**CONTENTS**

**ASME B31 Piping System Standards**

| No. | Title | Typical Coverage |
|---|---|---|
| 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 systems |
| B31.3 | Process Piping | piping typically found in petroleum refineries, chemical, textile, paper, semiconductor and cryogenic plants, and related processing plants and terminals |
| B31.4 | Liquid transportation Piping | piping transporting products which are predominately liquid 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 | 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 B31.1 |
| B31.11 | Slurry Transportation Piping | piping transporting aqueous slurries between plants and terminals and within terminals, pumping and regulating stations |
| BPE-1 | Bioprocessing Equipment | piping and equipment for bioprocess applications, including requirements for sterility and cleanability, surface finish, material joining and seals |
| PVHO-1 | Pressure Vessels for Human Occupancy | piping in pressure vessels occupied by humans such as submersibles, diving bells, decompression chambers, and hyperbaric chambers, in addition to the requirements for the PVHO |
| HPS | High Pressure Systems | piping system requirements for high pressure systems not covered in B31.3 and equipment requirements not covered the ASME B&PV Code |
| B&PV Code Section III | Nuclear Power Plants | NB-3600 – Class 1 Piping<br>NC/ND-3600 – Class 2/3 Piping (similar to B31.1)<br>Code Case N47 – Class 1 components in elevated temperature service |

**National Fire Protection Association (NFPA) Piping System Standards (selected)**

| No. | Title |
|---|---|
| 13 | Installation of Sprinkler Systems |
| 14 | Installation of Standpipe, Private Hydrant, and Hose Systems |
| 15 | Water Spray Fixed Systems for Fire Protection |
| 16 | Installation of Foam-Water Sprinkler and Foam-Water Spray Systems |
| 24 | Installation of Private Fire Service Mains and Their Appurtenances |
| 54 | National Fuel Gas Code |
| 58 | Liquefied Petroleum Gas Code |
| 59A | Production, Storage, and Handling of Liquefied Natural Gas (LNG) |

**Canadian Standards Association**

| No. | Title |
|---|---|
| Z662 | Oil and Gas Pipeline Systems |

**Compressed Gas Association (CGA) Piping System Standards (selected)**

| No. | Title |
|---|---|
| G2.1 | Requirements for the Storage and Handling of Anhydrous Ammonia (ANSI K61.1) |
| G4.4 | Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems |
| G5.4 | Standard for Hydrogen Piping Systems at Consumer Locations |

**Chlorine Institute Piping System Standards (selected)**

| No. | Title |
|---|---|
| 006 | Piping Systems for Dry Chlorine |
| 060 | Chlorine Pipelines |
| 094 | Sodium Hydroxide Solution and Potassium Hydroxide Solution (Caustic): Storage Equipment and Piping Systems |
| 163 | Hydrochloric Acid Storage and Piping Systems |

## HISTORY OF B31.3

In 1926 the American Standards Institute initiated Project B31 to develop a piping code. ASME was the sole administrative sponsor. The fIrst publication of this document, American Tentative Standard code for Pressure Piping, occurred in 1935. From 1942 through 1955, the code was published as the American Standard Code for Pressure Piping, ASA B31.1. It was composed of separate sections for different industries.

These sections were split off, starting in 1955 with the Gas Transmission and Distribution Piping Systems, ASA B31.8. ASA B31.3, Petroleum Refinery Piping Code Section was first published in 1959. A number of separate sections have been prepared, most of which have been published. The various section designations follow.

B31.1 Power Piping
B31.2 Fuel Gas Piping (withdrawn in 1988)
B31.3 Process Piping
B31.4 Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols
B31.5 Refrigeration Piping
B31.6 Chemical Plant Piping (never published)
B31.7 Nuclear Piping (moved to B&PV Code Section III)
B31.8 Gas Transmission and Distribution Piping Systems
B31.9 Building Services Piping
B31.10 Cryogenic Piping (never published)
B31.11 Slurry Piping
B31.12 Hydrogen Piping (project started in 2004)

A draft of the section for Chemical Plant Piping, B31.6, was completed in 1974. However, it was decided to merge this section into B31.3 because the two code sections were closely related. A joint code section, Chemical Plant and Petroleum Refinery Piping, was published in 1976. It was at this time that items such as fluid service categories such as Category M, nonmetallic piping, and safeguarding were introduced into B31.3.

In 1980 the nonmetals portions of the B31.3 Code were gathered and combined into one chapter, Chapter VII.

A draft code for Cryogenic Piping had been prepared by Section Committee B31.10 and was ready for approval in 1981. Again, since the coverage overlapped with B31.3, it was decided to merge the Section Committees and develop a single inclusive Code. This Code was issued in 1984.

In addition, in 1984 another potentially separate code was added as new chapter to B31.3, High Pressure Piping, Chapter IX.

The resulting document is a Code that is very broad in scope. It covers fluids as benign as water and as hazardous as mustard gas. It covers temperatures from cryogenic conditions to l500°F and beyond. It covers pressures from vacuum and atmospheric to 50,000 psi and higher. Part of the philosophy of the Code stems from this broad coverage. There is a great deal of responsibility placed with the Owner and latitude to use good engineering.

With respect to the initials that appear in front of B31.3, these have been ASA, ANSI and ASME. It is currently correct to refer to the Code as ASME B31.3. The initial designation ASA referred to the American Standards Association. This became the United States of America Standards Institute and then the American National Standards Institute between 1967 and 1969. Thus, ASA was changed to ANSI. In 1978, the Standards Committee was reorganized as a committee operating under ASME procedures with ANSI accreditation. Therefore, the initials ASME now appear in front of B31.3. These changes in acronyms have not changed the B31.3 committee structure or the Code.

## CODE ORGANIZATION

| | |
|---|---|
| Chapter I | Scope and Definitions |
| Chapter II | Design |
| Part 1 | Conditions and Criteria |
| Part 2 | Pressure Design of Piping Components |
| Part 3 | Fluid Service Requirements for Piping Components |
| Part 4 | Fluid Service Requirements for Piping Joints |
| Part 5 | Flexibility and Support |
| Part 6 | Systems |
| Chapter III | Materials |
| Chapter IV | Standards and Piping Components |
| Chapter V | Fabrication, Assembly, and Erection |
| Chapter VI | Inspection, Examination and Testing |
| Chapter VII | Nonmetallic Piping and Piping Lined with Nonmetals |
| Chapter VIII | Piping for Category M Fluid Service |
| Chapter IX | High Pressure Piping |
| Appendices | |
| A | Allowable Stresses and Quality Factors for Metallic Piping and Bolting Materials |
| B | Stress Tables and Allowable Pressure Tables for Nonmetals |
| C | Physical Properties of Piping Materials |
| D | Flexibility and Stress Intensification Factors |
| E | Reference Standards |
| F | Precautionary Considerations |
| G | Safeguarding |
| H | Sample Calculations for Branch Reinforcement |
| J | Nomenclature |
| K | Allowable Stress for High Pressure Piping |
| L | Aluminum Alloy Pipe Flanges |
| M | Guide to Classifying Fluid Services |
| Q | Quality System Program |
| V | Allowable Variations in Elevated Temperature Service |
| X | Metallic Bellows Expansion Joints |
| Z | Preparation of Technical Inquiries |

## ASME B31.3 FLUID SERVICE CONTAINMENT SYSTEM CHARACTERISTICS

| B31.3 Fluid Service | B31.3 Definition | Containment System Characteristics |
|---|---|---|
| Category D [Utility] | *Category D fluid Service:* a fluid service in which all of the following apply:<br>1) the fluid handled is nonflammable, nontoxic, and not damaging to human tissues…<br>2) the design gage pressure does not exceed 1035 kPa (150 psi), and<br>3) the design temperature is from -29ºC (-20ºF) to 186ºC (366ºF). | Lowest cost<br>Usually not fire resistant<br>Usually not blow-out resistant |
| Normal [Process] | *Normal Fluid Service:* a fluid service pertaining to most piping covered by this Code, i.e., not subject to the rules of Category D, Category M or High Pressure Fluid Service. | Moderate cost<br>May be fire resistant or not<br>May be blow-out resistant or not |
| High Pressure | *High Pressure Fluid Service:* a fluid service for which the owner specifies the use of Chapter IX for piping design and construction. | High cost<br>Usually fire resistant<br>Usually blow-out resistant |
| Category M [Lethal] | *Category M Fluid Service:* a fluid service in which the potential for personnel exposure is judged to be significant and in which a single exposure to a very small quantity of a toxic fluid, caused by leakage, can produce serious irreversible harm to persons on breathing or bodily contact, even when prompt restorative measures are taken. | High cost<br>Usually fire resistant<br>Usually blow-out resistant |

| **ASME B31.3 FLUID SERVICE WORKSHOP** For the fluid services described, what B31.3 fluid service definition is most nearly applicable? | | **PIPE AND FITTING SELECTION WORKSHOP** For the fluid services described, what piping system attributes and components would you select? | | | | |
|---|---|---|---|---|---|---|
| **Fluid Service** | **B31.3 Fluid Service** | **Fire Resistant?** | **Blow-out Resistant?** | **Material of Construction** | **Pressure Class** | **Thd, SW or BW NPS < 2?** |
| Steam condensate piping NPS ½ - 8. Downstream of an atmospheric flash tank, so maximum temperature is 212°F (100°C). Maximum pressure is 90 psig (6 bar). | | | | | | |
| Dry chlorine liquid, NPS ¾ - 4. Chlorine rail car to vaporizer. Relief pressure is 710 psig (49 bar) and temperatures range from -29°F to 140°F (-34°C to 60°C). Some studies indicate that there may be some human fatalities resulting from a 30-min exposure to 50 ppm and higher concentrations. | | | | | | |
| 96% sulfuric acid, NPS ¾ - 4. Type 316 stainless steel is required for line velocities greater than 3 ft/sec (1 m/sec), otherwise carbon steel is acceptable. Fluoropolymer lined steel is acceptable. Temperature is ambient, maximum pressure is 120 psig (8 bar). | | | | | | |
| Gasoline, NPS ½ - 8. Temperature is ambient, max. pressure is 60 psig (4 bar). | | | | | | |
| 650 psig (45 bar) steam superheated to 735°F (390°C), NPS ¾ - 16. Relief pressure is 725 psig (50 bar). | | | | | | |
| Therminol 66 heat transfer oil, NPS ¾ - 6. Max. temperature is 560°F (295°C), max. pressure is 120 psig (8 bar). | | | | | | |
| Styrene monomer, NPS ¾ - 12. Ambient temperature, max. pressure is 105 psig (7 bar). Flammable. Polymerizes when left stagnant at ambient temperature for long periods of time. | | | | | | |
| Lime/water slurry, NPS ¾ to 4. Ambient temperature, maximum pressure is 140 psig (9.5 bar). | | | | | | |

**ASME B16 Piping Component Standards**

| No. | Title |
|---|---|
| B16.1 | Cast Iron Pipe Flanges and Flanged Fittings |
| B16.3 | Malleable Iron Threaded Fittings |
| B16.4 | Gray Iron Threaded Fittings |
| B16.5 | Pipe Flanges and Flanged Fittings |
| B16.9 | Factory-Made Wrought Steel Buttwelding Fittings |
| B16.10 | Face-to-Face and End-to-End Dimensions of Valves |
| B16.11 | Forged Fittings, Socket Welding and Threaded |
| B16.12 | Cast Iron Threaded Drainage Fittings |
| B16.14 | Ferrous Pipe Plugs, Bushings and Locknuts with Pipe Threads |
| B16.15 | Cast Bronze Threaded Fittings |
| B16.18 | Cast Copper Alloy Solder Joint Pressure Fittings |
| B16.20 | Metallic Gaskets for Pipe Flanges – Ring Joint, Spiral Wound and Jacketed |
| B16.21 | Nonmetallic Flat Gaskets for Pipe Flanges |
| B16.22 | Wrought Copper and Copper Alloy Solder Joint Pressure Fittings |
| *B16.23 | Cast Copper Alloy Solder Joint Drainage Fittings – DWV |
| B16.24 | Cast Copper Alloy Pipe Flanges and Flanged Fittings |
| B16.25 | Buttwelding Ends |
| B16.26 | Cast Copper Alloy fittings for Flared Copper Tube |
| *B16.29 | Wrought Copper and Wrought Copper Alloy Solder Joint Drainage Fittings – DWV |
| *B16.32 | Cast Copper Alloy Solder Joint Fittings for Sovent Drainage Systems |
| *B16.33 | Manually Operated Metallic Gas Valves or Use in Gas Piping Systems up to 125 psig |
| B16.34 | Valves – Flanged, Threaded and Welding End |
| B16.36 | Orifice Flanges |
| *B16.38 | Large Metallic Valves for Gas Distribution |
| B16.39 | Malleable Iron Threaded Pipe Unions |
| *B16.40 | Manually Operated Thermoplastic Gas Shutoffs and Valves in Gas Distribution |
| *B16.41 | Functional Qualification Requirement for Power Operated Active Valve Assemblies for Nuclear Power Plants |
| B16.42 | Ductile Iron Pipe Flanges and Flanged Fittings |
| *B16.44 | Manually Operated Metallic Gas Valves for Use in House Piping Systems |
| *B16.45 | Cast Iron Fittings for Sovent Drainage Systems |
| B16.47 | Large Diameter Steel Flanges |
| B16.48 | Steel Line Blanks |
| *B16.49 | Factory-Made Wrought Steel Buttwelding Induction Bends for Transportation and Distribution Systems |
| *B16.50 | Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings |
| *B16.51 | Cast and Wrought Copper and Copper Alloy Press-Connect Pressure Fittings (draft) |

