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

2. Metallic Pipe & Fitting Selection

- Piping System Failure
- Bases for Selection
- Listed versus Unlisted Piping Components
- Fluid Service Requirements
- Pipe
- Fittings
- Branch Connections
- Flanges
- Gaskets
- Bolting
- Flanged Joints

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

Chapter II - Design

Chapter IV - Standards for Piping Components

Appendix G - Safeguarding

Piping System Failure

How can you recognize a failure in a piping system?

Bases for Selection

- Pressure Class
- Reliability
  - Robustness
  - Fire Resistance
  - Blow-out Resistance
  - Tendencies to leak
- Material of Construction
  - Corrosion Resistance
  - Material Toughness
- Cost

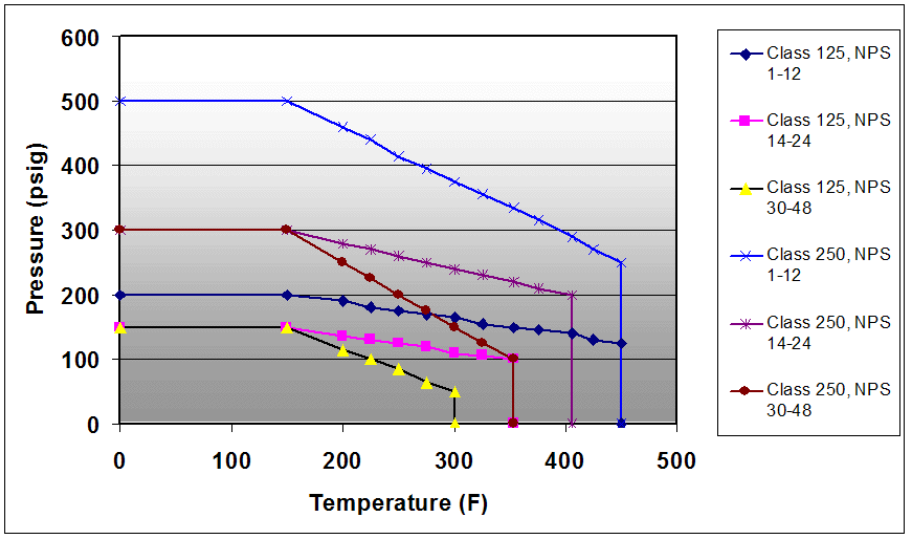
Pressure Class

Ratings for above ground metallic systems are generally governed by their joints. Frequently these are flanged joints manufactured in accordance with ASME B16.1 (iron flanges) and ASME B16.5 (other metallic flanges).

Ratings for flanges (and some other piping components) are designated by pressure class.

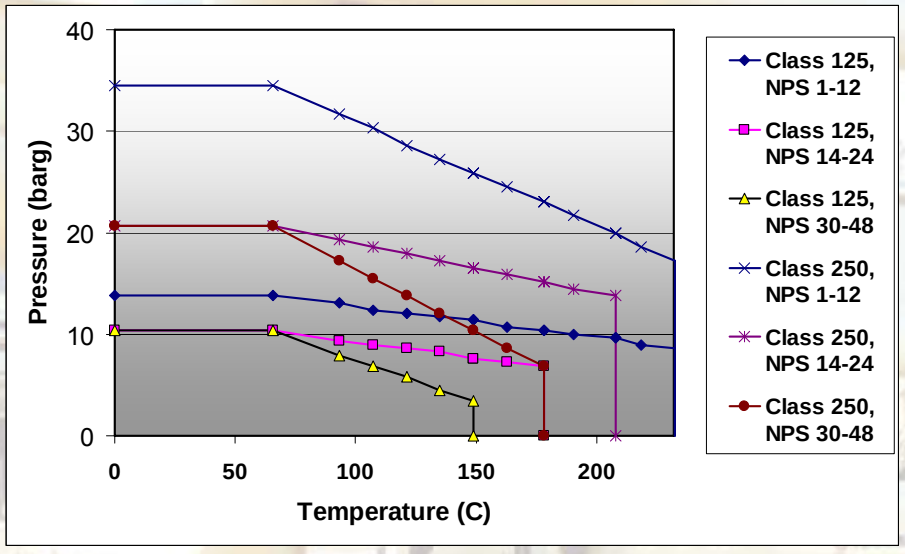
Flange P-T Ratings– Gray Iron (psi)

(Class Rated in accordance with ASME B16.1)



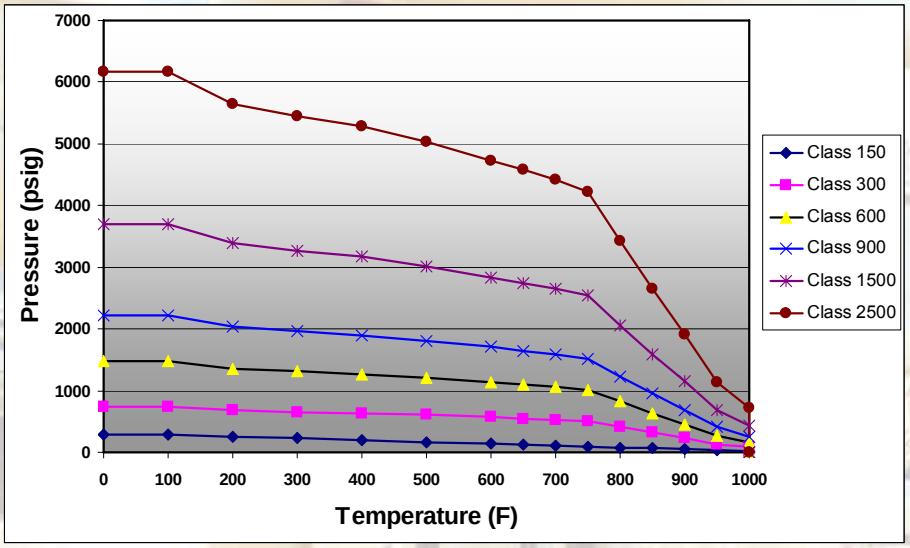
Flange P-T Ratings– Gray Iron (bar)

