ASME B31.3 Process Piping

Charles Becht IV, PhD, PE
Don Frikken, PE
Instructors

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)

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 150ºF (65ºC): Shall be taken as fluid temperature, unless solar radiation or other effects make the temperature higher
- fluid temperatures 150ºF (65ºC) 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

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 nor more than 500 hr/year

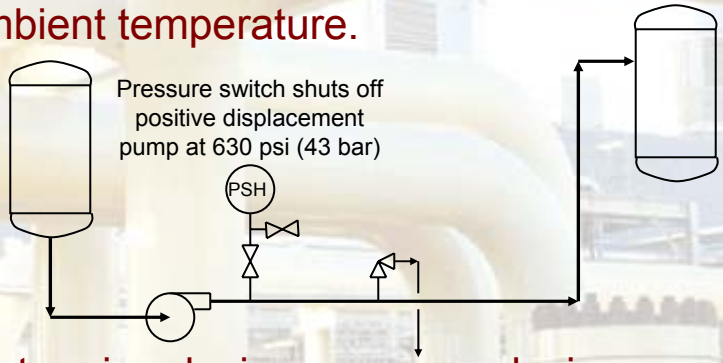
Design Pressure & Temperature

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 nor 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.



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

Type of Weld	**Factor** (Table 302.2.4)
None (seamless)	1.00
Electric Resistance Weld	0.85
Furnace Butt Weld	0.60
Single Fusion Weld	0.80 to 1.00*
Double Fusion Weld	0.85 to 1.00*
API 5L SAW, GMAW	0.95

*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 950ºF (510ºC) and below
  - 0.50 for all materials at 1500ºF (815ºC)
  - 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

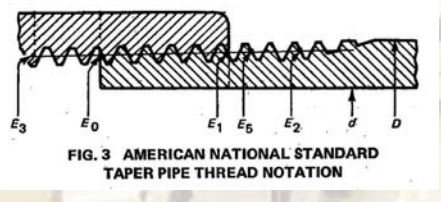


FIG. 3 AMERICAN NATIONAL STANDARD TAPER PIPE THREAD NOTATION

Straight Pipe

Threading allowance – nominal thread depth described in ASME B1.20.1

NPS	Depth (in.)	Depth (mm)
½ & ¾	0.057	1.45
1 thru 2	0.069	1.77

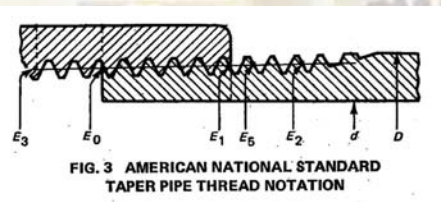


FIG. 3 AMERICAN NATIONAL STANDARD TAPER PIPE THREAD NOTATION

Straight Pipe

$$t = PD / [2 (SEW + PY)]$$

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

	≤900ºF ≤482ºC	950ºF 510ºC	1000ºF 538ºC	1050ºF 566ºC	1100ºF 593ºC	≥1150ºF ≥ 621ºC
Ferritic Steels	0.4	0.5	0.7	0.7	0.7	0.7
Austenitic Steels	0.4	0.4	0.4	0.4	0.5	0.7
Other Ductile Metals	0.4	0.4	0.4	0.4	0.4	0.4
Cast Iron	0.0	---	---	---	---	---

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

Carbon Steel	Also for Carbon Steel	Stainless Steel
STD WT	Sch 10	Sch 5S
XS WT	Sch 20	**Sch 10S**
XXS WT	Sch 30	**Sch 40S**
	Sch 40	Sch 80S
	Sch 60	
	Sch 80	
	Sch 160	