* Not listed in ASME B31.3

**MSS (Manufacturers Standardization Society of the Valve and Fittings Industry) Piping Component Standards**

| No. | Title |
|---|---|
| SP-42 | Class 150 Corrosion Resistant Gate, Globe, Angle, Check Valves with Flanged, Butt Weld Ends |
| SP-43 | Wrought Stainless Steel Butt-Welding Fittings |
| SP-44 | Steel Pipeline Flanges |
| SP-51 | Class 150LW Corrosion Resistant Cast Flanged Fittings |
| SP-58 | Pipe Hangers and Supports -- Materials, Design and Manufacture |
| *SP-60 | Connecting Flange Joint Between Tapping Sleeves and Tapping Valves |
| SP-65 | High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets |
| *SP-67 | Butterfly Valves |
| *SP-68 | High Pressure-Offset Seat Butterfly Valves |
| *SP-69 | Pipe Hangers and Supports -- Selection and Application |
| SP-70 | Cast Iron Gate Valves, Flanged and Threaded Ends |
| SP-71 | Cast Iron Swing Check valves, Flanged and Threaded Ends |
| SP-72 | Ball Valves with Flanged or Butt-Welding Ends for General Service |
| SP-75 | Specification for High Test Wrought Butt Welding Fittings |
| *SP-78 | Cast Iron Plug Valves, Flanged and Threaded Ends |
| SP-79 | Socket-Welding Reducer Inserts |
| SP-80 | Bronze Gate, Globe, Angle and Check Valves |
| SP-81 | Stainless Steel, Bonnetless, Flanged, Knife Gate Valves |
| SP-83 | Class 3000 Steel Pipe Unions, Socket-Welding and Threaded |
| SP-85 | Cast Iron Globe & Angle Valves, Flanged and Threaded Ends |
| *SP-87 | Factory-Made Butt-Welding Fittings for Call 1 Nuclear Piping Applications |
| SP-88 | Diaphragm Type Valves |
| SP-95 | Swage(d) Nipples and Bull Plugs |
| SP-97 | Integrally Reinforced Forged Branch Outley Fittings |
| *SP-99 | Instrument Valves |
| *SP-103 | Wrought Copper and Copper Alloy Insert Fittings for Polybutylene Systems |
| *SP-104 | Wrought Copper Solder Joint Pressure Fittings |
| SP-105 | Instrument Valves for Code Applications |
| *SP-106 | Cast Copper Alloy Flanges and Flanged Fittings, Class 125, 150 and 300 |
| *SP-107 | Transition Union Fittings for Joining Metal and Plastic Products |
| *SP-108 | Resilient-Seated Cast Iron-Eccentric Plug Valves |
| *SP-109 | Welded Fabricated Copper Solder Joint Pressure Fittings |
| *SP-110 | Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends |
| *SP-111 | Gray-Iron and Ductile-Iron Tapping Sleeves |
| *SP-114 | Corrosion Resistant Pipe Fittings Threaded and Socket Welding, Class 150 and 1000 |
| *SP-115 | Excess Flow Valves for Natural Gas Service |
| *SP-116 | Service Line Valves and Fittings for Drinking Water Systems |
| *SP-118 | Compact Steel Globe & Check Valves -- Flanged, Flangeless, Threaded and Welding Ends |

| No. | Title |
|---|---|
| SP-119 | Belled End Socket Welding Fittings, Stainless Steel and Copper Nickel |
| *SP-122 | Plastic Industrial Ball Valves |
| *SP-123 | Non-Ferrous Threaded and Solder-Joint Unions for Use With Copper Water Tube |
| *SP-124 | Fabricated Tapping Sleeves |
| *SP-125 | Gray Iron and Ductile Iron In-Line, Spring-Loaded, Center-Guided Check Valves |
| *SP-127 | Bracing for Piping Systems Seismic-Wind-Dynamic Design, Selection, Application |

* Not listed in ASME B31.3

**API Piping Component Standards (selected)**

| No. | Title |
|---|---|
| 5L | Line Pipe |
| *6D | Pipeline Valves (Gate, Plug, Ball, and Check Valves) |
| 594 | Check Valves: Wafer, Wafer-lug and Double Flanged Type |
| 599 | Metal Plug Valves – Flanged and Welding Ends |
| 600 | Bolted Bonnet Steel Gate Valves for Petroleum and Natural Gas Industries – Modified National Adoption of ISO 10434 |
| 602 | Compact Steel Gate Valves – Flanged, Threaded, Welding, and Extended Body Ends |
| 603 | Corrosion-Resistant, Bolted Bonnet Gate Valves--Flanged and Butt-Welding Ends |
| 608 | Metal Ball Valves – Flanged, Threaded and Butt-Welding Ends |
| 609 | Butterfly Valves: Double Flanged, Lug- and Wafer-Type |

* Not listed in ASME B31.3

**ASTM Piping Component Standards (selected)**

| No. | Title |
|---|---|
| A53 | Pipe, Steel, Black and Hot-Dipped, Zinc Coated, Welded and Seamless |
| A106 | Seamless Carbon Steel Pipe for High-Temperature Service |
| A234 | Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperature |
| A312 | Seamless and Welded Austenitic Stainless Steel Pipe |
| A333 | Seamless and Welded Steel Pipe for Low-Temperature Service |
| A403 | Wrought Austenitic Stainless Steel Piping Fittings |
| B75 | Seamless Copper Tube |
| B88 | Seamless Copper Water Tube |
| B165 | Nickel-Copper Alloy (UNS N04400) Seamless Pipe and Tube |
| B167 | Nickel-Chromium-Iron Alloy (UNS N06600-N06690) Seamless Pipe and Tube |
| B241 | Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube |
| B280 | Seamless Copper Tube for Air Conditioning and Refrigeration Fluid Service |
| B337 | Seamless and Welded Titanium and Titanium Alloy Pipe |
| B361 | Factory-Made Wrought Aluminum and Aluminum-Alloy Welding Fittings |
| B366 | Factory-Made Wrought Nickel and Nickel-Alloy Welding Fittings |
| B658 | Zirconium and Zirconium Alloy Seamless and Welded Pipe |
| C599 | Process Glass Pipe and Fittings |
| D1785 | PVC Plastic Pipe |

| No. | Title |
|---|---|
| D2282 | ABS Plastic Pipe (SDR-PR) |
| D2464 | Threaded PVC Plastic Pipe Fittings, Sch 80 |
| D2468 | Socket-Type ABS Plastic Pipe Fittings, Sch 40 |
| D2517 | Reinforced Epoxy Resin Gas Pressure Pipe and Fittings |
| D2846 | CPVC Plastic Hot and Cold Water Distribution Systems |
| D3261 | Butt Heat Fusion PE Plastic Fittings for PE Plastic Pipe and Tubing |
| D5421 | Contact Molded Fiberglass RTR Flanges |
| F423 | PTFE Plastic-Lined Ferrous Metal Pipe and Fittings |
| F492 | Polypropylene and PP Plastic-Lined Ferrous Metal Pipe and Fittings |

**AWWA Piping Component Standards (selected)**

| No. | Title |
|---|---|
| *C104 | Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water |
| C110 | Ductile-Iron and Gray-Iron Fittings, 3 In.-48 In. (76 mm-1,219 mm), for Water |
| C115 | Flanged Ductile-Iron Pipe with Ductile-Iron or Gray-Iron Threaded Flanges |
| C151 | Ductile-Iron Pipe, Centrifugally Cast, for Water |
| *C153 | Ductile-Iron Compact Fittings for Water Service |
| C300 | Reinforced Concrete Pressure Pipe, Steel Cylinder Type, for Water and Other Liquids |
| C302 | Reinforced Concrete Pressure Pipe, Noncylinder Type, for Water and Other Liquids |
| *C501 | Cast-Iron Sluice Gates |
| *C502 | Dry-Barrel Fire Hydrants |
| *C503 | Wet-Barrel Fire Hydrants |
| C504 | Rubber-Seated Butterfly Valves |
| *C507 | Ball Valves, 6 In. Through 48 In. (150 mm Through 1,200 mm) |
| *C508 | Swing-Check Valves for Waterworks Service, 2 In. (50 mm) Through 24 In.( 600 mm) NPS |
| *C509 | Resilient-Seated Gate Valves for Water Supply Service |
| *C510 | Double Check Valve Backflow Prevention Assembly |
| *C511 | Reduced-Pressure Principle Backflow Prevention Assembly |
| C900 | PVC Pressure Pipe, 4-inch through 12-inch, for Water |
| C950 | Glass-Fiber-Reinforced Thermosetting Resin Pressure Pipe |

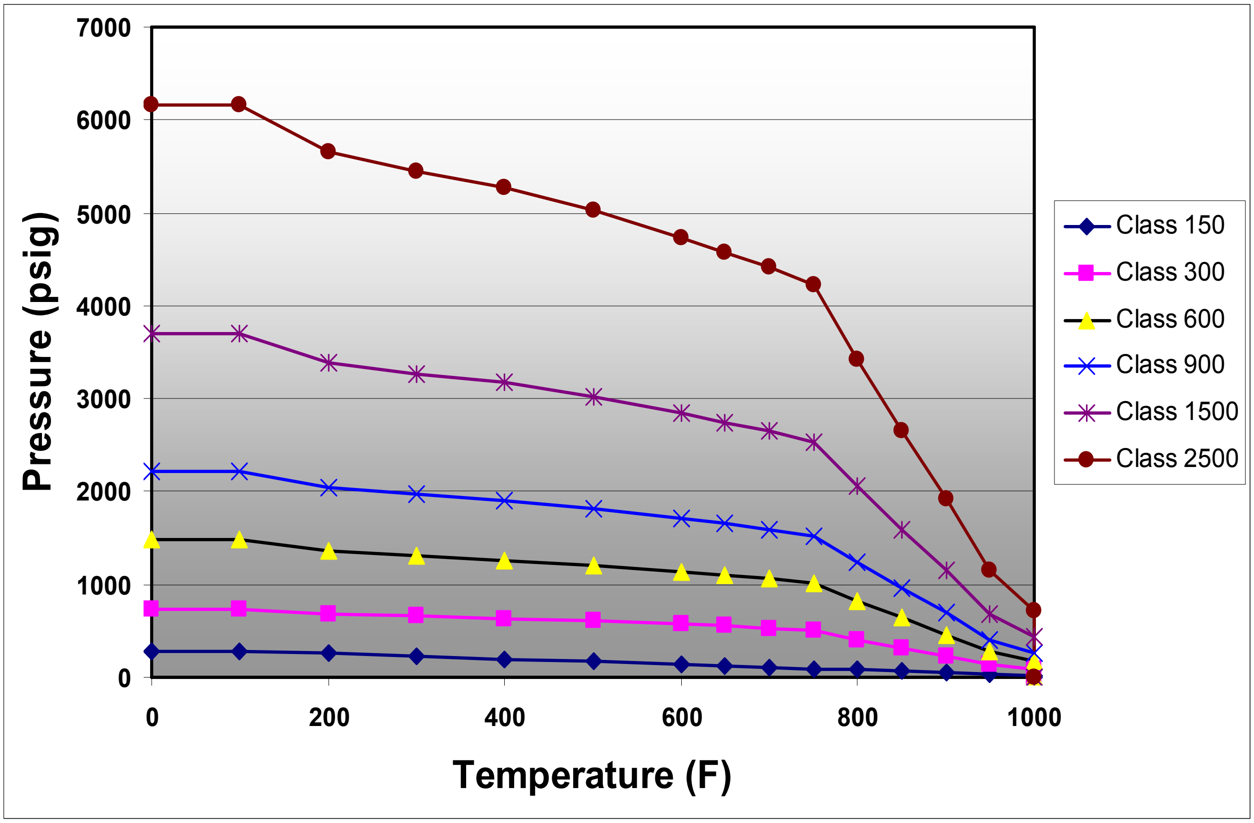
* Not listed in ASME B31.3

**Canadian Standards Association**

| No. | Title |
|---|---|
| *Z245.1 | Steel Pipe |
| *Z245.6 | Coiled Aluminum Line Pipe and Accessories |
| *Z245.11 | Steel Fittings |
| *Z245.12 | Steel Flanges |
| *Z245.15 | Steel Valves |