(Class Rated in accordance with ASME B16.1)



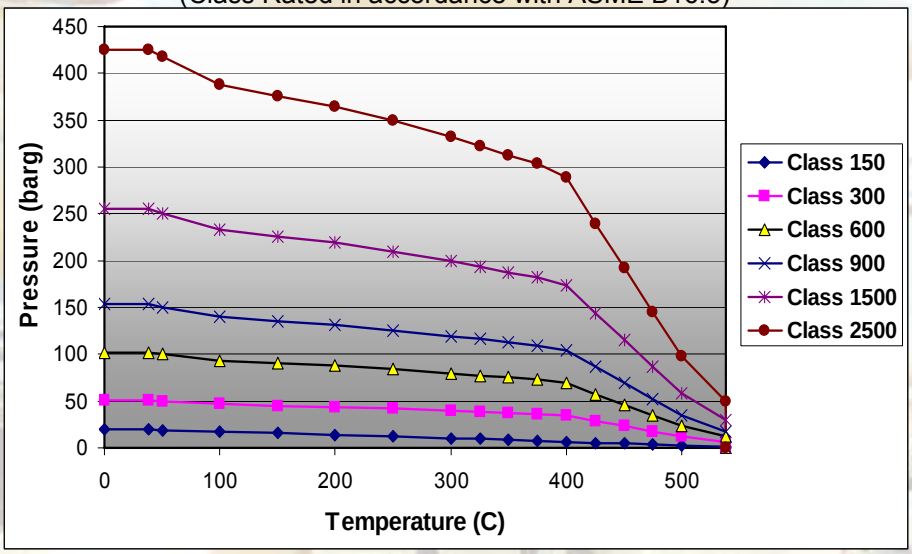
Flange P-T Ratings – Carbon Steel (psi)

(Class Rated in accordance with ASME B16.5)



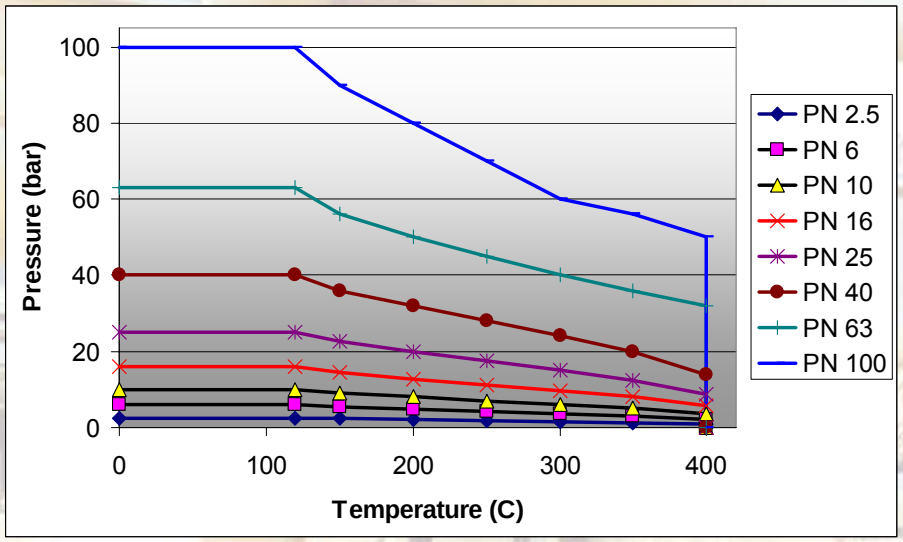
Flange P-T Ratings – Carbon Steel (bar)

(Class Rated in accordance with ASME B16.5)



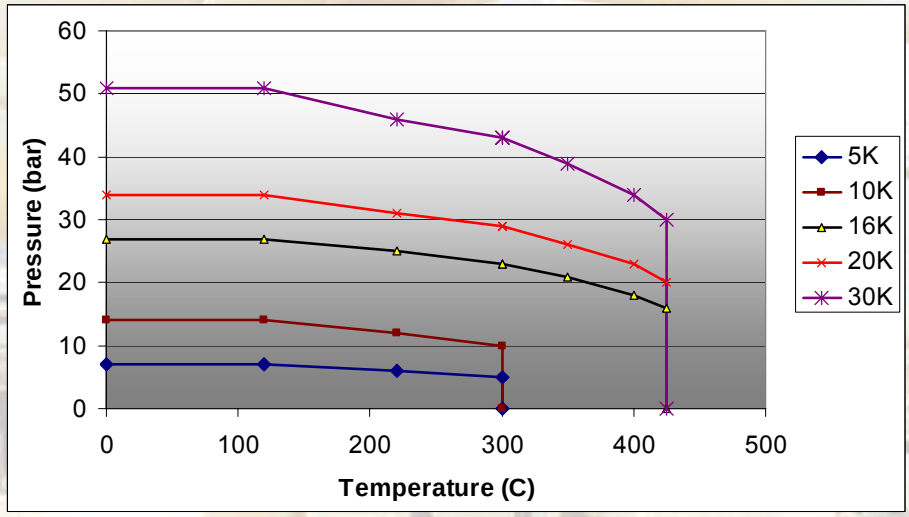
Flange P-T Ratings – Carbon Steel (bar)

(PN Rated in accordance with EN 1092-1)