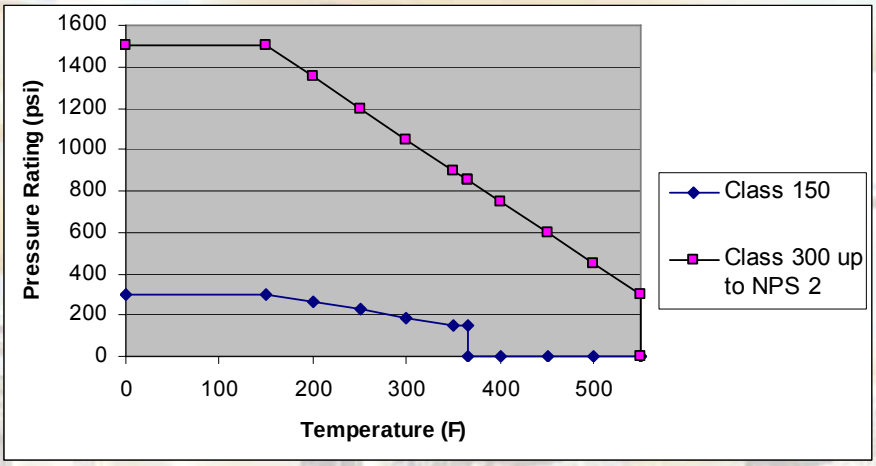
Pipe Wall Thickness

- 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

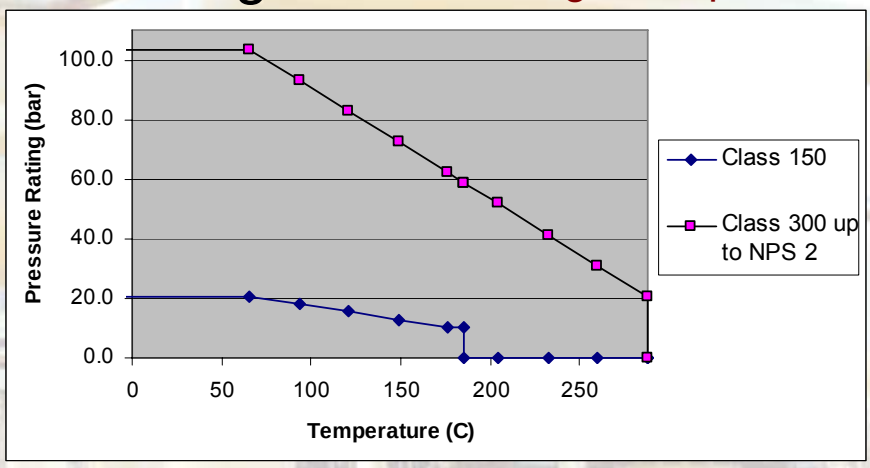
- *Listed Fittings* – Can be used within their pressure-temperature ratings
- *Unlisted Fittings* – Must have pressure-temperature ratings that conform with para. 304
  - Rules for specific geometries in paras. 304.2 through 304.6
  - Rules for other geometries in para. 304.7

Fittings - Listed Fitting Example



B16.3 – Malleable Iron Threaded Fittings
(US Customary Units)

Fittings - Listed Fitting Example



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

Fittings - Listed Fitting Example

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.

Fittings - Listed Fitting Example

B16.11 – Forged Fittings, Socket Welding & Threaded

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…

Fittings - Listed Fitting Example

B16.11 – Forged Fittings, Socket Welding & Threaded The schedule of pipe corresponding to each Class of fitting for rating purposes is shown…

Class	Thd/SW	Sch No.	Wall
2000	Thd	80	XS
3000	Thd	160	---
6000	Thd	---	XXS
3000	SW	80	XS
6000	SW	160	---
9000	SW	---	XXS

Pipe Bends

$$t = PD / [2 (SEW/I + PY)]$$

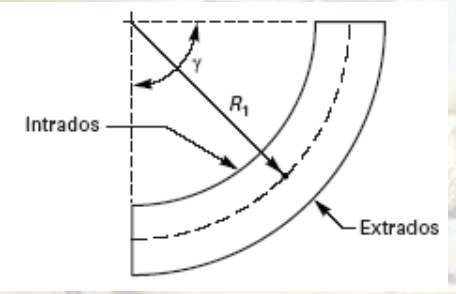
Where:

I = $[4(R_1/D) – 1] / [4(R_1/D) – 2]$ at the intrados

I = $[4(R_1/D) + 1] / [4(R_1/D) + 2]$ at the extrados

I = 1.0 at the side centerline

R_1 = Bend radius



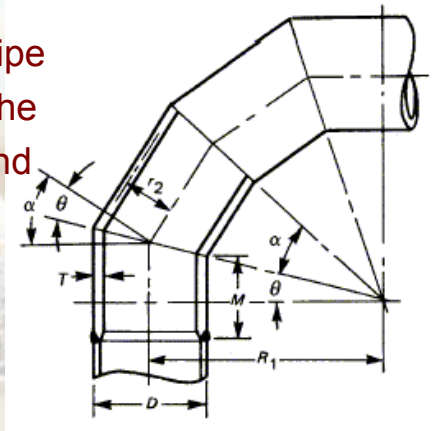
Miter Bends

$$P_m = [SEW(T-c)/r_2] * GF$$

Where:

r_2 = mean radius of pipe

GF = factor based on the miter angle (α) and bend radius

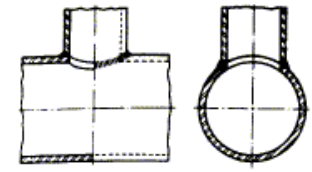


Reducers

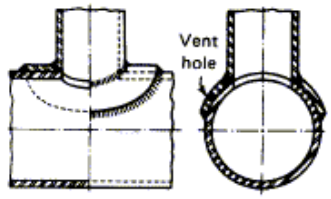
May be designed in accordance with rules in ASME B&PV Code, Section VIII, Division 1 for conical or toriconical sections.