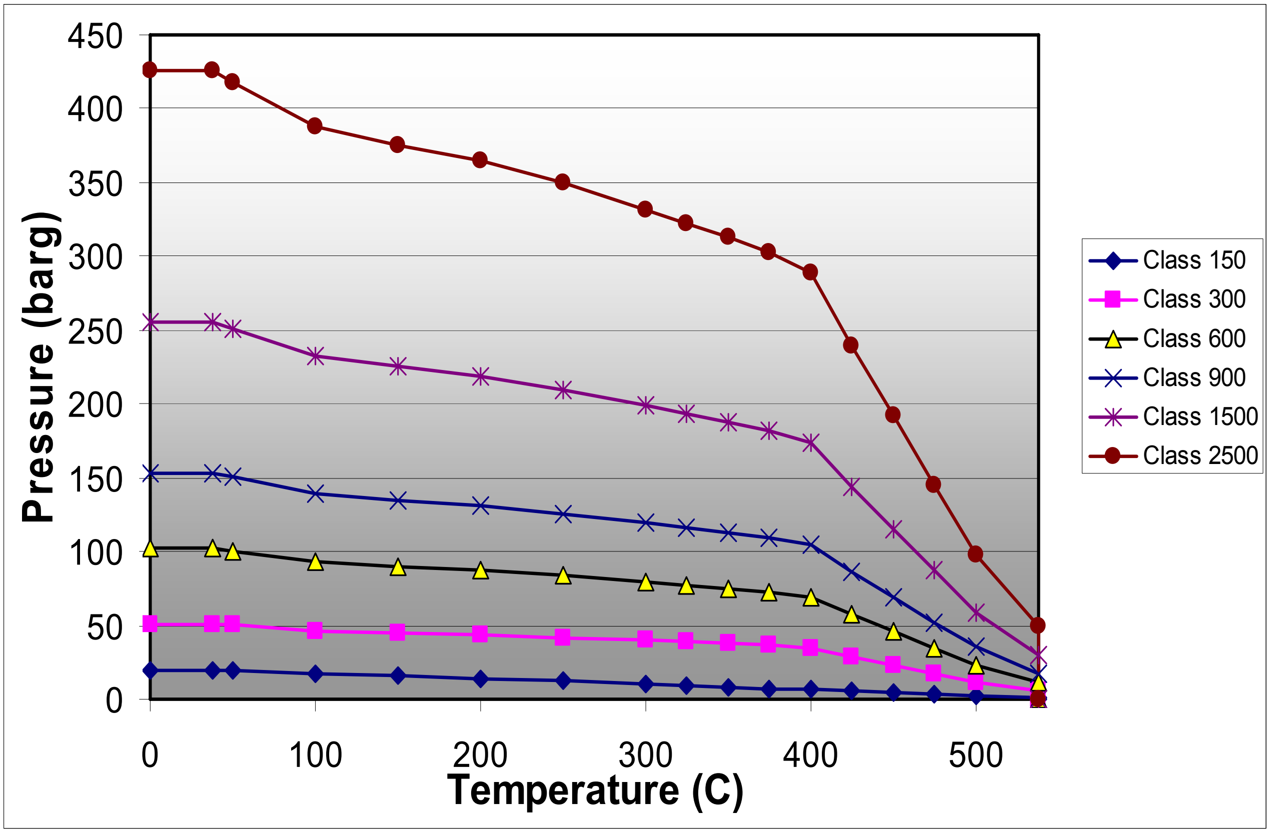
* Not listed in ASME B31.3

**ASME B16.5 Flange Ratings - Carbon Steel (US Customary Units - psi)**



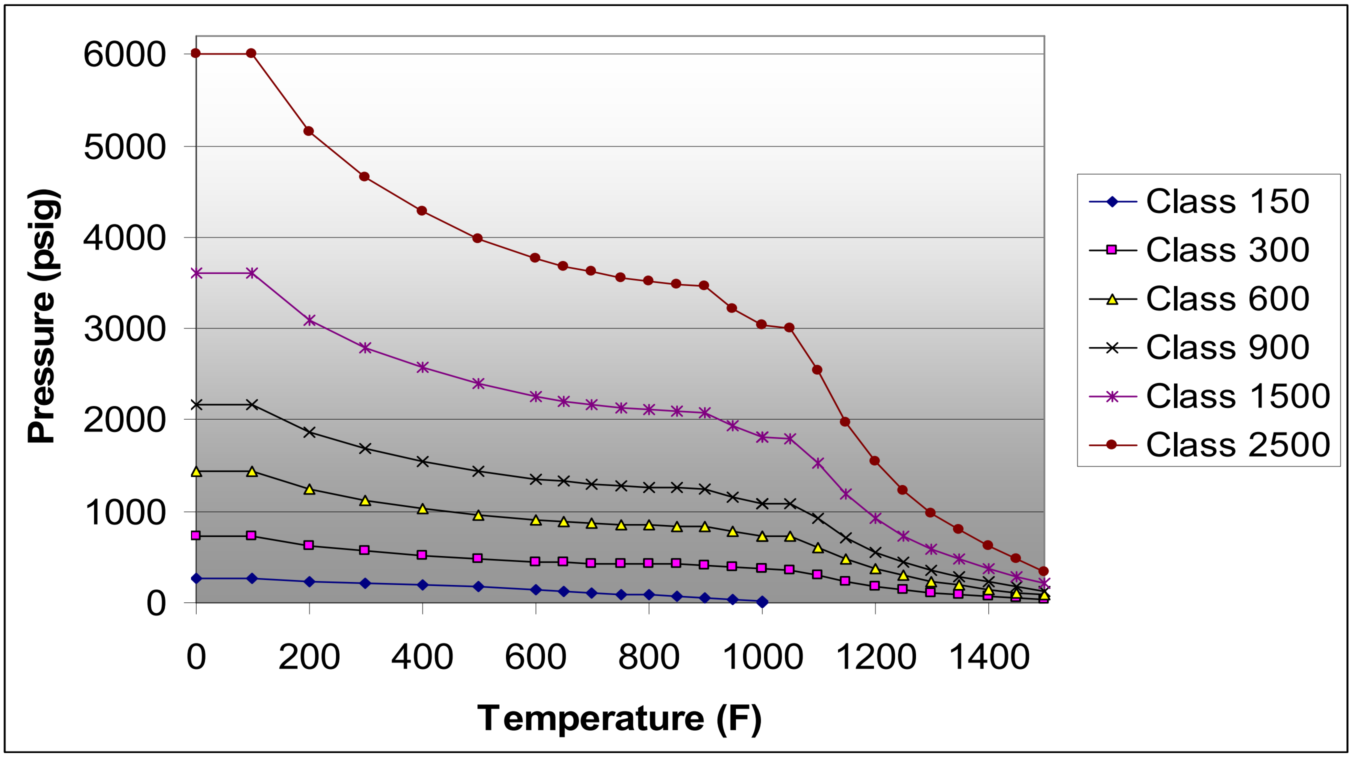

| Temp (F) | Class 150 | Class 300 | Class 600 | Class 900 | Class 1500 | Class 2500 |
|---|---|---|---|---|---|---|
| min to 100 | 285 | 740 | 1480 | 2220 | 3705 | 6170 |
| 200 | 260 | 680 | 1360 | 2035 | 3395 | 5655 |
| 300 | 230 | 655 | 1310 | 1965 | 3270 | 5450 |
| 400 | 200 | 635 | 1265 | 1900 | 3170 | 5280 |
| 500 | 170 | 605 | 1205 | 1810 | 3015 | 5025 |
| 600 | 140 | 570 | 1135 | 1705 | 2840 | 4730 |
| 650 | 125 | 550 | 1100 | 1650 | 2745 | 4575 |
| 700 | 110 | 530 | 1060 | 1590 | 2655 | 4425 |
| 750 | 95 | 505 | 1015 | 1520 | 2535 | 4230 |
| 800 | 80 | 410 | 825 | 1235 | 2055 | 3430 |
| 850 | 65 | 320 | 640 | 955 | 1595 | 2655 |
| 900 | 50 | 230 | 460 | 690 | 1150 | 1915 |
| 950 | 35 | 135 | 275 | 410 | 685 | 1145 |
| 1000 | 20 | 85 | 170 | 255 | 430 | 715 |

**ASME B16.5 Flange Ratings - Carbon Steel (Metric Units - bar)**



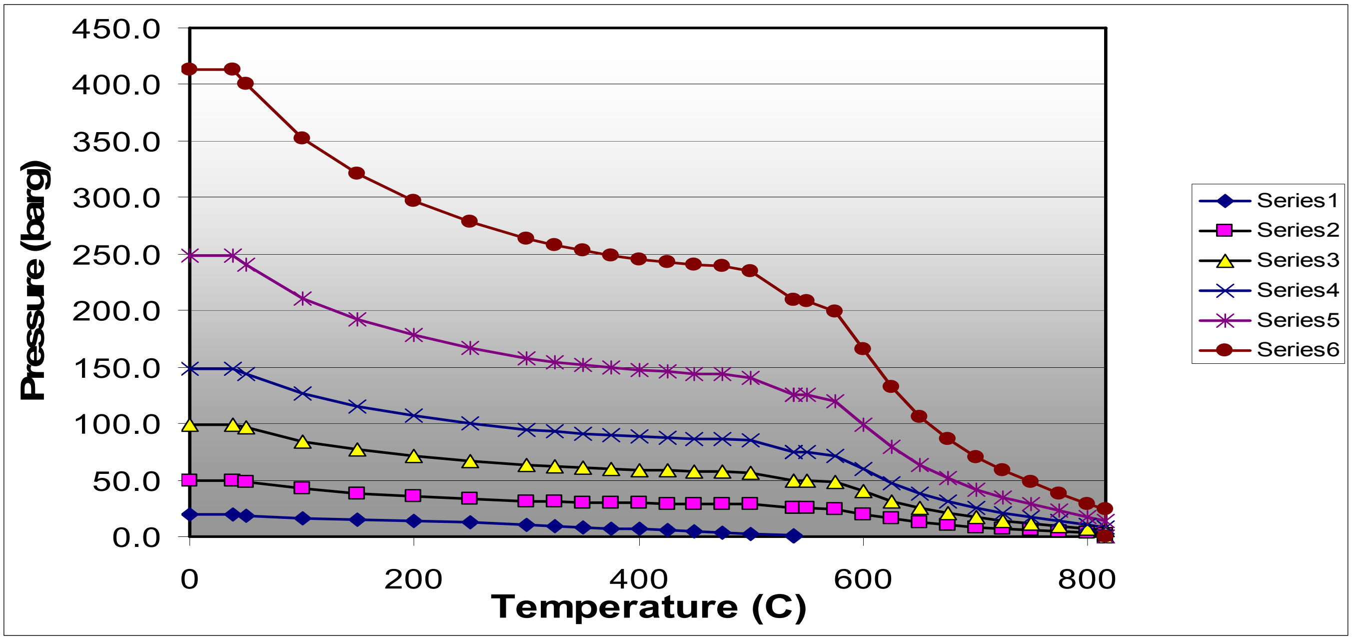

| Temp (C) | Class 150 | Class 300 | Class 600 | Class 900 | Class 1500 | Class 2500 |
|---|---|---|---|---|---|---|
| min to 38 | 19.6 | 51.1 | 102.1 | 153.2 | 255.3 | 425.5 |
| 50 | 19.2 | 50.1 | 100.2 | 150.4 | 250.6 | 417.7 |
| 100 | 17.7 | 46.6 | 93.2 | 139.8 | 233.0 | 388.3 |
| 150 | 15.8 | 45.1 | 90.2 | 135.2 | 225.4 | 375.6 |
| 200 | 13.8 | 43.8 | 87.6 | 131.4 | 219.0 | 365.0 |
| 250 | 12.1 | 41.9 | 83.9 | 125.8 | 209.7 | 349.5 |
| 300 | 10.2 | 39.8 | 79.6 | 119.5 | 199.1 | 331.8 |
| 325 | 9.3 | 38.7 | 77.4 | 116.1 | 193.6 | 322.6 |
| 350 | 8.4 | 37.6 | 75.1 | 112.7 | 187.8 | 313.0 |
| 375 | 7.4 | 36.4 | 72.7 | 109.1 | 181.8 | 303.1 |
| 400 | 6.5 | 34.7 | 69.4 | 104.2 | 173.6 | 289.3 |
| 425 | 5.5 | 28.8 | 57.5 | 86.3 | 143.8 | 239.7 |
| 450 | 4.6 | 23.0 | 46.0 | 69.0 | 115.0 | 191.7 |
| 475 | 3.7 | 17.4 | 34.9 | 52.3 | 87.2 | 145.3 |
| 500 | 2.8 | 11.8 | 23.5 | 35.3 | 58.8 | 97.9 |
| 538 | 1.4 | 5.9 | 11.8 | 17.7 | 29.5 | 49.2 |

**ASME B16.5 Flange Ratings – Type 316 Stainless Steel (US Customary Units - psi)**



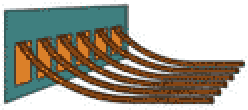

| Temp (F) | Class 150 | Class 300 | Class 600 | Class 900 | Class 1500 | Class 2500 |
|---|---|---|---|---|---|---|
| min to 100 | 275 | 720 | 1440 | 2160 | 3600 | 6000 |
| 200 | 235 | 620 | 1240 | 1860 | 3095 | 5160 |
| 300 | 215 | 560 | 1120 | 1680 | 2795 | 4660 |
| 400 | 195 | 515 | 1025 | 1540 | 2570 | 4280 |
| 500 | 170 | 480 | 955 | 1435 | 2390 | 3980 |
| 600 | 140 | 450 | 900 | 1355 | 2255 | 3760 |
| 650 | 125 | 440 | 885 | 1325 | 2210 | 3680 |
| 700 | 110 | 435 | 870 | 1305 | 2170 | 3620 |
| 750 | 95 | 425 | 855 | 1280 | 2135 | 3560 |
| 800 | 80 | 420 | 845 | 1265 | 2110 | 3520 |
| 850 | 65 | 420 | 835 | 1255 | 2090 | 3480 |
| 900 | 50 | 415 | 830 | 1245 | 2075 | 3460 |
| 950 | 35 | 385 | 775 | 1160 | 1930 | 3220 |
| 1000 | 20 | 365 | 725 | 1090 | 1820 | 3030 |
| 1050 | | 360 | 720 | 1080 | 1800 | 3000 |
| 1100 | | 305 | 610 | 915 | 1525 | 2545 |
| 1150 | | 235 | 475 | 710 | 1185 | 1970 |
| 1200 | | 185 | 370 | 555 | 925 | 1545 |
| 1250 | | 145 | 295 | 440 | 735 | 1230 |
| 1300 | | 115 | 235 | 350 | 585 | 970 |
| 1350 | | 95 | 190 | 290 | 480 | 800 |
| 1400 | | 75 | 150 | 225 | 380 | 630 |
| 1450 | | 60 | 115 | 175 | 290 | 485 |
| 1500 | | 40 | 85 | 125 | 205 | 345 |