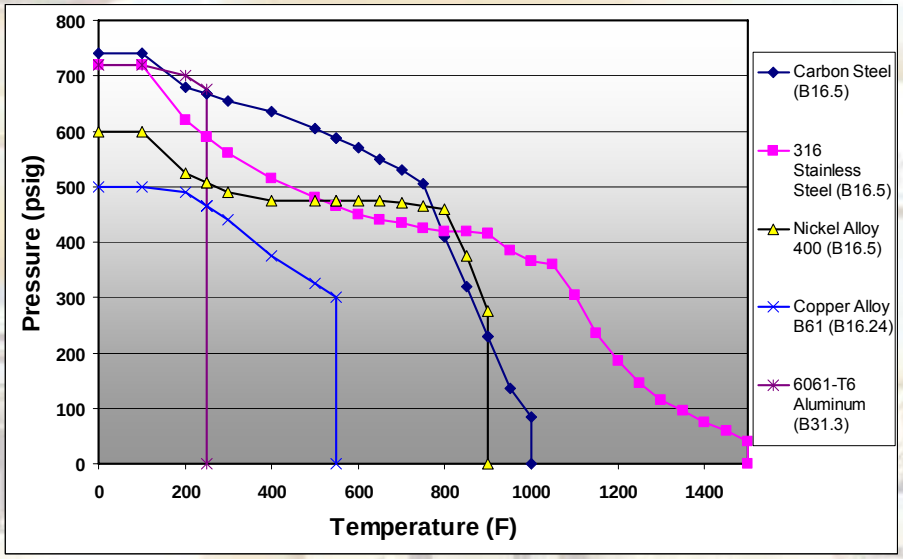
Flange P-T Ratings – Carbon Steel (bar)

(K Rated in accordance with JIS B2220)



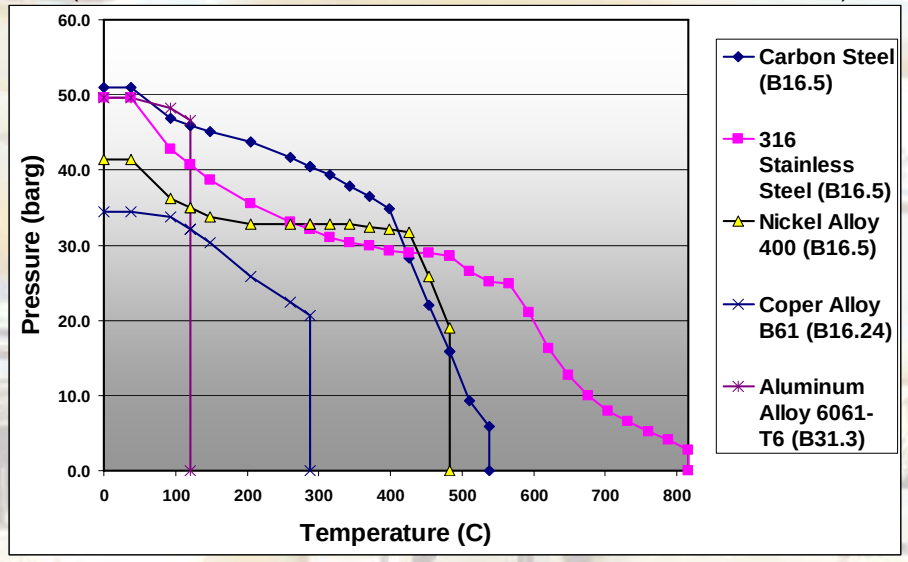
Cl 300 Flange Ratings – Several Materials (psi)

(Class Rated in accordance with ASME B16.5, B16.24 and B31.3)



Cl 300 Flange Ratings – Several Materials (bar)

(Class Rated in accordance with ASME B16.5, B16.24 and B31.3)



Reliability

- Robustness
- Fire Resistance
- Blow-out Resistance
- Tendencies to Leak

Robustness

Able to withstand exposure to loads such as:

- Being stepped on
- Dropped tool
- Dropped tool box
- Forklift traffic
- Truck traffic
- Crane booms

Fire Resistance

Usual Definition: Components able to maintain piping system integrity if subjected to approximately 1200ºF (650ºC) for 30 minutes.

Fire Resistance

Fire resistant components are used

- where there is a sufficient probability of a fire, and
- where there is a significant consequence as a result of piping system failure such as
  - adding fuel to the fire
  - exposure of fire fighters to danger due to leaking fluids

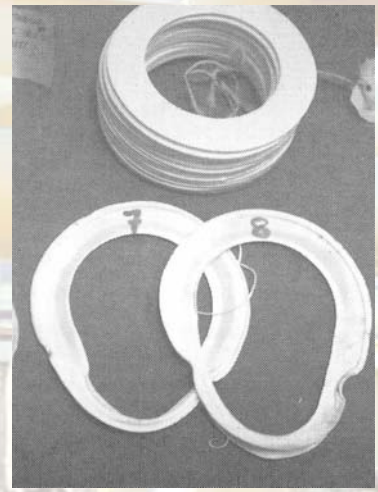
Being able to continue operation after a fire is usually not a consideration.

Blow-out Resistance

Gaskets and seals able to withstand high pressure without failing by extrusion or fracture. A short-term leak could be resealed by tightening the bolting. The intent is to avoid large leaks

- when a flanged joint is not tightened properly
- when the piping system is subjected to pressures much higher than design
- when large bending moments are applied to the flanged joint

Blow-out Resistance



Failure by Extrusion

Failure by Fracture

Tendencies to Leak

Some joints are more leak prone than others. These are usually a strong function of the construction and maintenance practices at a particular site. Examples:

- Threaded joints
- Unions
- Elastomeric seals such as o-rings

Corrosion Resistance

- Where corrosion is more or less uniform, extra pipe wall material can be provided in the form of a "corrosion allowance".
- Where material degradation is localized, either preventive measures must be used or a more resistant material must be provided. Examples of localized material problems:
  - Erosion
  - Stress-Corrosion Cracking
  - Hydrogen Embrittlement
  - Intergranular
  - Microbiological

