thicknesses allowed
Piping Material Specifications

Descriptions of components in a piping material specification should include as applicable:

- Generic description of the component
- Material specification, usually ASTM (include material grade)
- Rating or wall thickness
- Product specification, usually B16 or MSS
- Ends (buttweld, socket weld, threaded)
- Type and facing for flanges