**ASME B16.5 Flange Ratings – Type 316 Stainless Steel (Metric Units - bar)**

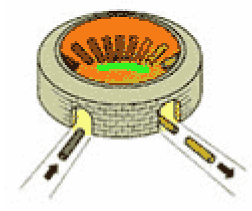



| Temp (C) | Class 150 | Class 300 | Class 600 | Class 900 | Class 1500 | Class 2500 |
|---|---|---|---|---|---|---|
| 38 | 19.0 | 49.6 | 99.3 | 148.9 | 248.2 | 413.7 |
| 50 | 18.4 | 48.1 | 96.2 | 144.3 | 240.6 | 400.9 |
| 100 | 16.2 | 42.2 | 84.4 | 126.6 | 211.0 | 351.6 |
| 150 | 14.8 | 38.5 | 77.0 | 115.5 | 192.5 | 320.8 |
| 200 | 13.7 | 35.7 | 71.3 | 107.0 | 178.3 | 297.2 |
| 250 | 12.1 | 33.4 | 66.8 | 100.1 | 166.9 | 278.1 |
| 300 | 10.2 | 31.6 | 63.2 | 94.9 | 158.1 | 263.5 |
| 325 | 9.3 | 30.9 | 61.8 | 92.7 | 154.4 | 257.4 |
| 350 | 8.4 | 30.3 | 60.7 | 91.0 | 151.6 | 252.7 |
| 375 | 7.4 | 29.9 | 59.8 | 89.6 | 149.4 | 249.0 |
| 400 | 6.5 | 29.4 | 58.9 | 88.3 | 147.2 | 245.3 |
| 425 | 5.5 | 29.1 | 58.3 | 87.4 | 145.7 | 242.9 |
| 450 | 4.6 | 28.8 | 57.7 | 86.5 | 144.2 | 240.4 |
| 475 | 3.7 | 28.7 | 57.3 | 86.0 | 143.4 | 238.9 |
| 500 | 2.8 | 28.2 | 56.5 | 84.7 | 140.9 | 235.0 |
| 538 | 1.4 | 25.2 | 50.0 | 75.2 | 125.5 | 208.9 |
| 550 | | 25.0 | 49.8 | 74.8 | 124.9 | 208.0 |
| 575 | | 24.0 | 47.9 | 71.8 | 119.7 | 199.5 |
| 600 | | 19.9 | 39.8 | 59.7 | 99.5 | 165.9 |
| 625 | | 15.8 | 31.6 | 47.4 | 79.1 | 131.8 |
| 650 | | 12.7 | 25.3 | 38.0 | 63.3 | 105.5 |
| 675 | | 10.3 | 20.6 | 31.0 | 51.6 | 86.0 |
| 700 | | 8.4 | 16.8 | 25.1 | 41.9 | 69.8 |
| 725 | | 7.0 | 14.0 | 21.0 | 34.9 | 58.2 |
| 750 | | 5.9 | 11.7 | 17.6 | 29.3 | 48.9 |
| 775 | | 4.6 | 9.0 | 13.7 | 22.8 | 38.0 |
| 800 | | 3.5 | 7.0 | 10.5 | 17.4 | 29.2 |
| 816 | | 2.8 | 5.9 | 8.6 | 14.1 | 23.8 |

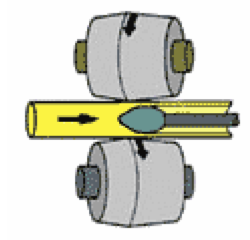
SEAMLESS MANUFACTURING PROCESS AT USS TUBULAR #3 MILL - 10.75" TO 26" O.D.
(http://www.usstubular.com/facilities/splplo.htm)



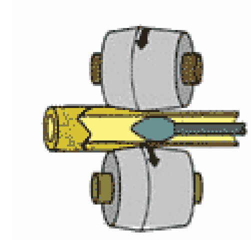
**Modern 6-Strand Caster** Lorain's 6-strand continuous caster incorporates the latest steel processing technology. This unit is capable of producing more than 600.000 annual tons [550,000 metric tons] of high quality rounds for superior seamless tubular products. These rounds are conditioned, as required, after visual inspection.



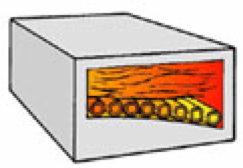
**Rotary Billet Heating** The billets are now brought to the proper temperature for piercing by heating them in a rotary hearth furnace.



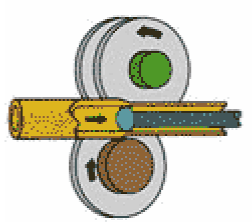
**Rotary Piercing Mill (RPM)** The billet is gripped by the rolls, which rotate and advance it over the piercer point, forming a hole through its length. Large sizes go through a second piercing mill.



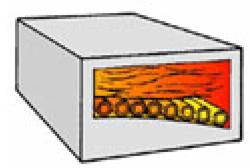
**Second Piercer (Elongator)** This piercing operation further increases the diameter and length and decreases the wall thickness.



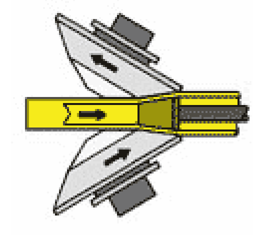
**Reheating Furnace** Before further working, the pierced billets are again brought to forging temperature in the reheat furnace.



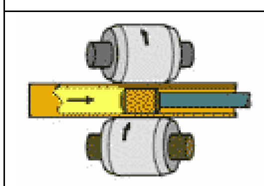
**Plug Rolling Mill** In this operation the pierced billet is rolled over a plug to reduce the diameter and wall thickness and to increase the length.



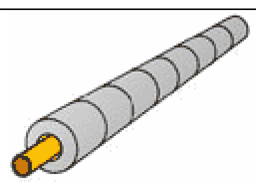
**Reheating Furnace** Shells must again be heated to forging temperatures for further working.



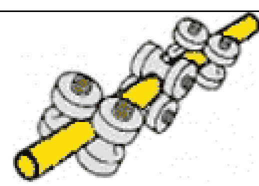
**Rotary Expanding Mill** For pipe NPS 16 and over, the diameter is enlarged and the wall thickness reduced to approximate finished dimensions in the rotary mill.



**Reeling Mill** The rolls of the reeling mill grip the pipe and advance it over a mandrel, burnishing both the inside and outside surfaces of the pipe.

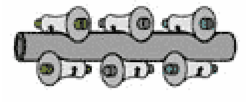
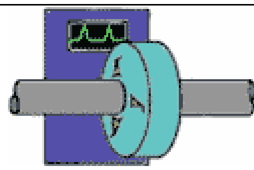
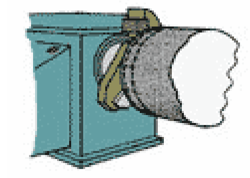
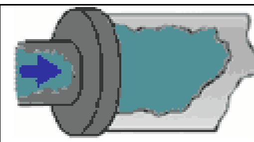
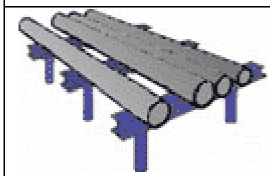


**Reheating Furnace** The purpose of reheating at this stage is to obtain uniformity of temperature for sizing.

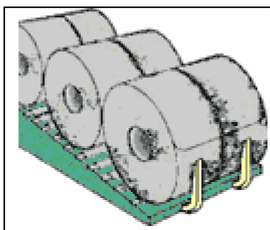
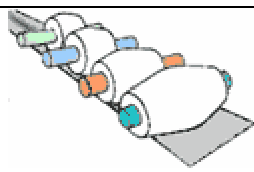
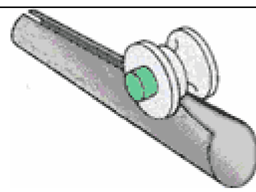
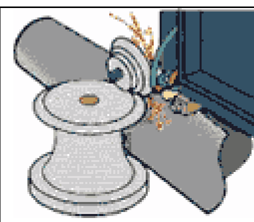


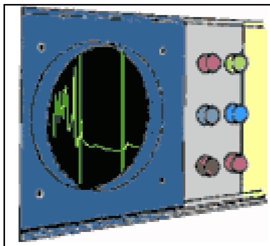
**Sizing Mill** The pipe, reheated if necessary, passes through a series of rolls where it is formed into a true round, and sized to the exact required diameter.

**Cooling Table** After sizing, the pipe is allowed to cool on a slowly moving conveyer table.

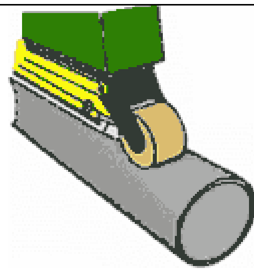
| | | | |
|---|---|---|---|
|  **Rotary Straightener** Here the pipe is brought to the required straightness. The "crop ends" of standard seamless are then cut off before end beveling. |  **NDT Inspection** At this station pipe is electromagnetically inspected to detect body wall imperfections. |  **Facing and Beveling** An expanding arbor holds the pipe in line while a revolving head faces and bevels the end of the pipe. |  **Hydrostatic Testing** The finished pipe is visually inspected and is subjected to a hydrostatic test as a strength and leak check before shipping. |
|  **Final Inspection** A final visual inspection is given the pipe prior to stenciling, loading and shipping. | | | |

**ELECTRIC RESISTANCE WELD (ERW) MANUFACTURING PROCESS AT USS TUBULAR- 8.625" TO 20" O.D. (**[http://www.usstubular.com/facilities/erw.htm](http://www.usstubular.com/facilities/erw.htm))

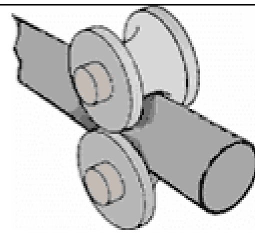
| | | | |
|---|---|---|---|
|  **Coil Feed Ramp** Coils are removed from storage and placed on a feed ramp. Here each coil is positioned on the center line of the mill and fed into the uncoiling unit. The leading edge feeds into the pinch rolls preceding the flattener. An electrically operated shear cuts off the end of each coil so that the coils can be welded together to form a continuous strip. |  **First Forming Section** The first forming section, composed of breakdown strands, begins the transformation of the strip from flat steel to a round pipe section. The roll transition section receives the product from the first forming section and continues the "rounding-up" process. |  **Fin Pass Section** The section of the forming rolls finishes the rounding process and contours the edges of the strip for welding. |  **High Frequency Welder** The High Frequency Welder heats the edges of the strip to approximately 2600ºF [1400ºC] at the fusion point location. Pressure rolls then squeeze the heated edges together to form a fusion weld. |



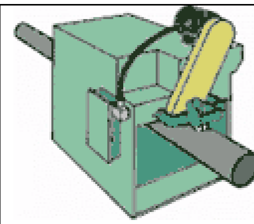
**In-Process Weld Non-Destructive Inspection** After welding, the weld is inspected by independent non-destructive inspection units.



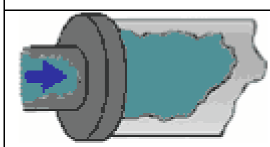
**Seam Normalizer** Here the weld area is subjected to the proper post-weld treatment as metallurgically required to remove welding stresses and produce a uniform normalized grain structure.



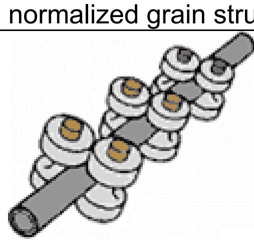
**Sizing Mill** Here the pipe passes through the sizing mill with idler side-closing rolls between the strands. This process sizes the pipe to proper outside diameter and straightens the pipe at the same time.



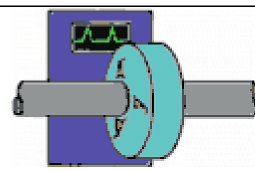
**Flying Cut-Off** As the continuous length moves down the mill, the flying cut-off cuts a designated length of pipe without interrupting continuous product flow of the mill.



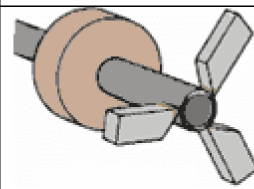
**Hydrostatic Testing** Each length of pipe is subjected to a hydrostatic test as a strength and leak check.



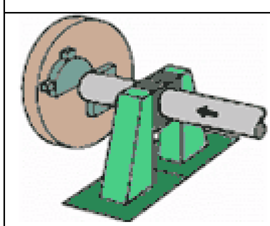
**Straightening** Any bow in the pipe is now removed by a series of horizontal deflection rolls.



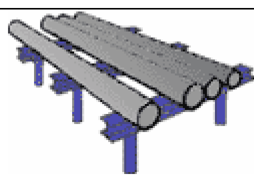
**Non-Destructive Inspection** The pipe now enters the finishing floor where the weld is ultrasonically inspected and the pipe body is examined by electromagnetic means.



**Cut-Off Facilities** This facility provides test barrels as required and cuts out defects detected by nondestructive inspection.

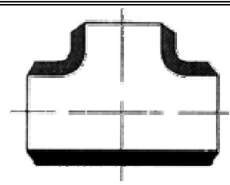
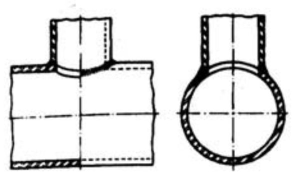
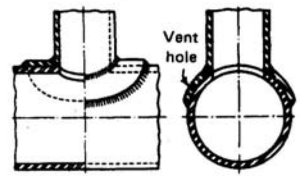


**Facing and Beveling** Carbide tools cut the desired end finish on the pipe.



**Final Inspection** A final visual inspection is given the pipe prior to computerized weighing and measuring in preparation for stenciling, loading and shipping.