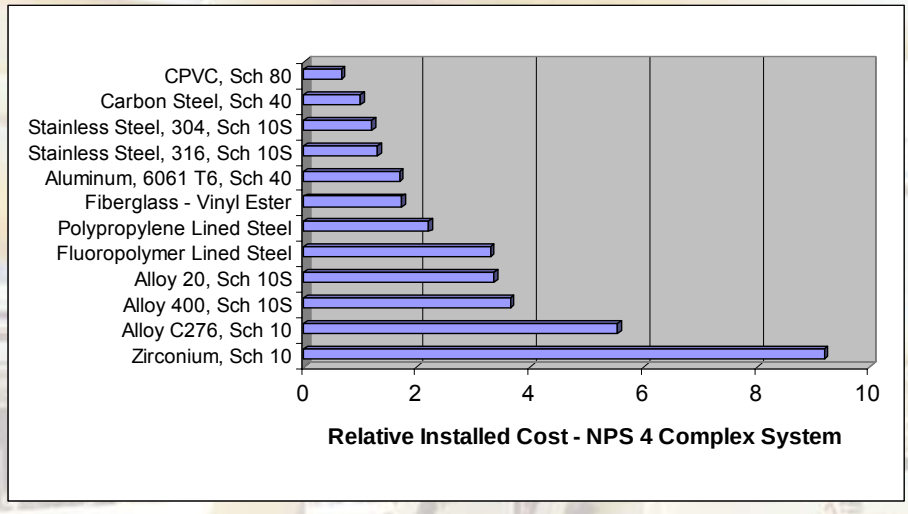
Material Toughness

- Measured by energy necessary to suddenly propagate a crack to failure
- Mostly of concern for carbon steels
- Generally decreases as temperature decreases
- Factors affecting fracture toughness include:
  - Chemical composition or alloying elements
  - Heat treatment
  - Grain size

Example of Brittle Fracture

Example of Ductile Deformation

Cost



Piping Component Standards

Provide consistent dimensions and ratings so that components will fit together and can be used interchangeably

- *Listed Components:* Those listed by standard number in Table 326.1 and Appendix A
- *Unlisted Components:* Those not so listed.

Some Listed Components - ASME

B16.1 – Cast Iron Pipe Flanges
B16.3 – Malleable Iron Threaded Fittings
B16.5 – Pipe Flanges and Flanged Fittings
B16.9 – Wrought Steel Buttweld Fittings
B16.11 – Forged Fittings, Socket Welding & Threaded
B16.20 – Metallic Gaskets
B16.22 – Wrought Copper Solder Joint Fittings
B16.34 – Valves Flanged, Threaded and Welded

See page 8 of the supplement.

Some Listed Components - Other

MSS	SP-80	Bronze Valves
MSS	SP-97	Branch Outlet Fittings
API	602	Compact Steel Gate Valves
API	608	Metal Ball Valves
ASTM	A53	Steel Pipe
ASTM	A312	Stainless Steel Pipe
AWWA	C110	Ductile & Gray Iron Fittings
AWWA	C151	Ductile Iron Pipe

See the pages 9 - 11 in the supplement.

Listed Components

Can be used within their pressure-temperature ratings and any additional limitations described in the Code.

Some Unlisted Components

- ASME B16.33 – Manually Operated Metallic Gas Valves or Use in Gas Piping Systems
- ASME B16.50 – Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings
- MSS SP-68 – High Pressure-Offset Seat Butterfly Valves
- MSS SP-108 – Resilient-Seated Cast Iron-Eccentric Plug Valves
- API 6D – Pipeline Valves (Gate, Plug, Ball, and Check)
- AWWA C153 – Ductile-Iron Compact Fittings for Water Service

Unlisted Components [302.2.3, 326.2.1]

Can be used within Code limitations if they:

- have dimensions that "conform to those of comparable listed components insofar as practicable"
- "provide strength and performance equivalent to standard components", and
- satisfy one of the following:
  - "composition, mechanical properties, method of manufacture, and quality control are comparable to listed components"; and have pressure-temperature ratings that conform with para. 304, or
  - are "qualified for pressure design as required by para. 304.7.2."

Fluid Service Requirements

- Specific requirements for components and joints are described in paras. 305-318.
- Some components are permitted for certain fluid services only when safeguarded.
- "Safeguarding is the provision of protective measures to minimize the risk of accidental damage to the piping or to minimize the harmful consequences of possible piping failure." Para. G300

Fluid Service Requirements

Safeguarding examples:

- Brazed or soldered copper water tube is not inherently fire resistant, but may be protected against fire exposure by insulation or by water sprays.
- Thermoplastic piping is not inherently blow-out resistant and is sensitive to abuse, but may be protected from both hazards by routing the piping in a secondary containment.

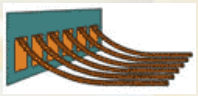
Piping Components

- Pipe
- Fittings
- Branch Connections
- Flanges
- Gaskets
- Bolting
- Flanged Joints

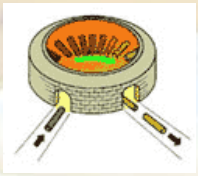
Pipe

"Pipe includes components designated as 'tube' or 'tubing' in the material specification, when intended for pressure service." *Para. 305*

