# A PIPING TUTORIAL

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   **Exam**

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1.0 Introduction

1.1 Definition of Piping

Pipe is a pressure tight cylinder used to convey a fluid or to transmit a fluid pressure, ordinarily designated pipe in applicable material specifications. Materials designated tube or tubing in the specifications are treated as pipe when intended for pressure service.

Piping is an assembly of piping components used to convey, distribute, mix, separate, discharge, meter, control or snub fluid flows. Piping also includes pipe-supporting elements but does not include support structures, such as building frames, bents, foundations, or any equipment excluded from Code definitions.

Piping components are mechanical elements suitable for joining or assembly into pressure-tight fluid-containing piping systems. Components include pipe, tubing, fittings, flanges, gaskets, bolting, valves and devices such as expansion joints, flexible joints, pressure hoses, traps, strainers, in-line portions of instruments and separators.

Piping is typically round.

1.2 Piping Nomenclature, Components

Graphic of piping system illustrating

- header
- branch connection
- valve
- flange
- expansion joint
- expansion loop
- pipe support
- reducer
- elbow
### Pipe System Essentials

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Header</td>
<td>• □ Main run of piping</td>
</tr>
<tr>
<td>Take off</td>
<td>• □ Branch run</td>
</tr>
<tr>
<td>Stub in</td>
<td>• □ Branch fitting connection made to header by direct attachment of branch</td>
</tr>
<tr>
<td>Branch reinforcement</td>
<td>• □ Material added in the vicinity of a branch opening to restore the mechanical integrity of the pipe</td>
</tr>
<tr>
<td>NPS</td>
<td>• □ Nominal pipe size</td>
</tr>
<tr>
<td>Pipe support</td>
<td>• □ Support elements which serve to maintain the structural integrity of the piping system, these are typically non-linear elements</td>
</tr>
<tr>
<td>Spring support</td>
<td>• □ Support provided by an element composed of a spring assembly, these are linear support elements</td>
</tr>
<tr>
<td>Snubber</td>
<td>• □ Support provided by an element composed of a non-linear, damping element</td>
</tr>
<tr>
<td>Category D</td>
<td>• □ Within reference of B31.3, a service classification</td>
</tr>
<tr>
<td>Category M</td>
<td>• □ Within reference of B31.3, a service classification</td>
</tr>
<tr>
<td>Expansible fluid</td>
<td>• □ Any vapour or gaseous substance, any liquid under such pressure and temperature such that when pressure is reduced to atmospheric, will change to a gas</td>
</tr>
<tr>
<td>Hydro test</td>
<td>• □ Test pressure = 1.5 x MAWP (some of the time)</td>
</tr>
<tr>
<td>MAWP</td>
<td>• □ Maximum allowable working pressure</td>
</tr>
<tr>
<td>MDMT</td>
<td>• □ Minimum design metal temperature</td>
</tr>
<tr>
<td>Fracture toughness</td>
<td>• □ Typically measured by CVN (Charpy V Number) at MDMT</td>
</tr>
</tbody>
</table>
1.3 Regulatory Acts, Codes & Standards

**Codes**
Codes are rules for the design of prescribed systems which are given the force of law through provincial, state and federal legislation. In Canada, provincial governments have the responsibility for public safety that includes these facilities, among others:

- Pressure piping
- Pressure vessels
- Boilers
- Pipelines
- Plumbing systems
- Gas piping

** Alberta Safety Codes Acts and Codes of Practice**
The following are applicable to the first four facilities listed above.

Boilers and Pressure Vessels Regulation
- Prescribes requirements for registration of pressure vessels, boilers, pressure piping and fittings

Design, Construction and Installation of Boilers and Pressure Vessels Regulations
- Cites the codes and “bodies of rules” that form part of the regulations
- CSA B51 Boiler, Pressure Vessel and Pressure Piping Code
- CSA B52 Mechanical Refrigeration Code
- CAN/CSA Z184 Gas Pipeline Systems
- ASME Boiler & Pressure Vessel Code
- ASME B31 Pressure Piping Codes
  - B31.1 Power Piping
  - B31.3 Process Piping
  - B31.4 Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia and Alcohols
  - B31.5 Refrigeration Piping
- ANSI K61.1 Safety Requirements for the Storage and Handling of Anhydrous Ammonia
- NFPA 58 Standard for the Storage and Handling of Liquefied Petroleum Gases
- DOT Regulations of the Department of Transportation Governing the Transportation of Hazardous Materials in Tank Motor Vehicles
- MSS Standard Practice SP 25 Standard Marking System for Valves, Fittings, Flanges and Unions
- TEMA Standards of Tubular Exchanger Manufacturers Association

**Pipeline Act**
Cites the “minimum requirements for the design, construction, testing, operation, maintenance and repair of pipelines”:

- CAN/CSA Z183 Oil Pipeline Systems
Currently, CSA Z662 Oil and Gas Pipeline Systems (This standard supercedes Z183 & Z184)

In the US:

As in Canada, some facilities are governed by federal regulations. Interstate pipeline facilities are defined by the:

- Code of Federal Regulations, Title 49
  - Part 192 Transportation of Natural and Other Gas by Pipeline – Minimum Federal Safety Standards
  - Part 193 Liquefied Natural Gas Facilities
  - Part 195 Transportation of Hazardous Liquids by Pipeline

Other pipeline pressure piping codes include:

- ASME B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids
- ASME B31.8 Gas Transmission and Distribution Systems

1.4 Line Designation Tables

The Province of Alberta Safety Codes Act "Design, Construction and Installation of Boilers & Pressure Vessels Regulations" par 7(2) requires that construction of a pressure piping system must include submission of drawings, specifications and other information and include:

(a) flow or line diagrams showing the general arrangement of all boilers, pressure vessels, pressure piping systems and fittings (2 copies)

(b) pipeline identification lists showing the maximum pressures and temperatures for each pressure piping system (2 copies)

(c) a list of pressure relief devices, including the set pressure (2 copies)

(d) material specifications, size, schedule and primary service rating of all pressure piping and fittings (2 copies)

(e) the welding procedure registration number

(f) the pressure pipe test procedure outlining the type, method, test media , test pressure, test temperature, duration and safety precautions (1 copy)

(g) a form, provided by the Administrator, completed by the engineering designer or contractor which relates to the general engineering requirements for design and field construction of pressure piping systems (AB 96)

(h) such other information as is necessary for a safety codes officer to survey the design and determine whether it is suitable for approval and registration

Problem Set 1
1 Which Act governs the design of plant pressure piping systems in Alberta?