## BRANCH CONNECTIONS

| | Tee | Unreinforced Fabricated Tee | Reinforced Fabricated Tee | Branch Connection Fitting |
|---|---|---|---|---|
| |  |  |   |  |
| Stress Intensification Factor (NPS 8 STD WT header) | 2.3 | 4.9 | 2.5 | 2.2 |
| Effective examination methods | Radiographic Visual | Visual | Visual | Visual |

## CHARACTERISTICS OF SELECTED GASKET TYPES

| Gasket Type | Chemical Resistance | Approximate Max Temp | | Fire Resistance | Blow-out Resistance | Leak Performance | Strength of Bolting Required |
|---|---|---|---|---|---|---|---|
| | | °F | °C | | | | |
| Rubber | OK for most | 200 | 95 | No | No | Best | Low |
| Reinforced Rubber | OK for most | 325 | 160 | No | No | Fair | Low |
| PTFE | OK for almost all | 350 | 180 | No | No | Good | Low |
| Flexible Graphite | OK for almost all | 900 (625) | 480 (330) | Yes | No, unless thicker metal insert | Good | Medium |
| Kammprofile | Both metal & sealing material have to be OK | 1500 | 820 | Depends on sealing material | Yes | Good | Medium |
| Spiral Wound | Both metal winding & filler have to be OK | 1500 | 820 | Depends on filler | Yes | Good | Medium to High |
| Ring Joint | Metal has to be OK | 1500 | 820 | Yes | Yes | Good | High |

## CHARACTERISTICS OF SELECTED BOLTING

| Material | Low Strength | Medium Strength | High Strength |
|---|---|---|---|
| Carbon Steel | A307<br>SAE Gr 1<br>SAE Gr 5 | | |
| Low Alloy Steel | SAE Gr 5 | A193 Gr B7M, hardness controlled | A193 Gr B7<br>A193 Gr B16, high temperature<br>A320 Gr L7, low temperature |
| Stainless Steel | A193 Gr B8 – 304 SS<br>A193 Gr B8M – 316 SS | A193 Gr B8 Cl 2– 304 SS<br>A193 Gr B8M Cl2 – 316 SS | |

## TABLE 323.2.2
## REQUIREMENTS FOR LOW TEMPERATURE TOUGHNESS TESTS FOR METALS
### These Toughness Test Requirements Are in Addition to Tests Required by the Material Specification

| | Type of Material | Column A Design Minimum Temperature at or Above Min. Temp. in Table A-1 or Fig. 323.2.2A | | Column B Design Minimum Temperature Below Min. Temp. in Table A-1 or Fig. 323.2.2A |
|---|---|---|---|---|
| Listed materials | 1 Gray cast iron | A-1 No additional requirements | | B-1 No additional requirements |
| Listed materials | 2 Malleable and ductile cast iron; carbon steel per Note (1) | A-2 No additional requirements | | B-2 Materials designated in Box 2 shall not be used. |
| | | (a) Base Metal | (b) Weld Metal and Heat Affected Zone (HAZ) [Note (2)] | |
| Listed materials | 3 Other carbon steels; low and intermediate alloy steels; high alloy ferritic steels; duplex stainless steels | A-3 (a) No additional requirements | A-3 (b) Weld metal deposits shall be impact tested per para. 323.3 if design min. temp. < −29°C (−20°F), except as provided in Notes (3) and (5), and except as follows: for materials listed for Curves C and D of Fig. 323.2.2A, where corresponding welding consumables are qualified by impact testing at the design minimum temperature or lower in accordance with the applicable AWS specification, additional testing is not required. | B-3 Except as provided in Notes (3) and (5), heat treat base metal per applicable ASTM specification listed in para. 323.3.2; then impact test base metal, weld deposits, and HAZ per para. 323.3 [see Note (2)]. When materials are used at design min. temp. below the assigned curve as permitted by Notes (2) and (3) of Fig. 323.2.2A, weld deposits and HAZ shall be impact tested [see Note (2)]. |
| Listed materials | 4 Austenitic stainless steels | A-4 (a) If: (1) carbon content by analysis > 0.1%; or (2) material is not in solution heat treated condition; then, impact test per para. 323.3 for design min. temp. < −29°C (−20°F) except as provided in Notes (3) and (6) | A-4 (b) Weld metal deposits shall be impact tested per para. 323.3 if design min. temp. < −29°C (−20°F) except as provided in para. 323.2.2 and in Notes (3) and (6) | B-4 Base metal and weld metal deposits shall be impact tested per para. 323.3. See Notes (2), (3), and (6). |
| Listed materials | 5 Austenitic ductile iron, ASTM A 571 | A-5 (a) No additional requirements | A-5 (b) Welding is not permitted | B-5 Base metal shall be impact tested per para. 323.3. Do not use < −196°C (−320°F). Welding is not permitted. |
| Materials | 6 Aluminum, copper, nickel, and their alloys; unalloyed titanium | A-6 (a) No additional requirements | A-6 (b) No additional requirements unless filler metal composition is outside the range for base metal composition; then test per column B-6 | B-6 Designer shall be assured by suitable tests [see Note (4)] that base metal, weld deposits, and HAZ are suitable at the design min. temp. |
| Unlisted | 7 An unlisted material shall conform to a published specification. Where composition, heat treatment, and product form are comparable to those of a listed material, requirements for the corresponding listed material shall be met. Other unlisted materials shall be qualified as required in the applicable section of column B. | | | |

See notes on the next page.

NOTES:

(1) Carbon steels conforming to the following are subject to the limitations in Box B-2; plates per ASTM A 36, A 283, and A 570; pipe per ASTM A 134 when made from these plates; and pipe per ASTM A 53 Type F and API 5L Gr. A25 buttweld.

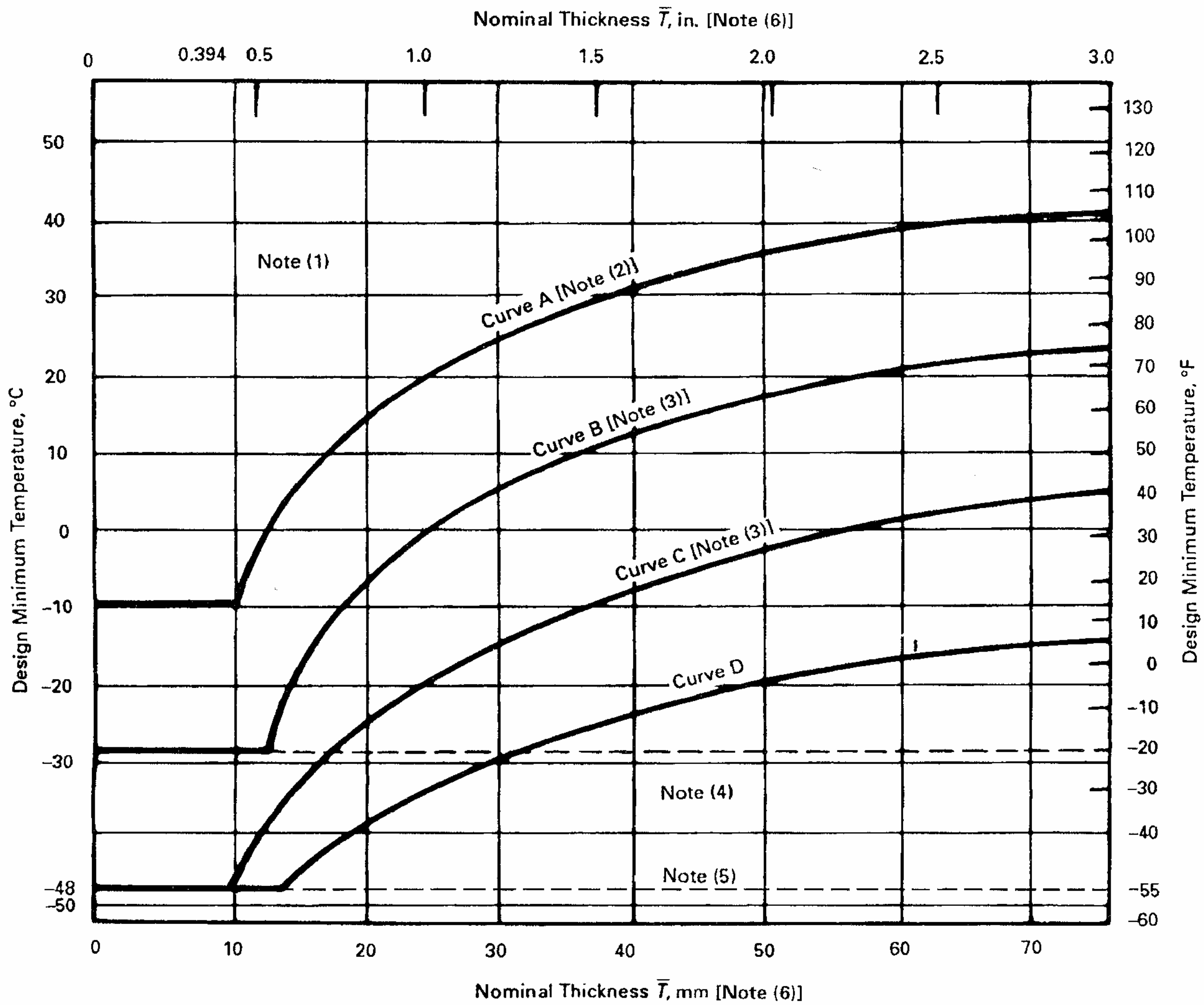
(2) Impact tests that meet the requirements of Table 323.3.1, which are performed as part of the weld procedure qualification, will satisfy all requirements of para. 323.2.2, and need not be repeated for production welds.

(3) Impact testing is not required if the design minimum temperature is below −29°C (−20°F) but at or above −104°C (−155°F) and the Stress Ratio defined in Fig. 323.2.2B does not exceed 0.3 times *S*.

(4) Tests may include tensile elongation, sharp-notch tensile strength (to be compared with unnotched tensile strength), and/or other tests, conducted at or below design minimum temperature. See also para. 323.3.4.

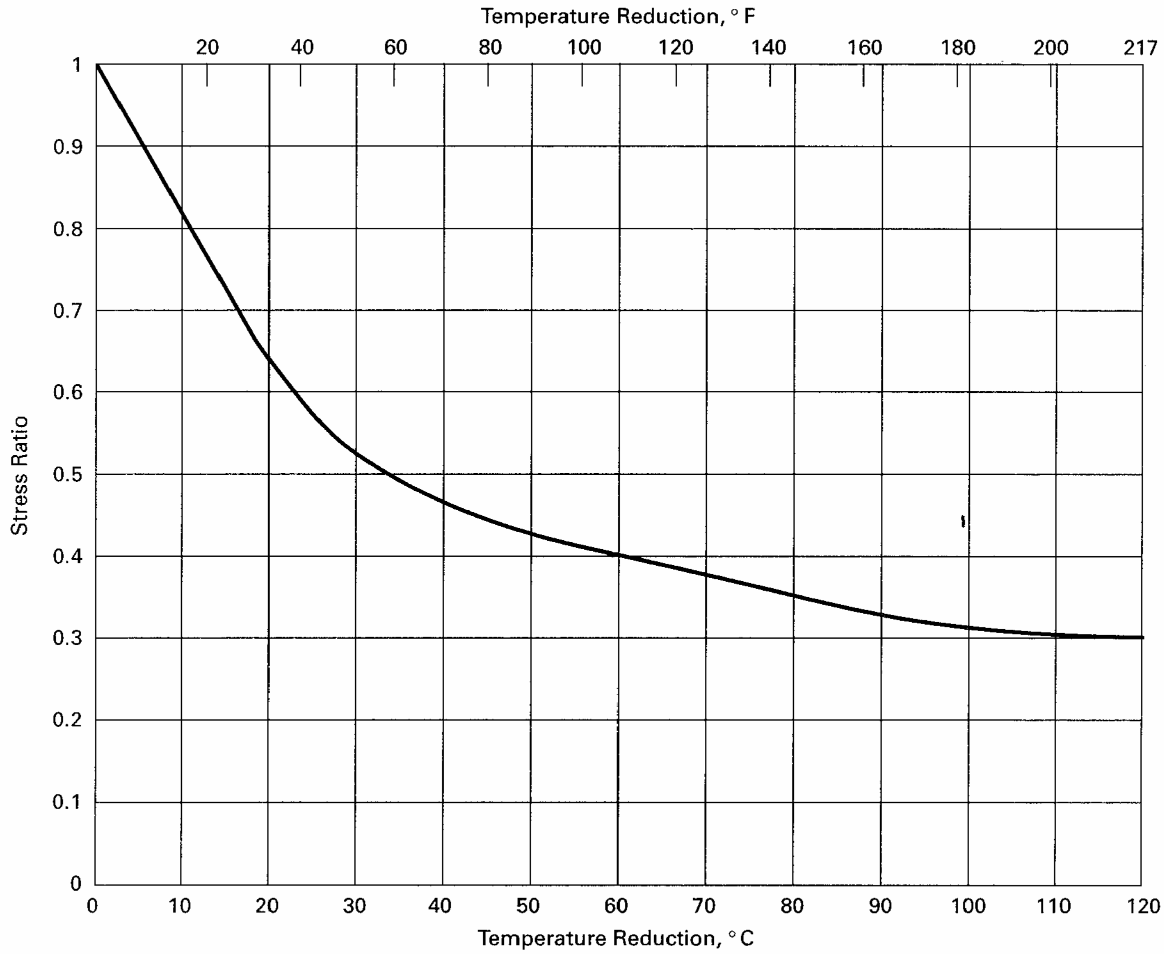
(5) Impact tests are not required when the maximum obtainable Charpy specimen has a width along the notch of less than 2.5 mm (0.098 in.). Under these conditions, the design minimum temperature shall not be less than the lower of −48°C (−55°F) or the minimum temperature for the material in Table A-1.

(6) Impact tests are not required when the maximum obtainable Charpy specimen has a width along the notch of less than 2.5 mm (0.098 in.).




NOTES:
(1) Any carbon steel material may be used to a minimum temperature of −29°C (−20°F) for Category D Fluid Service.
(2) X Grades of API 5L, and ASTM A 381 materials, may be used in accordance with Curve B if normalized or quenched and tempered
(3) The following materials may be used in accordance with Curve D if normalized:
(a) ASTM A 516 Plate, all grades:
(b) ASTM A 671 Pipe, Grades CE55, CE60, and all grades made with A 516 plate;
(c) ASTM A 672 Pipe, Grades E55, E60, and all grades made with A 516 plate.
(4) A welding procedure for the manufacture of pipe or components shall include impact testing of welds and HAZ for any design minimun temperature below −29°C (−20°F), except as provided in Table 323.2.2, A-3(b).
(5) Impact testing in accordance with para. 323.3 is required for any design minimum temperature below −48°C (−55°F), except a permitted by Note (3) in Table 323.2.2.
(6) For blind flanges and blanks, $\overline{T}$ shall be ¼ of the flange thickness.

FIG. 323.2.2A MINIMUM TEMPERATURES WITHOUT IMPACT TESTING FOR CARBON STEEL MATERIALS
(See Table A-1 for Designated Curve for a Listed Material)
(See Table 323.2.2A for tabular values)




GENERAL NOTES:

(a) The Stress Ratio is defined as the maximum of the following:

(1) nominal pressure stress (based on minimum pipe wall thickness less allowances) divided by *S* at the design minimum temperature;

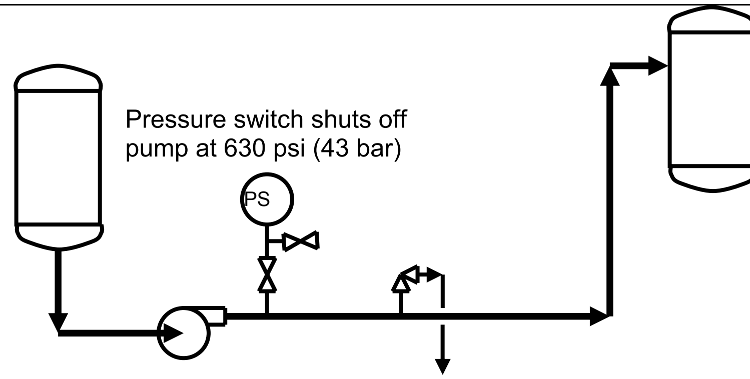
(2) for piping components with pressure ratings, the pressure for the condition under consideration divided by the pressure rating at the design minimum termperature;

(3) combined longitudinal stess due to pressure, dead weight, and displacement strain (stress intensification factors are not included in this calulation) divided by *S* at the design minimum temperature. In calculating longitudinal stress, the forces and moments in the piping system shall be calculated using nominal dimensions and the stresses shall be calculated using section properties based on the nominal dimensions less corrosion, erosion, and mechanical allowances.