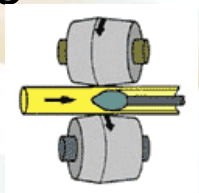
Pipe - seamless



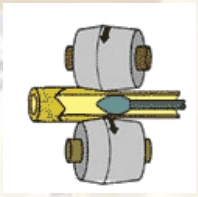
Strand Caster



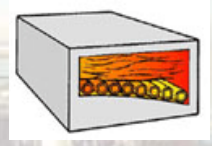
Billet Heating



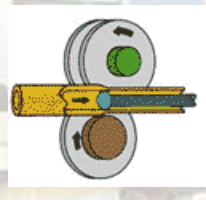
Rotary Piercing Mill



Elongator

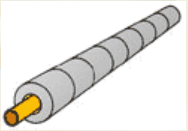


Reheat

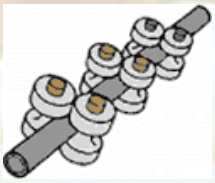


Pug Rolling Mill

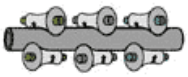
Pipe - seamless



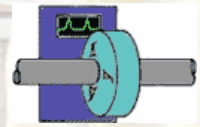
Reheat



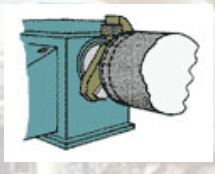
Sizing Mill



Finishing



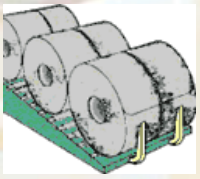
NDT



Facing & Beveling

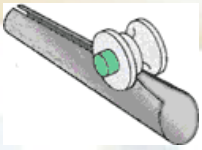
Hydrotesting

Pipe – ERW



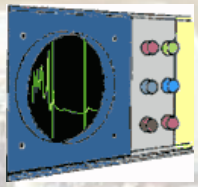
Coil Feed

First Forming

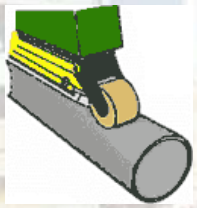


Fin Pass

Welding

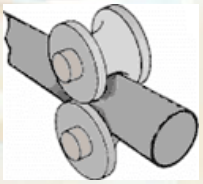


NDT

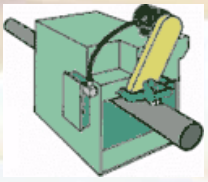


Seam Normalizer

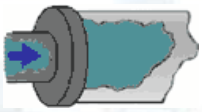
Pipe - ERW



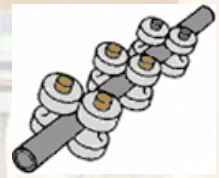
Sizing Mill



Flying Cut-Off

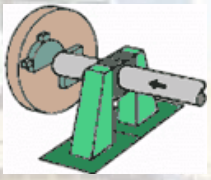


Hydrotesting



Straightening

NDT



Facing & Beveling

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

Pipe Fluid Service Requirements

- Some specifications, including all furnace butt welded, are limited to Category D Fluid Service
- Some specifications may be used only in Category D Fluid Service unless safeguarded
- Only pipe listed in para. 305.2.3 may be used for Severe Cyclic Conditions

Fittings

Fittings are selected primarily by the way they are joined to the pipe.

- Threading
- Socket Welding
- Buttwelding
- OD Tubing (Compression fitting, Flare)
- Water Tubing (Solder, Braze)
- Others

Fittings: Threaded

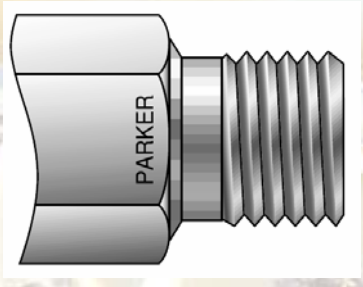
- **Common materials**
  - Gray iron (ASME B16.4)
  - Malleable iron (ASME B16.3)
  - Steel (ASME B16.11)

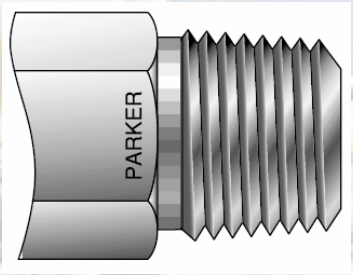
- **Size usually limited to ~NPS 2**
  - Potential injury for installers
  - Ability to get a good seal

- **Generally not used where leaks cannot be tolerated**

Threaded Joint Fluid Service Requirements

- Straight threaded coupling mating to taper thread permitted only for Category D



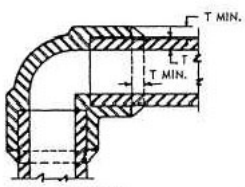


Threaded Joint Fluid Service Requirements

- NPS 1-1/2 and smaller tapered joints must be Sch 80 for notch sensitive material in Normal Service
- May be used for Severe Cyclic Conditions only if:
  - For taper threads must be, non-moment bearing such as for a thermowell
  - For straight threads with seating surface, must be safeguarded

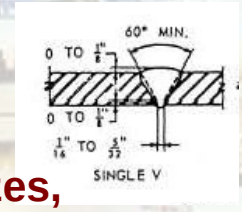
Fittings: Socket Welding

- **Common materials (ASME B16.11)**
  - Carbon Steel
  - Stainless Steel
- **Size usually limited to ~NPS 1-1/2**
- **Not used in services where**
  - Corrosion is accelerated in crevices
  - Severe erosion may occur

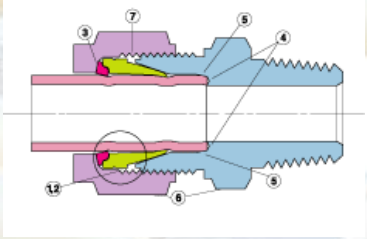


Fittings: Buttwelding

- **Common materials (ASME B16.9)**
  - Carbon Steel
  - Stainless Steel
  - Nickel alloys
- **Used in most piping systems ~NPS 2 and larger**
- **Use generally not restricted**
- **Welding is difficult in small sizes, especially for thin wall**



Fittings: OD Tubing



- **Common materials**
  - Copper
  - Steel
  - Nickel alloys
- **Compression Fittings**
- **Flared Fittings (ASME B16.26)**
- **Generally not used in most severe services because of leak potential**
  - Must be safeguarded for Severe Cyclic Service

Fittings: Water Tube

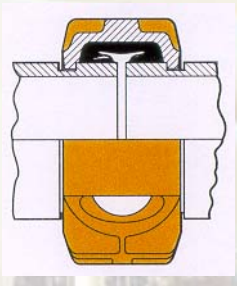
- **Common material: copper**
- **Solder joint (ASME B16.18 & B16.22)**
- **Braze joint (ASME B16.50)**
- **Not fire resistant**

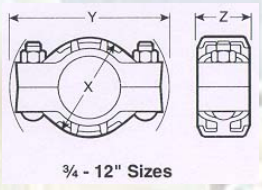
Solder & Brazed Joint Fluid Service Requirements

- Solder joints are permitted only for Category D Fluid Service
- Brazed joints are :
  - permitted for Normal Fluid Service
  - permitted for fluids that are flammable, toxic or damaging to human tissue if safeguarded
  - prohibited for Severe Cyclic Conditions