2 Are process plant water lines considered pressure piping systems?

3 For what fluid service category may a hydrotest be waived per B31.3?

4 What is the difference between a pipe elbow and a bend?

2.0 Codes and Standards

The following codes are used for the design, construction and inspection of piping systems in North America.

2.1 The ASME B31 Piping Codes

Piping codes developed by the American Society of Mechanical Engineers:

B31.1 Power Piping

Piping typically found in electric power generating stations, in industrial and institutional plants, geothermal heating systems and central and district heating and cooling plants.

B31.3 Process Piping

Piping typically found in petroleum refineries, chemical, pharmaceutical, textile, pet, semiconductor and cryogenic plants and related processing plants and terminals.

B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids

Piping transporting products which are predominately quid between plants and terminals and within terminals, pumping, regulating, and metering stations.

B31.5 Refrigeration Piping

Piping for refrigerants and secondary coolants.

B31.8 Gas Transportation and Distribution Piping Systems

Piping transporting products which are predominately gas between sources and terminals including compressor, regulating and metering stations, gas gathering pipelines.

B31.9 Building Services Piping
Piping typically found in industrial, institutional, commercial and public buildings and in multi-unit residences which does not require the range of sizes, pressures and temperatures covered in B311.1

B31.11 Slurry Transportation Piping Systems

Piping transporting aqueous slurries between plants and terminals within terminals, pumping and regulating stations.
The following codes are used to specify the geometric, material and strength of piping and components:

**ASME B16 Dimensional Codes**

**The ASME B16 Piping Component Standards**

Piping component standard developed by the American Society of Mechanical Engineers or the American National Standards Institute (ANSI)

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>B16.1</td>
<td>Cast Iron Pipe Flanges and Flanged Fittings</td>
</tr>
<tr>
<td>B16.3</td>
<td>Malleable Iron Threaded Fittings, Class 150 and 300</td>
</tr>
<tr>
<td>B16.4</td>
<td>Cast Iron Threaded Fittings, Classes 125 and 250</td>
</tr>
<tr>
<td>B16.5</td>
<td>Pipe Flanges and Flanged Fittings</td>
</tr>
<tr>
<td>B16.9</td>
<td>Factory Made Wrought Steel Buttwelding Fittings</td>
</tr>
<tr>
<td>B16.10</td>
<td>Face to Face and End to End Dimensions of Valves</td>
</tr>
<tr>
<td>B16.11</td>
<td>Forged Fittings, Socket Welding and Threaded</td>
</tr>
<tr>
<td>B16.12</td>
<td>Cast Iron Threaded Drainage Fittings</td>
</tr>
<tr>
<td>B16.14</td>
<td>Ferrous Pipe Plugs, Bushings and Locknuts with Pipe Threads</td>
</tr>
<tr>
<td>B16.15</td>
<td>Cast Bronze Threaded Fittings Class 125 and 250</td>
</tr>
<tr>
<td>B16.18</td>
<td>Cast Copper Alloy Solder Joint Pressure Fittings</td>
</tr>
<tr>
<td>B16.20</td>
<td>Ring Joint Gaskets and Grooves for Steel Pipe Flanges</td>
</tr>
<tr>
<td>B16.21</td>
<td>Nonmetallic Flat Gaskets for Pipe Flanges</td>
</tr>
<tr>
<td>B16.22</td>
<td>Wrought Copper and Copper Alloy Solder Joint Pressure Fittings</td>
</tr>
<tr>
<td>B16.23</td>
<td>Cast Copper Alloy Solder Joint Drainage Fittings – DWV</td>
</tr>
<tr>
<td>B16.24</td>
<td>Cast Copper Alloy Pipe Flanges and Flanged Fittings Class 150, 300, 400,600,900, 1500 and 2500</td>
</tr>
<tr>
<td>B16.25</td>
<td>Buttwelding Ends</td>
</tr>
<tr>
<td>B16.26</td>
<td>Cast Copper Alloy Fittings for Flared Copper Tubes</td>
</tr>
<tr>
<td>B16.28</td>
<td>Wrought Steel Buttwelding Short Radius Elbows and Returns</td>
</tr>
<tr>
<td>B16.29</td>
<td>Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings – DWV</td>
</tr>
<tr>
<td>B16.32</td>
<td>Cast Copper Alloy Solder Joint Fittings for Sovent Drainage Systems</td>
</tr>
<tr>
<td>B16.33</td>
<td>Manually Operated Metallic Gas Valves for Use in Gas Piping systems Up to 125 psig (sizes ½ through 2)</td>
</tr>
<tr>
<td>B16.34</td>
<td>Valves – Flanged, Threaded and Welding End</td>
</tr>
<tr>
<td>B16.36</td>
<td>Orifice Flanges</td>
</tr>
<tr>
<td>B16.37</td>
<td>Hydrostatic Testing of Control Valves</td>
</tr>
<tr>
<td>B16.38</td>
<td>Large Metallic Valves for Gas Distribution (Manually Operated, NPS 2 ½ to 12, 125 psig maximum)</td>
</tr>
<tr>
<td>B16.39</td>
<td>Malleable Iron Threaded Pipe Unions, Classes 1150, 250 and 300</td>
</tr>
<tr>
<td>B16.40</td>
<td>Manually Operated Thermoplastic Gs Shutoffs and Valves in Gas Distribution Systems</td>
</tr>
<tr>
<td>B16.42</td>
<td>Ductile Iron Pipe Flanges and Flanged Fittings, Class 150 and 300</td>
</tr>
<tr>
<td>B16.47</td>
<td>Large Diameter Steel Flanges (NPS 26 through NPS 60)</td>
</tr>
</tbody>
</table>
ASME B36 Piping Component Standards

Piping standards developed by the American Society of Mechanical Engineers / American National Standards Institute:

B36.10  Welded and Seamless Wrought Steel Pipe
B36.19  Stainless Steel Pipe

Other ASME or ANSI
B73.1  Horizontal, End Suction Centrifugal Pumps
B73.2  Vertical In-line Centrifugal Pumps
B133.2  Basic Gas Turbine

2.2 NEPA Codes

National Electrical Protection Association

Piping covering fire protection systems using water, carbon dioxide, halon, foam, dry chemical and wet chemicals.