(b) Loadings coincident with the metal temperature under consideration shall be used in determining the Stress Ratio as defined above.

FIG. 323.2.2B REDUCTION IN MINIMUM DESIGN METAL TEMPERATURE WITHOUT IMPACT TESTING

## DESIGN PRESSURE AND TEMPERATURE WORKSHOP

| | |
|---|---|
| **Problem 1:** Ambient temperature styrene monomer is pumped from a holding tank to a reactor. The normal discharge pressure is 390 psi (27 bar), and the pressure switch shuts off the positive displacement pump when the pressure reaches 630 psi (43 bar). The material of construction for the line is carbon steel. The piping is capable of 740 psi (51.1 bar).<br>o What should the design pressure be?<br>o What should the design temperature be?<br>o What should the relief valve setting be? |  |
| **Problem 2:** If the line in problem 1 is steam cleaned with 50 psi (3.5 bar) steam superheated to 735°F (390°C)<br>o What should the design pressure be?<br>o What should the design temperature be?<br>o What should the relief valve setting be? | |
| **Problem 3:** Styrene monomer at ambient temperature on outdoor pipe rack. The maximum operating pressure is 95 psig. The piping is capable of 275 psi (19.6 bar).<br>o What should the design pressure be?<br>o What should the design temperature be?<br>o What should the relief valve setting be? |  |

## B31.3 Appendix A – Allowable Stresses: Carbon Steel Example (1 of 2)



### TABLE A-1 (CONT'D)
### BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

| Material | Spec. No. | P-No. or S-No. (5) | Grade | Notes | Min. Temp., °F (6) | Specified Min. Strength, ksi Tensile | Specified Min. Strength, ksi Yield | Min. Temp. to 100 | 200 | 300 |
|---|---|---|---|---|---|---|---|---|---|---|
| Carbon Steel | | | | | | | | | | |
| Pipes and Tubes (2) | | | | | | | | | | |
| A 285 Gr. A | A 134 | 1 | . . . | (8b)(57) | B | 45 | 24 | 15.0 | 14.6 | 14.2 |
| A 285 Gr. A | A 672 | 1 | A45 | (57)(59)(67) | B | 45 | 24 | 15.0 | 14.6 | 14.2 |
| Butt weld | API 5L | S-1 | A25 | (8a) | −20 | 45 | 25 | 15.0 | 15.0 | 14.5 |
| Smls & ERW | API 5L | S-1 | A25 | (57)(59) | B | 45 | 25 | 15.0 | 15.0 | 14.5 |
| . . . | A 179 | 1 | . . . | (57)(59) | −20 | 47 | 26 | 15.7 | 15.0 | 14.2 |
| Type F | A 53 | 1 | Gr. A | (8a)(77) | 20 | 48 | 30 | 16.0 | 16.0 | 16.0 |
| . . . | A 139 | S-1 | A | (8b)(77) | A | 48 | 30 | 16.0 | 16.0 | 16.0 |
| . . . | A 587 | 1 | . . . | (57)(59) | −20 | 48 | 30 | 16.0 | 16.0 | 16.0 |
| . . . | A 53 | 1 | A | (57)(59) | | | | | | |
| . . . | A 106 | 1 | A | (57) | | | | | | |
| . . . | A 135 | 1 | A | (57)(59) | B | 48 | 30 | 16.0 | 16.0 | 16.0 |
| . . . | A 369 | 1 | FPA | (57) | | | | | | |
| . . . | API 5L | S-1 | A | (57)(59)(77) | | | | | | |
| A 285 Gr. B | A 134 | 1 | . . . | (8b)(57) | B | 50 | 27 | 16.7 | 16.4 | 16.0 |
| A 285 Gr. B | A 672 | 1 | A50 | (57)(59)(67) | B | 50 | 27 | 16.7 | 16.4 | 16.0 |
| A 285 Gr. C | A 134 | 1 | . . . | (8b)(57) | A | 55 | 30 | 18.3 | 18.3 | 17.7 |
| . . . | A 524 | 1 | Gr. II | (57) | −20 | 55 | 30 | 18.3 | 18.3 | 17.7 |
| . . . | A 333 | 1 | 1 | | | | | | | |
| . . . | A 334 | 1 | 1 | (57)(59) | −50 | 55 | 30 | 18.3 | 18.3 | 17.7 |
| A 285 Gr. C | A 671 | 1 | CA55 | (59)(67) | A | | | | | |
| A 285 Gr. C | A 672 | 1 | A55 | (57)(59)(67) | A | | | | | |
| A 516 Gr. 55 | A 672 | 1 | C55 | (57)(67) | C | 55 | 30 | 18.3 | 18.3 | 17.7 |
| A 516 Gr. 60 | A 671 | 1 | CC60 | (57)(67) | C | 60 | 32 | 20.0 | 19.5 | 18.9 |
| A 515 Gr. 60 | A 671 | 1 | CB60 | | | | | | | |
| A 515 Gr. 60 | A 672 | 1 | B60 | (57)(67) | B | 60 | 32 | 20.0 | 19.5 | 18.9 |
| A 516 Gr. 60 | A 672 | 1 | C60 | (57)(67) | C | | | | | |
| . . . | A 139 | S-1 | B | (8b) | A | 60 | 35 | 20.0 | 20.0 | 20.0 |
| . . . | A 135 | 1 | B | (57)(59) | B | | | | | |
| . . . | A 524 | 1 | Gr. 1 | (57) | −20 | 60 | 35 | 20.0 | 20.0 | 20.0 |
| . . . | A 53 | 1 | B | (57)(59) | | | | | | |
| . . . | A 106 | 1 | B | (57) | B | | | | | |
| . . . | A 333 | | | | | | | | | |
| . . . | A 334 | 1 | 6 | (57) | −50 | 60 | 35 | 20.0 | 20.0 | 20.0 |
| . . . | A 369 | 1 | FPB | (57) | −20 | | | | | |
| . . . | A 381 | S-1 | Y35 | . . . | A | | | | | |
| . . . | API 5L | S-1 | B | (57)(59)(77) | B | | | | | |

*(continued)*

## B31.3 Appendix A – Allowable Stresses: Carbon Steel Example (2 of 2)

ASME B31.3-2002 Table A-1

### TABLE A-1 (CONT'D)
### BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

| Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 400 | 500 | 600 | 650 | 700 | 750 | 800 | 850 | 900 | 950 | 1000 | 1050 | 1100 | Grade | Spec. No. |
| | | | | | | | | | | | | | | Carbon Steel<br>Pipe and Tubes (2) |
| 13.7 | 13.0 | 11.8 | 11.6 | 11.5 | 10.3 | 9.0 | 7.8 | 6.5 | ... | ... | ... | ... | ... | A 134 |
| 13.7 | 13.0 | 11.8 | 11.6 | 11.5 | 10.3 | 9.0 | 7.8 | 6.5 | 4.5 | 2.5 | 1.6 | 1.0 | A45 | A 672 |
| 13.8 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | A25 | API 5L |
| 13.8 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | A25 | API 5L |
| 13.5 | 12.8 | 12.1 | 11.8 | 11.5 | 10.6 | 9.2 | 7.9 | 6.5 | 4.5 | 2.5 | 1.6 | 1.0 | ... | A 179 |
| 16.0 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | Gr. A | A 53 |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | A | A 139 |
| 16.0 | 16.0 | 14.8 | 14.5 | 14.4 | 10.7 | 9.3 | 7.9 | ... | ... | ... | ... | ... | ... | A 587 |
| 16.0 | 16.0 | 14.8 | 14.5 | 14.4 | 10.7 | 9.3 | 7.9 | 6.5 | 4.5 | 2.5 | 1.6 | 1.0 | A<br>A<br>A<br>FPA<br>A | A 53<br>A 106<br>A 135<br>A 369<br>API 5L |
| 15.4 | 14.6 | 13.3 | 13.1 | 13.0 | 11.2 | 9.6 | 8.1 | 6.5 | ... | ... | ... | ... | ... | A 134 |
| 15.4 | 14.6 | 13.3 | 13.1 | 13.0 | 11.2 | 9.6 | 8.1 | 6.5 | 4.5 | 2.5 | 1.6 | 1.0 | A 50 | A 672 |
| 17.2 | 16.2 | 14.8 | 14.5 | 14.4 | 12.0 | 10.2 | 8.3 | 6.5 | ... | ... | ... | ... | ... | A 134 |
| 17.2 | 16.2 | 14.8 | 14.5 | 14.4 | 12.0 | 10.2 | 8.3 | 6.5 | 4.5 | 2.5 | ... | ... | Gr. II | A 524 |
| 17.2 | 16.2 | 14.8 | 14.5 | 14.4 | 12.0 | 10.2 | 8.3 | 6.5 | 4.5 | 2.5 | 1.6 | 1.0 | 1<br>1 | A 333<br>A 334 |
| 17.2 | 16.2 | 14.8 | 14.5 | 14.4 | 12.1 | 10.2 | 8.4 | 6.5 | 4.5 | 2.5 | 1.6 | 1.0 | CA55<br>A55<br>C55 | A 671<br>A 672<br>A 672 |
| 18.3 | 17.3 | 15.8 | 15.5 | 15.4 | 13.0 | 10.8 | 8.7 | 6.5 | 4.5 | 2.5 | ... | ... | CC60 | A 671 |
| 18.3 | 17.3 | 15.8 | 15.5 | 15.4 | 13.0 | 10.8 | 8.7 | 6.5 | 4.5 | 2.5 | 1.6 | 1.0 | CB60<br>B60<br>C60 | A 671<br>A 672<br>A 672 |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | B | A 139 |
| 20.0 | 18.9 | 17.3 | 17.0 | 16.5 | 13.0 | 10.8 | 8.7 | 6.5 | 4.5 | 2.5 | ... | ... | B<br>Gr. 1 | A 135<br>A 524 |
| 20.0 | 18.9 | 17.3 | 17.0 | 16.5 | 13.0 | 10.8 | 8.7 | 6.5 | 4.5 | 2.5 | 1.6 | 1.0 | B<br>B<br>6<br>6<br>FPB<br>Y35<br>B | A 53<br>A 106<br>A 333<br>A 334<br>A 369<br>A 381<br>API 5L |