Fabricated Branch Connections

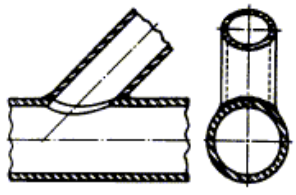
Typical Welded Branch Connections [Fig.328.5.4]



Unreinforced



Reinforced



Lateral (angular branch)

Fabricated Branch Connections

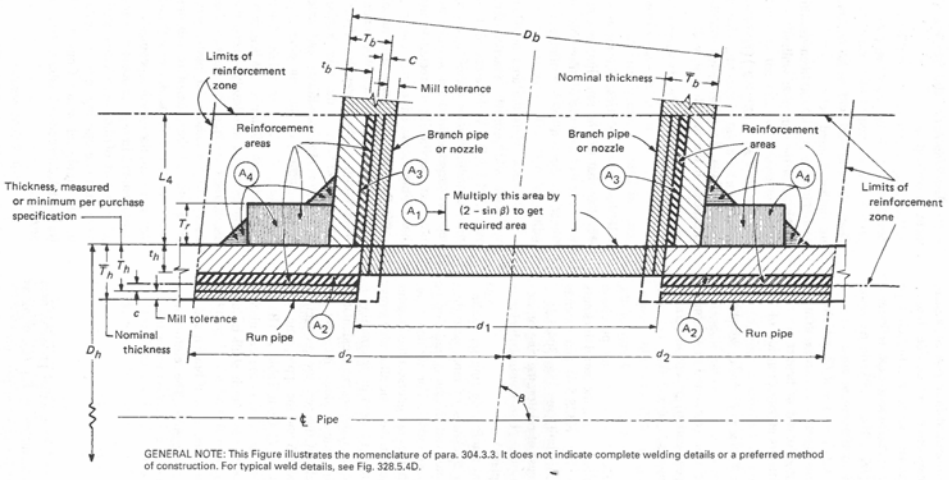


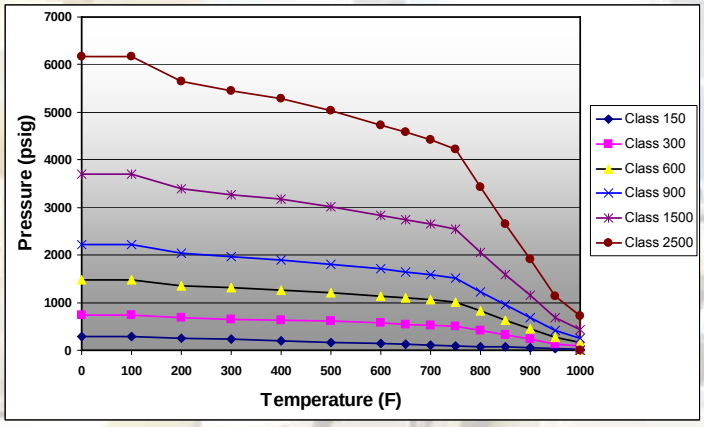
FIG. 304.3.3 BRANCH CONNECTION NOMENCLATURE

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

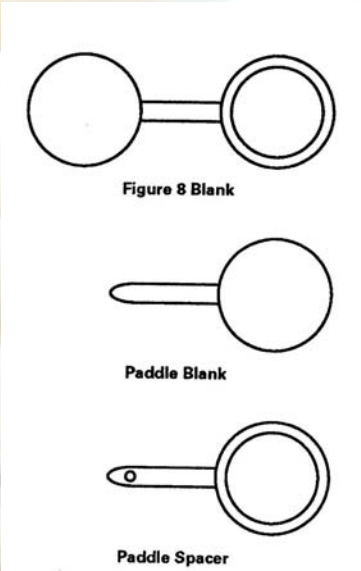
Listed Flange Example: B16.5 – Pipe Flanges and Flanged Fittings



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