Fittings: Grooved

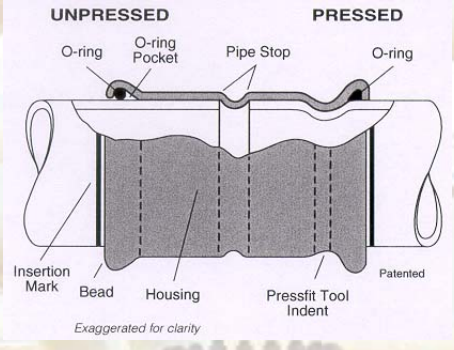
Fittings that use grooves in pipe – elastomeric seal required

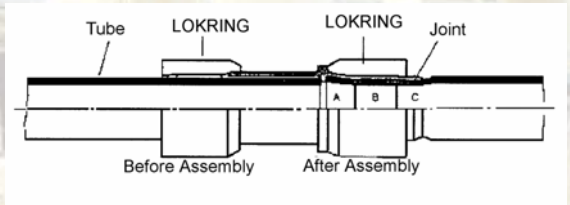




Fittings: Compression for Pipe

Pressfit by Victaullic (B16.51 draft for copper)





Lokring (metal-to-metal seal)

Miter Bend Fluid Service Requirements

- A bend with α greater than 45º may be used only in Category D Fluid Service
- For Severe Cyclic Conditions, α must be less than or equal to 22.5º.

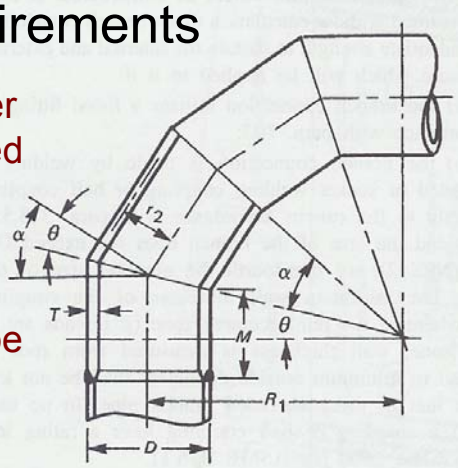


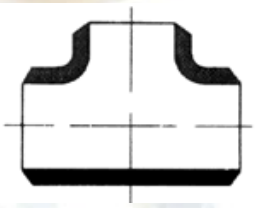
FIG. 304.2.3 NOMENCLATURE FOR MITER BENDS

Branches

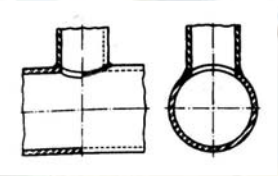
- **Generally many choices NPS 3 and larger**
- **Choices include:**
  - Tee
  - Unreinforced Fabricated Tee
  - Reinforced Fabricated Tee
  - Branch Connection Fitting

Branches

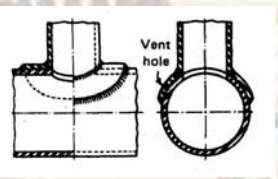
Tee



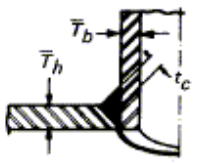
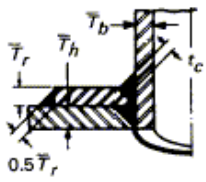
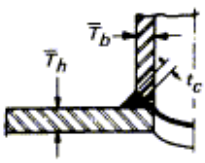
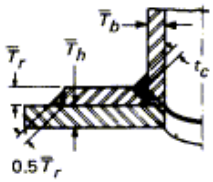
Unreinforced Fabricated Tee
(Capable of less than full pressure)



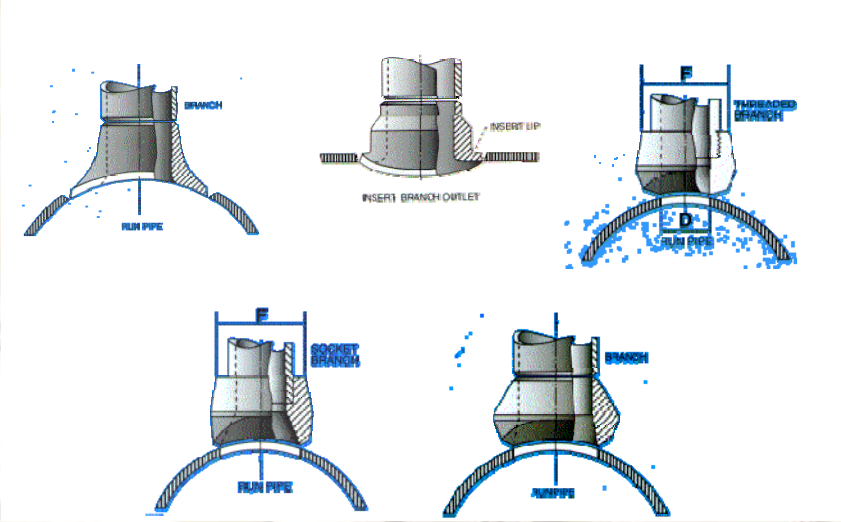
Reinforced Fabricated Tee



Fabricated Branches

	Unreinforced	Reinforced
Stub in		
Stub on		

Branches - Branch Connection Fittings



Branches

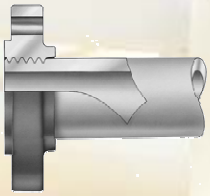
Basis for selection:

- **Cost: depends on material, sizes & fabricator**
- **Resistance to external moment**
- **Ability to examine fabrication**

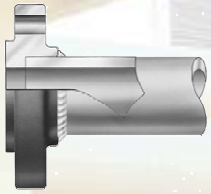
See table on page 19 in the supplement.