NFC - NFPA Codes

National Fire Code / National Fire Protection Association

NFPA 99 Health Care Facilities
Piping for medical and laboratory gas systems.

2.3 CSA Standards

Canadian Standards Association

CSA Z662 - 94 Oil & Gas Pipeline Systems This standard supercedes these standards:

- □  CAN/CSA Z183 Oil Pipeline Systems
- □  CAN/CSA Z184 Gas Pipeline Systems
- □  CAN/CSA Z187 Offshore Pipelines

Other CSA Piping and Component Codes:

B 51  Boilers and Pressure Vessels
B 53  Identification of Piping Systems
B 52  Mechanical Refrigeration Code
B 63  Welded and Seamless Steel Pipe
B 137.3  Rigid Poly-Vinyl Chloride (PVC) Pipe
B 137.4  Polyethylene Piping Systems for Gas Service
W 48.1  Mild Steel Covered Arc-Welding Electrodes
W 48.3  Low-Alloy Steel Arc-Welding Electrodes
Z 245.1  Steel Line Pipe
Z 245.11  Steel Fittings
Z 245.12  Steel Flanges
Z 245.15  Steel Valves
Z 245.20  External Fusion Bond Epoxy Coating for Steel Pipe
Z 245.21  External Polyethylene Coating for Pipe
Z 276  LNG - Production, Storage and Handling
2.4 **MSS Standard Practices**

Piping and related component standards developed by the Manufacturer’s Standardization Society. The MSS standards are directed at general industrial applications. The pipeline industry makes extensive use of these piping component and quality acceptance standards.

- **SP-6** Standard Finishes for Contact Faces Pipe Flanges and Connecting End Flanges of Valves and Fittings
- **SP-25** Standard Marking System for Valves, Fittings, Flanges and Union
- **SP-44** Steel Pipeline Flanges
- **SP-53** Quality Standards for Steel Castings and Forgings for Valves, Flanges and Fittings and Other Piping Components - Magnetic Particle
- **SP-54** Quality Standards for Steel Castings and for Valves, Flanges and Fittings and Other Piping Components - Radiographic
- **SP-55** Quality Standards for Steel Castings and for Valves, Flanges and Fittings and Other Piping Components - Visual
- **SP-58** Pipe Hangers and Supports - Material, Design and Manufacture
- **SP-61** Pressure Testing of Steel Valves
- **SP-69** Pipe Hangers and Supports - Selection and Application
- **SP-75** High Test Wrought Butt Welding Fittings
- **SP-82** Valve Pressure Testing Methods
- **SP-89** Pipe Hangers and Supports - Fabrication and Installation Practices
American Petroleum Institute

The API standards are focused on oil production, refinery and product distribution services. Equipment specified to these standards are typically more robust than general industrial applications.

Spec. 5L  Line Pipe
Spec. 6D  Pipeline Valves
Spec. 6FA  Fire Test for Valves
Spec. 12D  Field Welded Tanks for Storage of Production Liquids
Spec. 12F  Shop Welded Tanks for Storage of Production Liquids
Spec. 12J  Oil and Gas Separators
Spec. 12K  Indirect Type Oil Field Heaters

Std. 594  Wafer and Wafer-Lug Check Valves
Std. 598  Valve Inspection and Testing
Std. 599  Metal Plug Valves - Flanged and Butt-Welding Ends
Std. 600  Steel Gate Valves-Flanged and Butt-Welding Ends
Std. 602  Compact Steel Gate Valves-Flanged Threaded, Welding, and Extended-Body Ends
Std. 603  Class 150, Cast, Corrosion-Resistant, Flanged-End Gate Valves
Std. 607  Fire Test for Soft-Seated Quarter-Turn Valves
Std. 608  Metal Ball Valves-Flanged and Butt-Welding Ends
Std. 609  Lug-and Wafer-Type Butterfly Valves
Std. 610  Centrifugal Pumps For Petroleum, Heavy Duty Chemical and Gas Industry Services
Std. 611  General Purpose Steam Turbines for Refinery Services
Std. 612  Special Purpose Steam Turbines for Refinery Services
Std. 613  Special Purpose Gear Units for Refinery Services
Std. 614  Lubrication, Shaft-Sealing and Control Oil Systems for Special Purpose Application
Std. 615  Sound Control of Mechanical Equipment for Refinery Services
Std. 616  Gas Turbines for Refinery Services
Std. 617  Centrifugal Compressors for General Refinery Services
Std. 618  Reciprocating Compressors for General Refinery Services
Std. 619  Rotary-Type Positive Displacement Compressors for General Refinery Services
Std. 620  Design and Construction of Large, Welded, Low Pressure Storage Tanks
Std. 630  Tube and Header Dimensions for Fired Heaters for Refinery Service
Std. 650  Welded Steel Tanks for Oil Storage
Std. 660  Heat Exchangers for General Refinery Service
Std. 661  Air-Cooled Heat Exchangers for General Refinery Service
Std. 670  Vibrations, Axial Position, and Bearing-Temperature Monitoring Systems
Std. 671  Special Purpose Couplings for Refinery Service
Std. 674  Positive Displacement Pumps-Reciprocating
Std. 675  Positive Displacement Pumps-Controlled Volume
Std. 676  Positive Displacement Pumps-Rotary
Std. 677  General Purpose Gear Units for Refineries Services
Std. 678  Accelerometer-Base Vibration Monitoring System
Std. 1104  Welding Pipelines and Related Facilities
Std. 2000  Venting Atmospheric and Low-Pressure Storage Tanks - Non-Refrigerated and Refrigerated
RP 530  Calculation for Heater Tube Thickness in Petroleum Refineries
RP 560  Fired Heater for General Refinery Services
2.6  **ASTM**

There are numerous American Society for Testing and Materials designations cover the specification of wrought materials, forgings and castings used for plate, fittings, pipe and valves. The ASTM standards are directed to dimensional standards, materials and strength considerations.