*(continued)*

## B31.3 Appendix A – Allowable Stresses: Stainless Steel Example (1 of 2)

Table A-1 ASME B31.3-2002

### TABLE A-1 (CONT'D)
### BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

| Material | Spec. No. | P-No. or S-No. (5) | Grade | Notes | Min. Temp., °F (6) | Specified Min. Strength, ksi Tensile | Yield | Min. Temp. to 100 | 200 | 300 | 400 | 500 | 600 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stainless Steel (3) (4) (Cont'd) | | | | | | | | | | | | | |
| Pipes and Tubes (2) (Cont'd) | | | | | | | | | | | | | |
| 18Cr-10Ni-Cb pipe | A 312 | 8 | TP347 | . . . | −425 | | | | | | | | |
| Type 347 A 240 | A 358 | 8 | 347 | (30)(36) | −425 | | | | | | | | |
| 18Cr-10Ni-Cb pipe | A 376 | 8 | TP347 | (30)(36) | −425 | | | | | | | | |
| 18Cr-10Ni-Cb pipe | A 409 | 8 | TP347 | (30)(36) | −425 | 75 | 30 | 20.0 | *20.0* | *20.0* | *20.0* | *19.9* | 19.3 |
| 18Cr-10Ni-Cb pipe | A 312 | 8 | TP348 | . . . | −325 | | | | | | | | |
| Type 348 A 240 | A 358 | 8 | 348 | (30)(36) | −325 | | | | | | | | |
| 18Cr-10Ni-b pipe | A 376 | 8 | TP348 | (30)(36) | −325 | | | | | | | | |
| 18Cr-10Ni-Cb pipe | A 409 | 8 | TP348 | (30)(36) | −325 | | | | | | | | |
| 23Cr-13Ni | A 451 | 8 | CPH10 or CPH20 | (12)(14)(28)(35)(39) | −325 | 70 | 30 | 20.0 | *20.0* | *20.0* | *20.0* | *20.0* | 19.2 |
| 25Cr-20Ni pipe | A 312 | 8 | TP310 | (28)(29)(35)(39) | −325 | 75 | 30 | 20.0 | *20.0* | *20.0* | *20.0* | *20.0* | 19.2 |
| Type 310S A 240 | A 358 | 8 | 310S | (28)(29)(31)(35)(36) | | | | | | | | | |
| 18Cr-10Ni-Cb | A 451 | 8 | CPF8C | (28) | −325 | 70 | 30 | 20.0 | *20.0* | *20.0* | *20.0* | 19.3 | 18.3 |
| 18Cr-10Ni-Ti pipe smls ≤ 3/8 in. thk; wld | A 312 | 8 | TP321 | (28)(30) | | | | | | | | | |
| Type 321 A 240 | A 358 | 8 | 321 | | | | | | | | | | |
| 18Cr-10Ni-Ti pipe ≤ 3/8 in. thick | A 376 | 8 | TP321 | (28)(30)(36) | −425 | 75 | 30 | 20.0 | *20.0* | *20.0* | *20.0* | 19.3 | 18.3 |
| 18Cr-10Ni-Ti pipe | A 409 | | | | | | | | | | | | |
| 18Cr-10Ni-Ti pipe ≤ 3/8 in. thick | A 376 | 8 | TP321H | (30)(36) | −325 | | | | | | | | |
| 18Cr-10Ni-Ti pipe smls ≤ 3/8 in. thk; wld | A 312 | 8 | TP321H | . . . | −325 | | | | | | | | |
| 16Cr-12Ni-Mo tube | A 269 | 8 | TP316 | (14)(26)(28)(31)(36) | −425 | | | | | | | | |
| 16Cr-12Ni-2Mo pipe | A 312 | 8 | TP316 | (26)(28) | −425 | | | | | | | | |
| Type 316 A 240 | A 358 | 8 | 316 | (26)(28)(31)(36) | −425 | | | | | | | | |
| 16Cr-12Ni-2Mo pipe | A 376 | 8 | TP316 | (26)(28)(31)(36) | −425 | 75 | 30 | 20.0 | *20.0* | *20.0* | 19.3 | 17.9 | 17.0 |
| 16Cr-12Ni-2Mo pipe | A 409 | 8 | TP316 | (26)(28)(31)(36) | −425 | | | | | | | | |
| 18Cr-3Ni-3Mo pipe | A 312 | 8 | TP317 | (26)(28) | −325 | | | | | | | | |
| 18Cr-3Ni-3Mo pipe | A 409 | 8 | TP317 | (26)(28)(31)(36) | −325 | | | | | | | | |
| 16Cr-12Ni-2Mo pipe | A 376 | 8 | TP316H | (26)(31)(36) | −325 | | | | | | | | |
| 16Cr-12Ni-2Mo pipe | A 312 | 8 | TP316H | (26) | −325 | 75 | 30 | 20.0 | *20.0* | *20.0* | 19.3 | 17.9 | 17.0 |
| 18Cr-10Ni-Cb pipe | A 376 | 8 | TP347H | (30)(36) | −325 | | | | | | | | |
| 18Cr-0Ni-Cb pipe | A 312 | 8 | TP347 | (28) | −425 | | | | | | | | |
| Type 347 A 240 | A 358 | 8 | 347 | (28)(30)(36) | −425 | | | | | | | | |
| 18Cr-10Ni-Cb pipe | A 376 | 8 | TP347 | (28)(30)(36) | −425 | | | | | | | | |
| 18Cr-10Nib pipe | A 409 | 8 | TP347 | (28)(30)(36) | −425 | 75 | 30 | 20.0 | *20.0* | *20.0* | *20.0* | *19.9* | 19.3 |
| 18Cr-10Ni-b pipe | A 312 | 8 | TP348 | (28) | −325 | | | | | | | | |
| Type 348 A 240 | A 358 | 8 | 348 | (28)(30)(36) | −325 | | | | | | | | |
| 18Cr-10Ni-Cb pipe | A 376 | 8 | TP348 | (28)(30)(36) | −325 | | | | | | | | |
| 18Cr-10Ni-Cb pipe | A 409 | 8 | TP348 | (28)(30)(36) | −325 | | | | | | | | |
| 18Cr-10Ni-Cb pipe | A 312 | 8 | TP347H | | | | | | | | | | |
| 18Cr-10Ni-Cb pipe | A 312 | 8 | TP348H | . . . | −325 | 75 | 30 | 20.0 | *20.0* | *20.0* | *20.0* | *19.9* | 19.3 |

*(continued)*

## B31.3 Appendix A – Allowable Stresses: Stainless Steel Example (2 of 2)

ASME B31.3-2002 Table A-1

### TABLE A-1 (CONT'D)
### BASIC ALLOWABLE STRESSES IN TENSION FOR METALS[1]

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

| Basic Allowable Stress *S*, ksi (1), at Metal Temperature, °F (7) | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 650 | 700 | 750 | 800 | 850 | 900 | 950 | 1000 | 1050 | 1100 | 1150 | 1200 | 1250 | 1300 | 1350 | 1400 | 1450 | 1500 | Grade | Spec. No. |
| | | | | | | | | | | | | | | | | | | Stainless Steel (3) (4) (Cont'd) Pipes and Tubes (2) (Cont'd) | |
| | | | | | | | | | | | | | | | | | | TP347 | A 312 |
| | | | | | | | | | | | | | | | | | | 347 | A 358 |
| | | | | | | | | | | | | | | | | | | TP347 | A 376 |
| 19.0 | 18.6 | 18.5 | 18.4 | *18.2* | *18.1* | *18.1* | *18.0* | *12.1* | 9.1 | 6.1 | 4.4 | 3.3 | 2.2 | 1.5 | 1.2 | 0.9 | 0.8 | TP347 | A 409 |
| | | | | | | | | | | | | | | | | | | TP348 | A 312 |
| | | | | | | | | | | | | | | | | | | 348 | A 358 |
| | | | | | | | | | | | | | | | | | | TP348 | A 376 |
| | | | | | | | | | | | | | | | | | | TP348 | A 409 |
| 18.8 | 18.3 | 18.0 | 17.4 | *13.5* | *13.3* | *12.4* | 10.5 | 8.4 | 6.4 | 5.0 | 3.7 | 2.9 | 2.3 | 1.7 | 1.3 | 0.9 | 0.8 | CPH10 or CPH20 | A 451 |
| 18.8 | 18.3 | 18.0 | 17.5 | *14.6* | *13.9* | *12.5* | 11.0 | 9.8 | 8.5 | 7.3 | 6.0 | 4.8 | 3.5 | 2.3 | 1.6 | 1.1 | 0.8 | TP310 | A 312 |
| | | | | | | | | | | | | | | | | | | 310S | A 358 |
| 18.0 | 17.5 | 17.2 | 17.1 | *14.0* | *13.9* | *13.7* | *13.4* | *13.0* | *10.8* | 8.0 | 5.0 | 3.5 | 2.7 | 2.0 | 1.4 | 1.1 | 1.0 | CPF8C | A 451 |
| | | | | | | | | | | | | | | | | | | TP321 | A 312 |
| | | | | | | | | | | | | | | | | | | 321 | A 358 |
| 17.9 | 17.5 | 17.2 | 16.9 | *16.7* | *16.6* | *16.4* | *16.2* | *11.7* | 9.1 | 6.9 | 5.4 | 4.1 | 3.2 | 2.5 | 1.9 | 1.5 | 1.1 | TP321 | A 376 |
| | | | | | | | | | | | | | | | | | | TP321 | A 409 |
| | | | | | | | | | | | | | | | | | | TP321H | A 376 |
| | | | | | | | | | | | | | | | | | | TP321H | A 312 |
| | | | | | | | | | | | | | | | | | | TP316 | A 269 |
| | | | | | | | | | | | | | | | | | | TP316 | A 312 |
| | | | | | | | | | | | | | | | | | | 316 | A 358 |
| 16.7 | 16.3 | 16.1 | 15.9 | 15.7 | 15.5 | 15.4 | 15.3 | *14.5* | *12.4* | 9.8 | 7.4 | 5.5 | 4.1 | 3.1 | 2.3 | 1.7 | 1.3 | TP316 | A 376 |
| | | | | | | | | | | | | | | | | | | TP316 | A 409 |
| | | | | | | | | | | | | | | | | | | TP317 | A 312 |
| | | | | | | | | | | | | | | | | | | TP317 | A 409 |
| | | | | | | | | | | | | | | | | | | TP316H | A 376 |
| 16.7 | 16.3 | 16.1 | 15.9 | 15.7 | 15.5 | 15.4 | 15.3 | *14.5* | *12.4* | 9.8 | 7.4 | 5.5 | 4.1 | 3.1 | 2.3 | 1.7 | 1.3 | TP316H | A 312 |
| | | | | | | | | | | | | | | | | | | TP347H | A 376 |
| | | | | | | | | | | | | | | | | | | TP347 | A 312 |
| | | | | | | | | | | | | | | | | | | 347 | A 358 |
| | | | | | | | | | | | | | | | | | | TP347 | A 376 |
| 19.0 | 18.6 | 18.5 | 18.4 | 18.2 | 18.1 | 18.1 | 18.0 | *17.1* | *14.2* | 10.5 | 7.9 | 5.9 | 4.4 | 3.2 | 2.5 | 1.8 | 1.3 | TP347 | A 409 |
| | | | | | | | | | | | | | | | | | | TP348 | A 312 |
| | | | | | | | | | | | | | | | | | | 348 | A 358 |
| | | | | | | | | | | | | | | | | | | TP348 | A 376 |
| | | | | | | | | | | | | | | | | | | TP348 | A 409 |
| | | | | | | | | | | | | | | | | | | TP347H | A 312 |
| 19.0 | 18.6 | 18.5 | 18.4 | 18.2 | 18.1 | 18.1 | 18.0 | *17.1* | *14.2* | 10.5 | 7.9 | 5.9 | 4.4 | 3.2 | 2.5 | 1.8 | 1.3 | TP348H | A 312 |

*(continued)*

## B31.3 Appendix A – Quality Factors Example (1 of 2)



### TABLE A-1B
### BASIC QUALITY FACTORS FOR LONGITUDINAL WELD JOINTS IN PIPES, TUBES, AND FITTINGS $E_j$

These quality factors are determined in accordance with para. 302.3.4(a). See also para. 302.3.4(b) and Table 302.3.4 for increased quality factors applicable in special cases. Specifications, except API, are ASTM.

| Spec. No. | Class (or Type) | Description | $E_j$ (2) | Appendix A Notes |
|---|---|---|---|---|
| Carbon Steel | | | | |
| API 5L | ... | Seamless pipe | 1.00 | ... |
| | ... | Electric resistance welded pipe | 0.85 | ... |
| | ... | Electric fusion welded pipe, double butt, straight or spiral seam | 0.95 | ... |
| | ... | Furnace butt welded | 0.60 | ... |
| A 53 | Type S | Seamless pipe | 1.00 | ... |
| | Type E | Electric resistance welded pipe | 0.85 | ... |
| | Type F | Furnace butt welded pipe | 0.60 | ... |
| A 105 | ... | Forgings and fittings | 1.00 | (9) |
| A 106 | ... | Seamless pipe | 1.00 | ... |
| A 134 | ... | Electric fusion welded pipe, single butt, straight or spiral seam | 0.80 | ... |
| A 135 | ... | Electric resistance welded pipe | 0.85 | ... |
| A 139 | ... | Electric fusion welded pipe, straight or spiral seam | 0.80 | ... |
| A 179 | ... | Seamless tube | 1.00 | ... |
| A 181 | ... | Forgings and fittings | 1.00 | (9) |
| A 234 | ... | Seamless and welded fittings | 1.00 | (16) |
| A 333 | ... | Seamless pipe | 1.00 | ... |
| | ... | Electric resistance welded pipe | 0.85 | ... |
| A 334 | ... | Seamless tube | 1.00 | ... |
| A 350 | ... | Forgings and fittings | 1.00 | (9) |
| A 369 | ... | Seamless pipe | 1.00 | ... |
| A 381 | ... | Electric fusion welded pipe, 100% radiographed | 1.00 | (18) |
| | ... | Electric fusion welded pipe, spot radiographed | 0.90 | (19) |
| | ... | Electric fusion welded pipe, as manufactured | 0.85 | ... |
| A 420 | ... | Welded fittings, 100% radiographed | 1.00 | (16) |
| A 524 | ... | Seamless pipe | 1.00 | ... |
| A 587 | ... | Electric resistance welded pipe | 0.85 | ... |
| A 671 | 12, 22, 32, 42, 52 | Electric fusion welded pipe, 100% radiographed | 1.00 | ... |
| | 13, 23, 33, 43, 53 | Electric fusion welded pipe, double butt seam | 0.85 | ... |
| A 672 | 12, 22, 32, 42, 52 | Electric fusion welded pipe, 100% radiographed | 1.00 | ... |
| | 13, 23, 33, 43, 53 | Electric fusion welded pipe, double butt seam | 0.85 | ... |
| A 691 | 12, 22, 32, 42, 52 | Electric fusion welded pipe, 100% radiographed | 1.00 | ... |
| | 13, 23, 33, 43, 53 | Electric fusion welded pipe, double butt seam | 0.85 | ... |
| Low and Intermediate Alloy Steel | | | | |
| A 182 | ... | Forgings and fittings | 1.00 | (9) |
| A 234 | ... | Seamless and welded fittings | 1.00 | (16) |
| A 333 | ... | Seamless pipe | 1.00 | ... |
| | ... | Electric resistance welded pipe | 0.85 | ... |

*(continued)*

## B31.3 Appendix A – Quality Factors Example (2 of 2)



TABLE A-1B (CONT'D)
BASIC QUALITY FACTORS FOR LONGITUDINAL WELD JOINTS IN PIPES, TUBES, AND FITTINGS $E_j$
These quality factors are determined in accordance with para. 302.3.4(a). See also para. 302.3.4(b) and Table 302.3.4 for increased quality factors applicable in special cases. Specifications, except API, are ASTM.