Flanges (ASME B16.5)

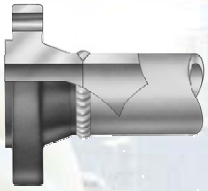
Flange types designated by joining method



Threaded



Socket welding



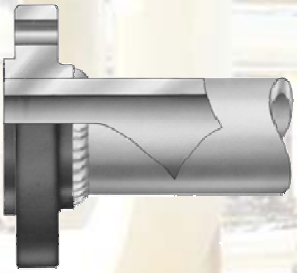
Welding Neck (buttweld)

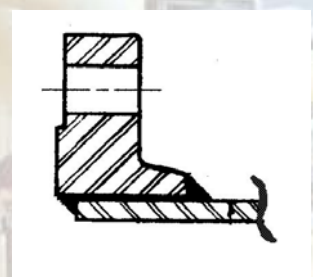
These flanges have the same advantages and restrictions as fittings with the same joining method. (Note that welding neck flanges are required for Severe Cyclic Conditions.)

Flanges (ASME B16.5)

Other types of flanges - Slip-on

- Has no crevice if installed with two welds
- Easier to get good alignment
- Unable to seat metal gaskets as well as WN & LJ





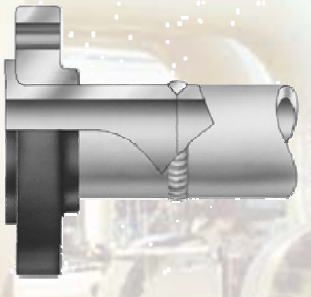
Slip-on Flange Fluid Service Requirements

- Required to be double welded for:
  - Severe erosion, crevice corrosion or cyclic loading
  - Flammable, toxic, or damaging to human tissue
  - Under Severe Cyclic Conditions
  - At temperatures below -101ºC (-150ºF)
- Should be avoided where many large temperature cycles are expected

Flanges (ASME B16.5)

Other types of flanges - Lapped joint

- Flange can be made from cheaper material
- Easier to fabricate and install than WN



Flanges Facings (ASME B16.5)

Raised – normal choice

Flat

- Standard for gray iron flanges
- More gasket has to be compressed, so only "softer" gaskets can be used
- Less likely to break flange when bolting (applicable to brittle materials like gray iron)

Gaskets

Important Gasket Characteristics

- Resists deterioration in normal service
  - Chemical resistance
  - Temperature resistance
- Low enough leak rate
- Blowout resistance
- Fire resistance

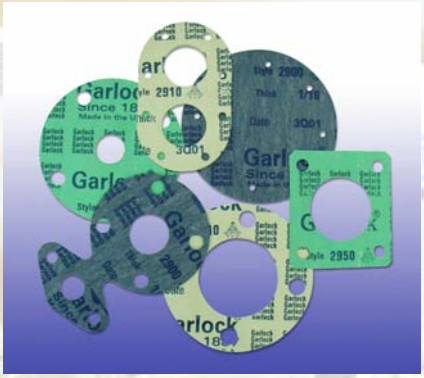
Gaskets – Rubber

Chemical Resistant	OK for most
Approximate Max. Temp.	200°F (95°C)
Leak Performance	Best
Blowout Resistant	No
Fire Resistant	No
Bolt Strength Needed	Low

(Thermoseal)

Gaskets – Reinforced Rubber

Chemical Resistant	OK for most
Approximate Max. Temp.	325°F (160°C)
Leak Performance	Fair
Blowout Resistant	No
Fire Resistant	No
Bolt Strength Needed	Low



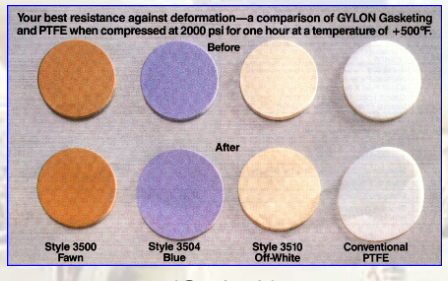
(Garlock)

Gaskets – Fluoropolymer

Chemical Resistant	OK for almost all
Approximate Max. Temp.	350°F (180°C)
Leak Performance	Good
Blowout Resistant	No
Fire Resistant	No
Bolt Strength Needed	Low

(Gore)

(Teadit)



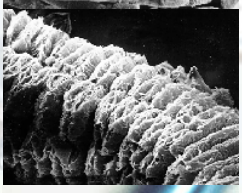
(Garlock)

Gaskets – Flexible Graphite

Chemical Resistant	OK for almost all
Approximate Max. Temp.	900 or 625°F (480 or 330°C)
Leak Performance	Good
Blowout Resistant	Not without heavier insert
Fire Resistant	Yes
Bolt Strength Needed	Medium

Natural Graphite Flake

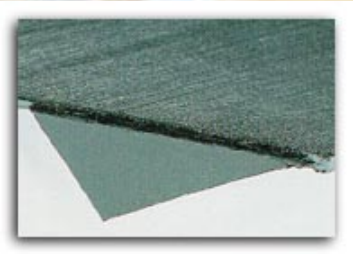
Thermally Decomposed (Worms)



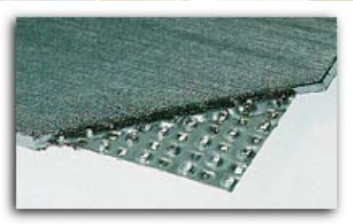
Worms Compressed Into Foils

(SGL Carbon Group)

Gaskets – Flexible Graphite



(Teadit)



(Teadit)

Foil Inserted
- Insert is usually 0.002” (0.05 mm) type 316 stainless steel
- Adhesive bonded

Tang Inserted
- Insert is usually 0.004” (0.10 mm) type 316 stainless steel
- Mechanically bonded

Gaskets – Flexible Graphite

(Garlock)

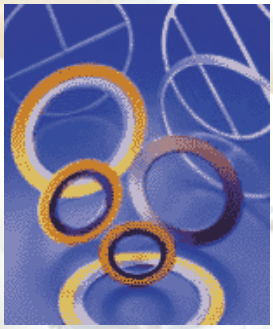
Corrugated Insert
- Insert is usually 0.018” (0.46 mm) type 316 stainless steel
- Adhesive bonded
- Blowout resistant
- Lower hand cutting potential
- Lower sealing stress
- Cannot be cut from sheet

Gaskets – Flexible Graphite

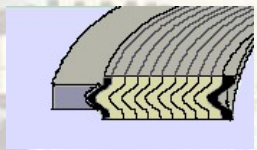
Flexible graphite tends to stick to flanges, but special coatings can help.