Some of the more material standards referenced are:

- A 36  Specification for Structural Steel
- A 53  Specification for Pipe, Steel, Black and Hot –Dipped, Zinc Coated Welded and Seamless
- A 105  Specification for Forgings, Carbon Steel, for Piping Components
- A 106  Specification for Seamless Carbon Steel Pipe for High Temperature Service
- A 181  Specification for Forgings, Carbon Steel for General Purpose Piping
- A 182  Specification for Forged or Rolled Alloy Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temperature Service
- A 193  Specification for Alloy Steel and Stainless Steel Bolting Materials for High Temperature Service
- A 194  Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure and High Temperature Service
- A 234  Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures
- A 333  Specification for Seamless and Welded Steel Pipe for Low Temperature Service
- A 350  Specification for Forgings, Carbon and Low Alloy Steel Requiring Notch Toughness Testing for Piping Components
- A 352  Specification for Steel Castings, Ferritic and Martensitic for Pressure Containing Parts Suitable for Low Temperature Service
- A 420  Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low Temperature Service
- A 694  Specification for Forgings, carbon and Alloy Steel for Pipe Flanges, Fittings, Valves and Parts for High Pressure Transmission Service
- A 707  Specification for Flanges, Forged, Carbon and Alloy Steel for Low Temperature Service

**Problem Set 2**

1.  1. A project award has been made. At the kick off meeting, the PM advises that piping design will be to B31.4. The facility is steam piping in a refinery extending from the boiler to the tank farm. What do you do or say and why?

2.  2. A liquid pipeline is to be built to Z184. You raise an issue. Why?

3.  3. What flange specification would you expect to reference for a gas pipeline facility?

Show the development of your answers.
Section 1 – References

Due to copyright laws, the following figures have not been published here. We leave as an exercise for the user to retrieve these for reference.

Fig 100.1.2(B) of ASME B31.1
Fig 300.1.1 of ASME B31.3 1996
Fig 300.1.1 of ASME B31.3 1999
Fig 400.1.1 of ASME B31.4
Fig 400.1.2 of ASME B31.4
Fig 1.1 of CSA Z 662
Fig 1.2 of CSA Z 662
Table of Contents CSA Z 662
3.0 Supplemental Documents

3.1 Owner’s Specifications & Documents

Many of the Owners in the industries we service are technically sophisticated and will often have supplementary specifications, standards or practices. It is the intent of these documents to clarify and provide interpretation of the legislated Codes and industry-accepted standards specific to the Owner’s facilities.

These specifications typically go beyond the requirements of Codes and without exception do not contravene a Code requirement.

3.2 Contractor’s Specifications & Documents

Engineering contractors may be called upon to provide the engineering specifications for a project if an Owner does not have his own standards or if required by terms of the contract.

Problem Set 3

1 1 What is the typical precedence of documents for engineering standards?
2 2 Can the Owner’s engineering standard override a Code provision?
3 3 Under what conditions can the Owner’s standard override a Code provision?
4 4 How would you deviate from an Owner’s engineering specification?
4.0 Piping Design

Piping design deals with the:

- analytical design
- material selection
- geometric layout
- fabrication
- inspection specification
- component specification

of piping and piping components.

4.1 Failure Mechanisms

Piping and piping components may fail if inadequately designed, by a number of different mechanisms. These failures, in the majority of cases are either load controlled or displacement controlled failures.

- Pipe rupture due to overpressure
- Bending failure in pipe span
- Elbow cracking after 10 years of service, 5000 cycles of heat up to 500 F
- On heat up, a line comes into contact with adjacent header which is at ambient temperature
- During startup on a cold winter day in Grande Prairie, an outdoor gas line located above grade and constructed to Z662 is suddenly subjected to full line pressure and ruptures.
- A 12” Sch.40 header, bottom supported, 40 feet long runs vertically up a tower and connects to a nozzle. On steam out of the vessel, a 1’ deflection is observed in the pipe and remains after the steam out procedure is completed and the pipe returns to ambient temperature.
- A header of a reciprocating compressor has been stressed checked; during operation vibration is observed in the line. During the unit turnaround, cracking is found at midspan in the wrought piping material.
- A stress check determines that a hot, high alloy line does not pass the flexibility requirements per B31.3. Twenty-five cycles are expected over the lifetime of the line.

4.2 Code Considerations for Design

Design of piping systems is governed by Codes. All codes have a common theme, they are intended to set forth engineering requirements deemed necessary for safe design and construction of piping installations.

The Codes are not intended to apply to the operation, examination, inspection, testing, maintenance or repair of piping that has been placed in service. The Codes do not prevent the User from applying the provisions of the Codes for those purposes.

Engineering requirements of the Codes, while considered necessary and adequate for safe design, generally use a simplified approach. A designer capable of applying a more rigorous analysis shall have the latitude to do so, but must be able to demonstrate the validity of such analysis.
Design Conditions

Design conditions refer to the operating and design temperature and pressure that the piping system will operate at over the course of its design life.
### Code Design Temperature & Design Pressure

<table>
<thead>
<tr>
<th>Code</th>
<th>Design Temperature</th>
<th>Design Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>B31.1</td>
<td>The piping shall be designed for a metal temperature representing the maximum sustained condition expected. The design temperature shall be assumed to be the same as the fluid temperature unless calculations or tests support the use of other data, in which case the design temperature shall not be less than the average of the fluid temperature and the outside wall temperature.</td>
<td>The internal design pressure shall be not less than the maximum sustained operating pressure (MSOP) within the piping system including the effects of static head.</td>
</tr>
<tr>
<td>B31.3</td>
<td>The design temperature of each component in a piping system is the temperature at which, under the coincident pressure, the greatest thickness or highest component rating is required in accordance with par. 301.2</td>
<td>The design pressure of each component in a piping system shall be not less than the pressure at the most severe condition of coincident internal or external pressure and temperature expected during service, except as provided in par. 302.2.4.</td>
</tr>
<tr>
<td>B31.4</td>
<td>The design temperature is the metal temperature expected in normal operation. It is not necessary to vary the design stress for metal temperatures between –20 °F and 250 °F.</td>
<td>The piping component at any point in the piping system shall be designed for an internal design pressure which shall not be less than the maximum steady state operating pressure at that point, or less than the static head pressure at that point with the line in a static condition. The maximum steady state operating pressure shall be the sum of the static head pressure, pressure required to overcome friction losses and any required back pressure.</td>
</tr>
<tr>
<td>B31.8</td>
<td>No design temperature. The Code mentions only ambient temperature and ground temperature. (1975)</td>
<td>Design pressure is the maximum operating pressure permitted by the Code, as determined by the design procedures applicable to the materials and locations involved.</td>
</tr>
<tr>
<td>Z662</td>
<td>For restrained piping, the temperature differential shall be the difference between the maximum flowing fluid temperature and the metal temperature at the time of restraint. For unrestrained piping, the thermal expansion range to be used in the flexibility analysis shall be the difference between the maximum and minimum operating temperatures.</td>
<td>The design pressure at any specific location shall be specified by the designer, shall not be less than the intended maximum operating pressure at any location, and shall include static head, pressure required to overcome friction loss and any required back pressure.</td>
</tr>
</tbody>
</table>

### Design of Piping – B31.1

B31.1 essentially limits the pressure design consideration to three items:

**Minimum thickness for pressure:**

\[
\begin{align*}
t_{\text{min}} &= \frac{(P + D_0)}{2(SE + PY)} + A, \text{ or} \\
&= \frac{P * d + 2SE + 2yPA}{2(SE + Py - P)}
\end{align*}
\]

The limit is based on the limit stress being less than the basic allowable stress at temperature. This limit is based on the static yield strength of the material.
Maximum longitudinal stress due to sustained loadings ($S_L$):

$S_L \leq S_h$; stress due to sustained loadings shall be less than the basic allowable stress at temperature. Sustained loadings are those due to pressure, self weight of contents & piping and other sustained loadings particular to the situation. The limit is based on the static yield strength of the material.

$$S_L = \frac{P \cdot D_0}{4 \cdot n}$$

The computed displacement stress range $S_E$:

$S_E \leq SA = f(1.25 S_c + 0.25 S_h)$. $S_E$ stresses arise from the constraint of the thermal strain displacements associated with the expansion of pipe due to temperature. The limit is based on fatigue considerations.

Where the sum of the longitudinal stresses is less than $S_h$, the difference may be used as an additional thermal expansion allowance.

$$S_E = \sqrt{S_b^2 + 4 \cdot S_t^2}$$

$$S_b = \sqrt{\frac{i_i M_i^2 + i_o M_o^2}{Z}}$$

The computed displacement stress range $S_E$:

The factor “f” is a stress range reduction factor:

<table>
<thead>
<tr>
<th>Cycles, N</th>
<th>Factor, f</th>
</tr>
</thead>
<tbody>
<tr>
<td>7,000 and less</td>
<td>1.0</td>
</tr>
<tr>
<td>&gt; 7,000 to 14,000</td>
<td>0.9</td>
</tr>
<tr>
<td>&gt;14,000 to 22,000</td>
<td>0.8</td>
</tr>
<tr>
<td>&gt; 22,000 to 45,000</td>
<td>0.7</td>
</tr>
<tr>
<td>&gt; 45,000 to 100,000</td>
<td>0.6</td>
</tr>
<tr>
<td>&gt; 100,000 to 200,000</td>
<td>0.5</td>
</tr>
<tr>
<td>&gt; 200,000 to 700,000</td>
<td>0.4</td>
</tr>
<tr>
<td>&gt; 700,000 to 2,000,000</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Design of Piping – B31.3

B31.3 essentially limits the pressure design consideration to three items:

**Minimum thickness for pressure:**

\[
\frac{P \times D}{2(SE + PY)} \quad \text{or} \quad \frac{P \times D}{2SE} \quad \text{or} \quad t = \frac{D}{2} \left(1 - \frac{SE - P}{SE + P}\right) \quad \text{(Lamé Equation)}
\]

The limit is based on the limit stress being less than the basic allowable stress at temperature. This limit is based on the static yield strength of the material.

**Maximum longitudinal stress due to sustained loadings (S_L):**

\[S_L \leq S_h;\] stress due to sustained loadings shall be less than the basic allowable stress at temperature. Sustained loadings are those due to pressure, self weight of contents & piping and other sustained loadings particular to the situation. The limit is based on the static yield strength of the material.

**The computed displacement stress range S_E:**

\[S_E \leq SA = f(1.25 S_c + 0.25 S_h);\] \(S_E\) stresses arise from the constraint of the thermal strain displacements associated with the expansion of pipe due to temperature. The limit is based on fatigue considerations.

Where the sum of the longitudinal stresses is less than \(S_h\), the difference may be used as an additional thermal expansion allowance.
Design of Piping – B31.4

B31.4 essentially limits the pressure design consideration to three items:

**Minimum thickness for pressure:**

\[
t = \frac{PD}{2S}
\]

The limit is based on the limit stress being less than the basic allowable stress at temperature. This limit is based on the static yield strength of the material.

\[
S = 0.72 \times E \times SMYS,
\]

where SMYS is the specified minimum yield strength of the material

**Maximum longitudinal stress due to sustained loadings \(S_L\):**

\[
S_L \leq 0.75 \times S_A
\]

where \(S_A = 0.72 \times SMYS\)

\(S_L\), the stress due to sustained loadings shall be less than 0.75 x the allowable stress range, \(S_A\) at temperature. Sustained loadings are those due to pressure, self weight of contents & piping and other sustained loadings particular to the situation.

**The computed displacement stress range \(S_E\):**

For restrained lines:

\[
S_L = E \times a \times \Delta T - v \times S_h \leq 0.9SMYS
\]

For unrestrained lines:

\[
S_E \leq S_A
\]
Design of Piping – B31.8

B31.8 (1975) essentially limits the pressure design consideration to three items:

**Design pressure:**

\[ P = \frac{2\cdot S\cdot t}{D} \cdot F \cdot E \cdot T \]

- **F** = design factor for construction type (includes a location factor)
- **E** = longitudinal joint factor
- **T** = temperature derating factor
- **SMYS**

Where SMYS is the specified minimum yield strength of the material

**Total combined stress:**

The total of the following shall not exceed **S**:

a) Combined stress due to expansion
b) Longitudinal pressure stress
c) Longitudinal bending stress due to internal + external loads

Further,

The sum of (b) + (c) \(\leq 0.75 \cdot S \cdot F \cdot T\)

**The computed displacement stress range \(S_E\):**

B31.8 applies itself to the above ground piping in discussing expansion and flexibility to a temperature of 450 °F.