Gaskets – Spiral Wound

Chemical Resistant	Both metal winding & filler must be OK
Approximate Max. Temp.	1500°F (820°C)
Leak Performance	Good
Blowout Resistant	Yes
Fire Resistant	Depends on Filler
Bolt Strength Needed	High



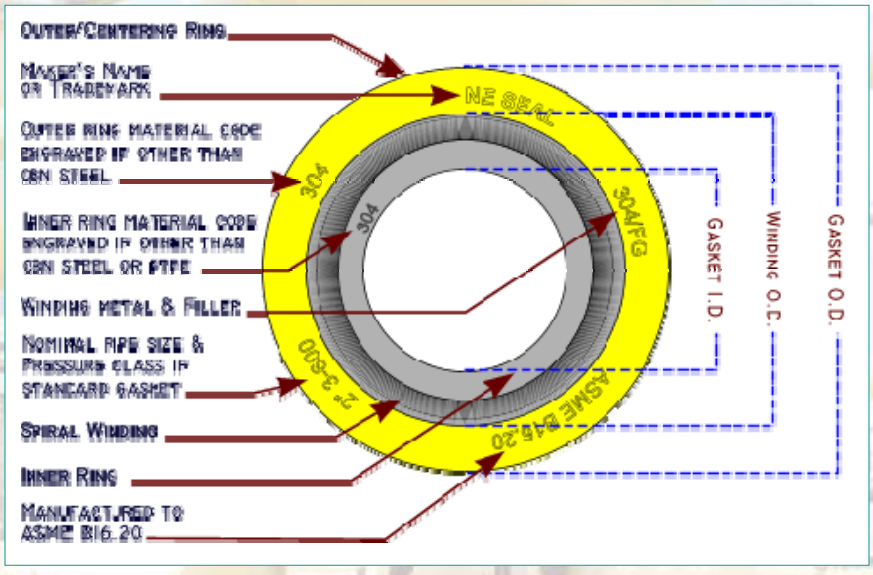
(Garlock)



(Flexitallic)

Gaskets – Spiral Wound

(NE Seal)



Gaskets – Spiral Wound

Winding Material	Ring Edge Color Code
304 SS	Yellow
316L SS	Green
Nickel 200	Red
Alloy C276	Beige
Alloy 400	Orange

Gaskets – Spiral Wound

Filler Material	Ring Stripe Color Code	Fire Resistant	Maximum Temp °F/ °C
Asbestos	None	Yes	1500 / 820
Flexible Graphite	Gray	Yes	900 / 480
Mica Graphite	Pink	No	325 / 160
PTFE	White	No	350 / 180
Vermiculite	No standard	Yes	1500 / 820

Gaskets – Spiral Wound

Internal buckling is a concern to some, especially in higher pressure classes and larger sizes.

Gaskets - Kammprofile

Chemical Resistant	Both metal & sealing material must be OK
Approximate Max. Temp.	1500°F (820°C)
Leak Performance	Good
Blowout Resistant	Yes
Fire Resistant	Depends on sealing material
Bolt Strength Needed	Medium

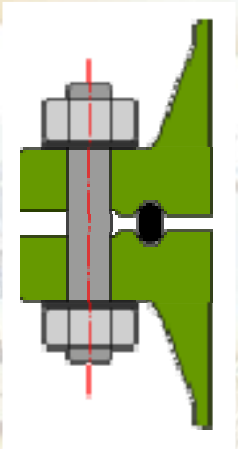
(Garlock)

Gaskets – Ring Joint

Chemical Resistant	Metal must be OK
Approximate Max. Temp.	1500°F (820°C)
Leak Performance	Very Good
Blowout Resistant	Yes
Fire Resistant	Yes
Bolt Strength Needed	High

Oval

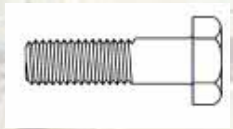
Octagonal



(NE Seal)

Bolting

- Has to be strong enough to seat the gasket
- Consider need to be corrosion resistant to process fluid
- Studs versus bolts



1st and 2nd degree burns…

after being sprayed with hot water. The bonnet of the valve had separated from the valve body due to corroded bonnet bolts.

Bolting Fluid Service Requirements

- Low strength bolting [SMYS not greater than 207 MPa (30 ksi)] may not be used with
  - Pressure classes higher than 300
  - Metal gaskets
- Carbon steel bolting may not be used with
  - Pressure classes higher than 300
  - Temperatures outside -29ºC to 204ºC (-20ºF to 400ºF) range
- Galvanized carbon steel bolting must be to heavy hex dimensions

More Bolting Fluid Service Requirements

- Low strength bolting shall be used for weaker and more brittle flanged joints unless
  - Both flanges are flat faced and a full face gasket is used, or
  - A careful bolt-up procedure is used
- Low strength bolting may not be used for Severe Cyclic Conditions

Flanged Joints

"A flanged joint is composed of three separate and independent, although interrelated components: the flanges, the gasket, and the bolting, which are assembled by yet another influence, the assembler. Proper controls must be exercised in the selection and application for all these elements to attain a joint which has acceptable leak tightness." [B16.5]

Flanged Joints

Flange A	Flange B	Fire Resist?	Blow-out Resist?	Facing	Gaskets	Bolting Strength
Class 125 gray iron	Class 125 gray iron	No	No			
Class 125 gray iron	Class 150 carbon stl	No	No			
Class 150 carbon stl	Class 150 carbon stl	Yes	Yes			
Class 150 stainless	Class 150 stainless	No	Yes			
Class 150 carbon stl	Class 125 gray iron	Yes	No			

Pipe & Fitting Selection

Workshop: What basic piping system characteristics would you provide for the following services:

Steam condensate	650 psig (45 bar) Steam
Chlorine	Heat transfer oil
Sulfuric acid	Styrene monomer
Gasoline	Lime-water slurry

See Supplement page 7 for details.