For these “unrestrained” lines:

\[ S_E \leq 0.72 \cdot S \]
Design of Piping – CSA Z662

Z662 essentially limits the pressure design consideration to three items:

**Pressure Design:**

\[
P = \frac{2S^* t \times 10^3 \times F \times L \times J \times T}{D} ; \text{ units are metric}
\]

* F = design factor = 0.8
* L = location factor per Table 4.1 (appear to be safety factors)
* J = longitudinal joint factor
* T = temperature derating factor
* S = Specified Minimum Yield Strength (SMYS)

**Maximum longitudinal stress due to sustained loadings (S_L):**

For restrained lines (below ground):

\[
S_h - S_L + S_B \leq 0.90 \cdot S \cdot T ; \text{ where, } S_L = \nu \cdot S_h - E \cdot a \cdot \Delta T \quad \text{(below ground)}
\]

* note conservatism with respect to definition of $\Delta T$, Code requires use of temperature at time of restraint

For unrestrained lines (above ground, freely spanning segments):

\[
S_h - S_L + S_B \leq S \cdot T ; \quad \text{(above ground, freely spanning segments)}
\]

**The computed displacement stress range $S_E$:**

For unrestrained lines (above ground):

\[
S_E \leq 0.72 \cdot S \cdot T
\]
Design of Piping

The Design Effort Continuum

**Code**

Calculation Method

- Simple
- Complex

**Code +**

Answer Quality

- Conservative
- Accurate

Effort

- Least
- Most
Design Loads

The Codes prescribe minimum rules for stress conditions and alert the designer explicitly to some of the loadings likely to act on a system. In addition to the previous listing, most of the Codes specify design rules for:

- Occasional loads such as wind & earthquake
- External pressure

The Codes caution the designer to consider the effect of other loadings and their impact on the stress state of the system:

- Impact events (hydraulic shock, liquid & solid slugging, flashing, transients)
- Auto-refrigeration, seasonal temperature variations
- Vibration
- Discharge reactions
- Temperature gradients
- Bi-metallic connections
- Effects of support & restraint movements
- Cyclic effects

The Codes do not explicitly alert the designer to other loadings which may cause failure in the piping system, including:

- Buckling (shell & column)
- Nozzle loadings on attached equipment, such as pumps, compressors, engines
- Pressure vessels
- Steam generating equipment
- Fired heaters
- Heat exchangers
- Loadings on in-line equipment such as flanges, valves, filters, strainers
4.3 Material Selection

Key Considerations
• Material specification
• Chemical Composition
• Mechanical Properties
  • Brittle fracture toughness
  • Carbon equivalent
• Inspection
• Repair Welding Procedure

Let’s discuss a couple of these considerations at this time.

Material Selection – Common Specifications for Carbon Steel Systems

<table>
<thead>
<tr>
<th>Commodity</th>
<th>B31.1</th>
<th>B31.3</th>
<th>B31.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>ASTM A 106</td>
<td>ASTM A 53</td>
<td>ASTM A 53</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipe – Low Temp</td>
<td>ASTM A 333 Gr.6</td>
<td>ASTM A 333 Gr.6</td>
<td>ASTM A 333 Gr.6</td>
</tr>
<tr>
<td>Pipe – High Temp</td>
<td>ASTM A 106</td>
<td>ASTM A 106</td>
<td>ASTM A 106</td>
</tr>
<tr>
<td>Bolting</td>
<td>ASTM A 193 B7</td>
<td>ASTM A 193 B7</td>
<td>ASTM A 193 B7</td>
</tr>
<tr>
<td>Nut</td>
<td>ASTM A 194 2H</td>
<td>ASTM A 194 2H</td>
<td>ASTM A 194 2H</td>
</tr>
<tr>
<td>Fittings</td>
<td>ASTM A 234 WPB</td>
<td>ASTM A 234 WPB</td>
<td>ASTM A 234 WPB</td>
</tr>
<tr>
<td>Fittings – Low Temp</td>
<td>ASTM A 420 WPL6</td>
<td>ASTM A 420 WPL6</td>
<td>ASTM A 420 WPL6</td>
</tr>
<tr>
<td>Fittings – High Temp</td>
<td>ASTM A 234 WPB</td>
<td>ASTM A 234 WPB</td>
<td>ASTM A 234 WPB</td>
</tr>
<tr>
<td></td>
<td>ASTM A 216 WCB</td>
<td>ASTM A 216 WCB</td>
<td>ASTM A 216 WCB</td>
</tr>
<tr>
<td>Flanges</td>
<td>ASTM A 105</td>
<td>ASTM A 105</td>
<td>ASTM A 105</td>
</tr>
<tr>
<td></td>
<td>ASTM A 181</td>
<td>ASTM A 181</td>
<td>ASTM A 181</td>
</tr>
<tr>
<td></td>
<td>ASME B16.5</td>
<td>ASME B16.5</td>
<td>ASME B16.5</td>
</tr>
<tr>
<td>Flanges – Low Temp</td>
<td>ASTM A 350 LF2</td>
<td>ASTM A 350 LF2</td>
<td>ASTM A 350 LF2</td>
</tr>
<tr>
<td></td>
<td>ASTM A 352 LCB</td>
<td>ASTM A 352 LCB</td>
<td>ASTM A 352 LCB</td>
</tr>
<tr>
<td>Flanges – High Temp</td>
<td>ASTM A 105</td>
<td>ASTM A 105</td>
<td>ASTM A 105</td>
</tr>
<tr>
<td></td>
<td>ASTM A 181</td>
<td>ASTM A 181</td>
<td>ASTM A 181</td>
</tr>
<tr>
<td></td>
<td>ASTM A 216 WCB</td>
<td>ASTM A 216 WCB</td>
<td>ASTM A 216 WCB</td>
</tr>
<tr>
<td>Valves</td>
<td>ASTM A 105</td>
<td>ASTM A 105</td>
<td>API 6D</td>
</tr>
<tr>
<td></td>
<td>ASME B16.34</td>
<td>API 600</td>
<td>API 600</td>
</tr>
<tr>
<td>Valves – Low Temp</td>
<td>ASTM A 350 LF2</td>
<td>ASTM A 350 LF2</td>
<td>ASTM A 350 LF2</td>
</tr>
<tr>
<td></td>
<td>ASTM A 352 LCB</td>
<td>ASTM A 352 LCB</td>
<td>ASTM A 352 LCB</td>
</tr>
<tr>
<td>Valves – High Temp</td>
<td>ASTM A 216 WCB</td>
<td>ASTM A 216 WCB</td>
<td>ASTM A 216 WCB</td>
</tr>
</tbody>
</table>
As can be seen from the Table, material selection can be made from available national standards such as ASTM and API.
### Material Selection – Common Specifications for Carbon Steel Systems (cont’d)

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Specification</th>
<th>CSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>B31.8</td>
<td>CSA Z662</td>
</tr>
<tr>
<td>Pipe – Low Temp</td>
<td>ASTM A 53</td>
<td>CSA Z 245.1</td>
</tr>
<tr>
<td></td>
<td>API 5L</td>
<td></td>
</tr>
<tr>
<td>Pipe – High Temp</td>
<td>ASTM A 333 Gr.6</td>
<td>CSA Z 245.1</td>
</tr>
<tr>
<td>Bolting</td>
<td>ASTM A 193 B7</td>
<td>CSA Z 245.1</td>
</tr>
<tr>
<td></td>
<td>ASTM A 354</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ASTM A 449</td>
<td></td>
</tr>
<tr>
<td>Nut</td>
<td>ASTM A 194 2H</td>
<td></td>
</tr>
<tr>
<td>Fittings</td>
<td>MSS SP-75</td>
<td>CSA Z 245.11</td>
</tr>
<tr>
<td>Fittings – Low Temp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fittings – High Temp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flanges</td>
<td>ASTM A 105</td>
<td>CSA Z 245.12</td>
</tr>
<tr>
<td></td>
<td>ASTM A 372</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MSS SP-44</td>
<td></td>
</tr>
<tr>
<td>Flanges – Low Temp</td>
<td></td>
<td>CSA Z 245.12</td>
</tr>
<tr>
<td>Flanges – High Temp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valves</td>
<td>ASTM A 105</td>
<td>CSA Z 245.15</td>
</tr>
<tr>
<td></td>
<td>API 6D</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ASME B16.34</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ASME B16.38</td>
<td></td>
</tr>
<tr>
<td>Valves – Low Temp</td>
<td></td>
<td>CSA Z 245.15</td>
</tr>
<tr>
<td>Valves – High Temp</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Brittle Fracture

Brittle fracture refers to the often catastrophic failure of materials when subjected to stresses at a lower temperature which the material would normally be able to withstand at higher temperatures.

A “transition temperature” can be defined at the 13.5, 20, 27 J (10, 15, 20 ft-lb) energy level.

Charpy test results for steel plate obtained from failures of Liberty ships revealed that plate failure never occurred at temperatures greater than the 20-J (15 ft-lb) transition temperature.

This transition temperature varies with the material and is not used as a criterion.

Transition Temperatures

The transition temperature establishes the temperature at which a material “goes brittle”. It’s major shortcoming is it’s imprecision and non-repeatability.

Charpy Testing

Impact testing provides a repeatable means to establish the impact toughness capability of a material under temperature. The more common method is the Charpy drop test measurement which determines the energy absorbing capacity of a standard specimen.

Minimum Required Charpy V Notch Impact Values (B31.3-1999)

<table>
<thead>
<tr>
<th>Specified Minimum Tensile Strength</th>
<th>Number of Specimens</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Fully Deoxidized Steels</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Joules</td>
</tr>
<tr>
<td>(a) Carbon &amp; Low Alloy Steels</td>
<td>Average for 3 specimens</td>
<td></td>
</tr>
<tr>
<td>SMTS ≤ 65 ksi</td>
<td>Minimum for 1 specimen</td>
<td></td>
</tr>
<tr>
<td>65 ksi &lt; SMTS ≤ 75 ksi</td>
<td></td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>75 ksi &gt; SMTS &lt; 95 ksi</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral Expansion</td>
<td></td>
<td>96 ksi &lt; SMTS Minimum for 3 specimen</td>
</tr>
<tr>
<td>(b) Steels in P-Nos. 6, 7, 8</td>
<td>Minimum for 3 specimen</td>
<td></td>
</tr>
</tbody>
</table>
Impact Testing Exemption Temperatures – B31.3

Refer to Figure 323.2.2 in the Code.

This figure provides a correlation between material group, reference thickness and exemption temperature.

Material group is defined in Table A-1. For example, SA 106 B is given a Min Temp rating of “B”. Entering Figure 323.2.2A, this material is impact testing exempt up to a thickness of 0.5” down to a minimum temperature of –20 F. Curve B rises to a minimum temperature of 75 F for a material thickness of 3”.

Minimum Required Charpy V Notch Impact Values (CSA Z 662-1999)

Table 5.1 provides a toughness category matrix. This matrix is somewhat cumbersome to apply as it requires cross referencing to CSA Z 245 and makes use of toughness categories I, II & III. It is not intuitively obvious what these categories represent.

This Table also inherently provides for a risk based approach by bringing in service fluid, test fluid and pipe design operating stress parameters.

Case Study:

On the next page, the Material Requisition Form has certain boxes marked off to indicated inspection needs. Not all marked boxes are appropriate! Do you know which?
**INSPECTION REQUIREMENTS**

<table>
<thead>
<tr>
<th>Project No.</th>
<th>Project Name</th>
<th>Requisition No.</th>
<th>Page 1 of 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Equipment / Material**  
Large Bore Flanges & Fittings

**DOCUMENTATION:** In addition to the copies required in Section III, one copy of the Documents marked (X) must be provided by the Vendor to the Inspector when he/she visits the Shop.

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Document</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASME Code Report</td>
<td>X</td>
</tr>
<tr>
<td>Material Certificates (Mech. and Chem. Test Reports)</td>
<td></td>
</tr>
<tr>
<td>Charpy Impact Tests</td>
<td></td>
</tr>
<tr>
<td>Postweld Heat Treatment</td>
<td></td>
</tr>
<tr>
<td>Hardness Test</td>
<td></td>
</tr>
<tr>
<td>Performance Test Curves</td>
<td></td>
</tr>
<tr>
<td>Nameplate Rubbings or Fascimile</td>
<td></td>
</tr>
<tr>
<td>Certificate of Compliance</td>
<td></td>
</tr>
<tr>
<td>Certificate of Compliance (Batch Tests)</td>
<td></td>
</tr>
<tr>
<td>Union Label (Describe)</td>
<td></td>
</tr>
<tr>
<td>Valve Manufacturer’s Certificate</td>
<td></td>
</tr>
<tr>
<td>Surface Preparation and Coating Reports</td>
<td></td>
</tr>
</tbody>
</table>

**PROCEDURES:** The procedures and qualifications checked below are subject to approval by engineering prior to fabrication.

<table>
<thead>
<tr>
<th>Procedure Type</th>
<th>Document</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Pot Test Procedures</td>
<td>Tube Rolling Procedures</td>
</tr>
<tr>
<td>Motor Test Procedures</td>
<td>Tube Cleaning and Installation Procedure</td>
</tr>
<tr>
<td>Machining Procedures</td>
<td>Quality Control Procedures</td>
</tr>
<tr>
<td>Welding Procedures (WPS and PQR)</td>
<td>Surface Preparation, Painting &amp; Coating Procedures</td>
</tr>
<tr>
<td>Welding Repair Procedures (WPS and PQR)</td>
<td>Preparation for Shipment Procedure</td>
</tr>
<tr>
<td>Noise Test Procedures</td>
<td>Performance Test Procedure</td>
</tr>
<tr>
<td>Routine Electrical Procedures</td>
<td>Material Hardness Test Procedures</td>
</tr>
<tr>
<td>NDT Procedures</td>
<td>QC Inspection and Test Plan</td>
</tr>
<tr>
<td>Heat Treatment Procedure</td>
<td>Calibration Procedure</td>
</tr>
<tr>
<td>Casting Repair Procedure</td>
<td></td>
</tr>
<tr>
<td>Hydrotest Procedure</td>
<td></td>
</tr>
</tbody>
</table>

**INSPECTION CHECKLIST:** The Inspector may check (C), review (R), approve (A) and/or witness (W) the following items marked (X) below.

<table>
<thead>
<tr>
<th>Inspection Item</th>
<th>Document</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welder’s Qualifications (R)</td>
<td>Sandblast, Painting, Coating and Galvanizing (A)</td>
</tr>
<tr>
<td>Drawing and Procedures (R)</td>
<td>Mechanical/Electrical/Pneumatic Run Test (W &amp; A)</td>
</tr>
<tr>
<td>Material Test Reports (C, R, &amp; A)</td>
<td>Nameplates, Tagging (C); Marking</td>
</tr>
<tr>
<td>Hydrotest (C)</td>
<td>Machining Tolerances (C)</td>
</tr>
<tr>
<td>Performance Test (W on one pump per model)</td>
<td>Tube Cleaning and Installation Marking (C)</td>
</tr>
<tr>
<td>Complete Train Test (W &amp; A)</td>
<td>Tube Bundle Insertion (W &amp; A)</td>
</tr>
<tr>
<td>NPSH Test (A) One per pump model</td>
<td>Shop Fit Up Prior to Assembly (W)</td>
</tr>
<tr>
<td>Sound Level Test</td>
<td>Compliance with Specifications (C)</td>
</tr>
<tr>
<td>Dimensional Check (C)</td>
<td>Cleanliness Prior to Shipmen (C)</td>
</tr>
<tr>
<td>NDT (R)</td>
<td>Electrical and Mechanical Runout (C)</td>
</tr>
<tr>
<td>Charts (C)</td>
<td>Wiring Continuity/High Pot Test (C)</td>
</tr>
<tr>
<td>Rotor Balancing (R)</td>
<td>Flange Finish (C)</td>
</tr>
<tr>
<td>Compliance w/ Dimensional Outline Drawing (C)</td>
<td>Final Equipment Inspection (A)</td>
</tr>
<tr>
<td>Compliance w/ Vendor’s P&amp;ID (C)</td>
<td>Final Packaging Inspection (W &amp; A)</td>
</tr>
<tr>
<td>Coupling Type and Size (R)</td>
<td>Seal Pressure Test (C)</td>
</tr>
<tr>
<td>Coupling Hub Contact</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** 1) The Contractor’s inspector or designate shall have access to Vendor’s premises for the purpose of documentation auditing or source inspection.

Note: Mark all revisions in column “R” with revision number.
4.4 Fabricated Tees & Area Reinforcement

Paragraph 304.3.2 of the Code provides explicit direction on the proper design of branch connections.

In summary, this paragraph states that branch connections must be made using fittings that are inherently reinforced such as those listed in Table 326.1 or fabricated and sufficiently reinforced using design criteria based on area reinforcement principles. This presumes that a branch connection opening weakens the pipe wall and requires reinforcement by replacement of the removed area to the extent it is in excess to that required for pressure containment. The Code is fully detailed in the necessary calculations. These calculations can be very tedious, time consuming prone to error if done by hand. A computer program is advised for productivity; a spreadsheet based program is more than adequate.

No calculation is required for branch connections made by welding a threaded or socket weld coupling or half coupling if the branch does not exceed 2 NPS nor \( \frac{1}{4} \) the nominal size of the run line. The coupling cannot be rated for less than 2000 CWP.

Multiple openings are addressed by the Code.

The area reinforcement rule can be at times, be overly conservative; in other instances, this approach can be deficient even within the limits of applicability defined in the Code. Code users must be aware of the limits of applicability of the Code rules which are given in paragraph 304.3.1. Jurisdictions such as the Alberta Boiler Safety Association (ABSA) have defined additional limits. WRC publications also have guidance on this issue.
4.5 Flexibility Analysis

Stress Analysis Criteria:
This stress analysis criteria establishes the procedure, lists critical lines and piping stress/design liaison flow sheet to be followed.

Lines to be analyzed:

- all lines attached to pumps, compressors, turbines and other rotating equipment
- all lines attached to reciprocating compressors
- all pressure relief valve piping
- all category M piping
- all lines on racks (with discretion)
- all lines which the piping designer is uncomfortable with
- all vacuum lines
- all jacketed piping
- all tie-ins to existing piping
- all non metallic piping
- all steam out, decoking and regeneration lines
- all lines 16” and larger
- all lines 6” and larger over 500 F
- all lines over 750 F
- all lines specifically requested by the stress department.
- all lines specifically requested by the Client.

The above list is actually very conservative and discretion is required in applying these rules to ensure economical approach to piping analysis.

Paragraph 319.4.1 lists the conditions under which flexibility analysis may be waived.

If formal analysis is deemed necessary, follow the requirements of paragraph 319.4.2.

The other Codes will have similar provisions.

Exam

There is no exam; take a break!