| Spec. No. | Class (or Type) | Description | $E_j$ (2) | Appendix A Notes |
|---|---|---|---|---|
| Low and Intermediate Alloy Steel (Cont'd) | | | | |
| A 334 | ... | Seamless tube | 1.00 | ... |
| A 335 | ... | Seamless pipe | 1.00 | ... |
| A 350 | ... | Forgings and fittings | 1.00 | ... |
| A 369 | ... | Seamless pipe | 1.00 | ... |
| A 420 | ... | Welded fittings, 100% radiographed | 1.00 | (16) |
| A 671 | 12, 22, 32, 42, 52 | Electric fusion welded pipe, 100% radiographed | 1.00 | ... |
| | 13, 23, 33, 43, 53 | Electric fusion welded pipe, double butt seam | 0.85 | ... |
| A 672 | 12, 22, 32, 42, 52 | Electric fusion welded pipe, 100% radiographed | 1.00 | ... |
| | 13, 23, 33, 43, 53 | Electric fusion welded pipe, double butt seam | 0.85 | ... |
| A 691 | 12, 22, 32, 42, 52 | Electric fusion welded pipe, 100% radiographed | 1.00 | ... |
| | 13, 23, 33, 43, 53 | Electric fusion welded pipe, double butt seam | 0.85 | ... |
| Stainless Steel | | | | |
| A 182 | ... | Forgings and fittings | 1.00 | ... |
| A 268 | ... | Seamless tube | 1.00 | ... |
| | ... | Electric fusion welded tube, double butt seam | 0.85 | ... |
| | ... | Electric fusion welded tube, single butt seam | 0.80 | ... |
| A 269 | ... | Seamless tube | 1.00 | ... |
| | ... | Electric fusion welded tube, double butt seam | 0.85 | ... |
| | ... | Electric fusion welded tube, single butt seam | 0.80 | ... |
| A 312 | ... | Seamless tube | 1.00 | ... |
| | ... | Electric fusion welded tube, double butt seam | 0.85 | ... |
| | ... | Electric fusion welded tube, single butt seam | 0.80 | ... |
| A 358 | 1, 3, 4 | Electric fusion welded pipe, 100% radiographed | 1.00 | ... |
| | 5 | Electric fusion welded pipe, spot radiographed | 0.90 | ... |
| | 2 | Electric fusion welded pipe, double butt seam | 0.85 | ... |
| A 376 | ... | Seamless pipe | 1.00 | ... |
| A 403 | ... | Seamless fittings | 1.00 | ... |
| | ... | Welded fitting, 100% radiographed | 1.00 | (16) |
| | ... | Welded fitting, double butt seam | 0.85 | ... |
| | ... | Welded fitting, single butt seam | 0.80 | ... |
| A 409 | ... | Electric fusion welded pipe, double butt seam | 0.85 | ... |
| | ... | Electric fusion welded pipe, single butt seam | 0.80 | ... |
| A 487 | ... | Steel castings | 0.80 | (9)(40) |
| A 789 | ... | Seamless tube | 1.00 | ... |
| | ... | Electric fusion welded, 100% radiographed | 1.00 | ... |
| | ... | Electric fusion welded, double butt | 0.85 | ... |
| | ... | Electric fusion welded, single butt | 0.80 | ... |
| A 790 | ... | Seamless pipe | 1.00 | ... |
| | ... | Electric fusion welded, 100% radiographed | 1.00 | ... |
| | ... | Electric fusion welded, double butt | 0.85 | ... |
| | ... | Electric fusion welded, single butt | 0.80 | ... |

*(continued)*

## CALCULATING REQUIRED WALL THICKNESS FOR STRAIGHT PIPE

$$t = \frac{PD}{2\,(SEW + PY)}$$

Where:

t = **pressure design thickness**
P = internal design gauge pressure
D = outside diameter of pipe
S = allowable stress value for material from piping code at the design temperature
E = longitudinal weld joint quality factor from piping code (next page)
W = weld joint strength reduction factor
  = 1.0 for all materials 950ºF (510ºC) and cooler
Y = coefficient. See the next page. The following values generally apply:
  = 0.4 for ductile metals 900ºF (482ºC) and cooler
  = 0.0 for cast iron

**The minimum nominal new thickness required is the sum of:**
**pressure design thickness (t)**
\+ manufacturing tolerance (ASTM A53 allows plus or minus 12.5%)
\+ corrosion (or erosion) allowance
\+ threading allowance

## STRAIGHT PIPE WALL THICKNESS WORKSHOP

1. What is the required nominal pipe wall thickness for NPS 1 and NPS 8 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 25
   S = 20,000 psi (138 MPa) - verify
   Corrosion allowance = 1/8” (3.2 mm)
   Socket welding thru NPS 1½
   Buttwelding NPS 2 and larger

2. If the construction was threading instead of socket welding NPS ¾ through 1½, what would the wall thickness have to be for NPS 1? [See discussion on Threaded Joint Fluid Service Requirements in Section 2 and para. 314.]

**VALUES OF COEFFICIENT Y**

When the pressure design thickness is less than 1/6 of the pipe outside diameter, the following values apply:

| | ≤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 | --- | --- | --- | --- | --- |

The factor Y increases with increasing temperature. At elevated temperatures, when creep effects become significant, creep leads to a more even distribution of stress across the pipe wall thickness. The larger factor Y leads to a decrease in the calculated wall thickness for the same allowable stress.

When the pressure design thickness is greater than or equal to 1/6 of the pipe outside diameter, the following equation applies:

$$Y = \frac{d + 2c}{D + d + 2c}$$

Where:

d = inside diameter of the pipe
D = outside diameter of the pipe
c = corrosion (or erosion) allowance plus threading allowance

## TABLE 302.3.4
## LONGITUDINAL WELD JOINT QUALITY FACTOR, $E_j$

| No. | Type of Joint | | Type of Seam | Examination | Factor, $E_j$ |
|---|---|---|---|---|---|
| 1 | Furnace butt weld, continuous weld |  | Straight | As required by listed specification | 0.60 [Note (1)] |
| 2 | Electric resistance weld |  | Straight or spiral | As required by listed specification | 0.85 [Note (1)] |
| 3 | Electric fusion weld | | | | |
| | (a) Single butt weld | | Straight or spiral | As required by listed specification or this Code | 0.80 |
| | (with or without filler metal) |  | | Additionally spot radiographed per para. 341.5.1 | 0.90 |
| | | | | Additionally 100% radiographed per para. 344.5.1 and Table 341.3.2 | 1.00 |
| | (b) Double butt weld | | Straight or spiral [except as provided in 4(a) below] | As required by listed specification or this Code | 0.85 |
| | (with or without filler metal) |  | | Additionally spot radiographed per para. 341.5.1 | 0.90 |
| | | | | Additionally 100% radiographed per para. 344.5.1 and Table 341.3.2 | 1.00 |
| 4 | Per specific specification | | | | |
| | (a) API 5L | Submerged arc weld (SAW)<br>Gas metal arc weld (GMAW)<br>Combined GMAW, SAW<br> | Straight with one or two seams<br>Spiral | As required by specification | 0.95 |

NOTE:
(1) It is not permitted to increase the joint quality factor by additional examination for joint 1 or 2.

**PIPE DIMENSIONS AND PROPERTIES IN US CUSTOMARY UNITS**

| NPS | OD, in. | ID | Schedule | Wall Thickness, in. | Inside Diameter, in. | Weight of Steel Pipe, lbm/ft | Weight of Water, lbm/ft | Moment of Inertia, in4 | Section Modulus, in3 |
|---|---|---|---|---|---|---|---|---|---|
| 1/8 | 0.405 | STD | 40 | 0.068 | 0.269 | 0.244 | 0.025 | 0.0011 | 0.0053 |
| | | XS | 80 | 0.095 | 0.215 | 0.314 | 0.016 | 0.0012 | 0.0060 |
| 1/4 | 0.540 | STD | 40 | 0.088 | 0.364 | 0.424 | 0.045 | 0.0033 | 0.0123 |
| | | XS | 80 | 0.119 | 0.302 | 0.534 | 0.031 | 0.0038 | 0.0139 |
| 3/8 | 0.675 | STD | 40 | 0.091 | 0.493 | 0.567 | 0.083 | 0.0073 | 0.0216 |
| | | XS | 80 | 0.126 | 0.423 | 0.738 | 0.061 | 0.0086 | 0.0255 |
| 1/2 | 0.840 | - | 10S | 0.083 | 0.674 | 0.670 | 0.155 | 0.0143 | 0.0341 |
| | | STD | 40 | 0.109 | 0.622 | 0.850 | 0.132 | 0.0171 | 0.0407 |
| | | XS | 80 | 0.147 | 0.546 | 1.09 | 0.101 | 0.0201 | 0.0478 |
| | | - | 160 | 0.188 | 0.464 | 1.31 | 0.073 | 0.0222 | 0.0528 |
| | | XXS | - | 0.294 | 0.252 | 1.71 | 0.022 | 0.0242 | 0.0577 |
| 3/4 | 1.050 | - | 10S | 0.083 | 0.884 | 0.856 | 0.266 | 0.0297 | 0.0566 |
| | | STD | 40 | 0.113 | 0.824 | 1.13 | 0.231 | 0.0370 | 0.0705 |
| | | XS | 80 | 0.154 | 0.742 | 1.47 | 0.187 | 0.0448 | 0.0853 |
| | | - | 160 | 0.219 | 0.612 | 1.94 | 0.127 | 0.0528 | 0.101 |
| | | XXS | - | 0.308 | 0.434 | 2.44 | 0.064 | 0.0579 | 0.110 |
| 1 | 1.315 | - | 10S | 0.109 | 1.097 | 1.40 | 0.410 | 0.0757 | 0.115 |
| | | STD | 40 | 0.133 | 1.049 | 1.68 | 0.375 | 0.0873 | 0.133 |
| | | XS | 80 | 0.178 | 0.959 | 2.16 | 0.313 | 0.105 | 0.160 |
| | | - | 160 | 0.250 | 0.815 | 2.84 | 0.226 | 0.125 | 0.190 |
| | | XXS | - | 0.358 | 0.599 | 3.66 | 0.122 | 0.140 | 0.214 |
| 1-1/4 | 1.660 | - | 10S | 0.109 | 1.442 | 1.80 | 0.708 | 0.160 | 0.193 |
| | | STD | 40 | 0.140 | 1.380 | 2.27 | 0.648 | 0.195 | 0.235 |
| | | XS | 80 | 0.191 | 1.278 | 2.99 | 0.556 | 0.242 | 0.291 |
| | | - | 160 | 0.250 | 1.160 | 3.76 | 0.458 | 0.284 | 0.342 |
| | | XXS | - | 0.382 | 0.896 | 5.21 | 0.273 | 0.341 | 0.411 |
| 1-1/2 | 1.900 | - | 10S | 0.109 | 1.682 | 2.08 | 0.963 | 0.247 | 0.260 |
| | | STD | 40 | 0.145 | 1.610 | 2.71 | 0.882 | 0.310 | 0.326 |
| | | XS | 80 | 0.200 | 1.500 | 3.63 | 0.766 | 0.391 | 0.412 |
| | | - | 160 | 0.281 | 1.338 | 4.85 | 0.609 | 0.482 | 0.508 |
| | | XXS | - | 0.400 | 1.100 | 6.40 | 0.412 | 0.568 | 0.598 |
| 2 | 2.375 | - | 10S | 0.109 | 2.157 | 2.64 | 1.58 | 0.499 | 0.420 |
| | | STD | 40 | 0.154 | 2.067 | 3.65 | 1.45 | 0.666 | 0.561 |
| | | XS | 80 | 0.218 | 1.939 | 5.02 | 1.28 | 0.868 | 0.731 |
| | | - | 160 | 0.344 | 1.687 | 7.45 | 0.969 | 1.16 | 0.980 |
| | | XXS | - | 0.436 | 1.503 | 9.02 | 0.769 | 1.31 | 1.10 |
| 2-1/2 | 2.875 | - | 10S | 0.120 | 2.635 | 3.53 | 2.36 | 0.987 | 0.687 |
| | | STD | 40 | 0.203 | 2.469 | 5.79 | 2.07 | 1.53 | 1.06 |
| | | XS | 80 | 0.276 | 2.323 | 7.65 | 1.84 | 1.92 | 1.34 |
| | | - | 160 | 0.375 | 2.125 | 10.0 | 1.54 | 2.35 | 1.64 |
| | | XXS | - | 0.552 | 1.771 | 13.7 | 1.07 | 2.87 | 2.00 |
| 3 | 3.500 | - | 5S | 0.083 | 3.334 | 3.03 | 3.78 | 1.30 | 0.744 |
| | | - | 10S | 0.120 | 3.260 | 4.33 | 3.62 | 1.82 | 1.04 |
| | | STD | 40 | 0.216 | 3.068 | 7.57 | 3.20 | 3.02 | 1.72 |
| | | XS | 80 | 0.300 | 2.900 | 10.2 | 2.86 | 3.89 | 2.23 |
| | | - | 160 | 0.438 | 2.624 | 14.3 | 2.34 | 5.04 | 2.88 |

| NPS | OD, in. | ID | Schedule | Wall Thickness, in. | Inside Diameter, in. | Weight of Steel Pipe, lbm/ft | Weight of Water, lbm/ft | Moment of Inertia, in4 | Section Modulus, in3 |
|---|---|---|---|---|---|---|---|---|---|
| | | XXS | - | 0.600 | 2.300 | 18.6 | 1.80 | 5.99 | 3.42 |
| 4 | 4.500 | - | 5S | 0.083 | 4.334 | 3.91 | 6.39 | 2.81 | 1.25 |
| | | - | 10S | 0.120 | 4.260 | 5.61 | 6.18 | 3.96 | 1.76 |
| | | STD | 40 | 0.237 | 4.026 | 10.8 | 5.52 | 7.23 | 3.21 |
| | | XS | 80 | 0.337 | 3.826 | 15.0 | 4.98 | 9.61 | 4.27 |
| 6 | 6.625 | - | 5S | 0.109 | 6.407 | 7.58 | 14.0 | 11.8 | 3.58 |
| | | - | 10S | 0.134 | 6.357 | 9.28 | 13.8 | 14.4 | 4.35 |
| | | STD | 40 | 0.280 | 6.065 | 19.0 | 12.5 | 28.1 | 8.50 |
| | | XS | 80 | 0.432 | 5.761 | 28.5 | 11.3 | 40.5 | 12.2 |
| 8 | 8.625 | - | 5S | 0.109 | 8.407 | 9.90 | 24.1 | 26.4 | 6.13 |
| | | - | 10S | 0.148 | 8.329 | 13.4 | 23.6 | 35.4 | 8.21 |
| | | STD | 40 | 0.322 | 7.981 | 28.5 | 21.7 | 72.5 | 16.8 |
| | | XS | 80 | 0.500 | 7.625 | 43.3 | 19.8 | 105.7 | 24.5 |
| 10 | 10.750 | - | 5S | 0.134 | 10.482 | 15.2 | 37.4 | 63.0 | 11.7 |
| | | - | 10S | 0.165 | 10.420 | 18.6 | 37.0 | 76.9 | 14.3 |
| | | STD | 40 | 0.365 | 10.020 | 40.4 | 34.2 | 161 | 29.9 |
| | | XS | - | 0.500 | 9.750 | 54.7 | 32.4 | 212 | 39.4 |
| | | - | 80 | 0.594 | 9.562 | 64.4 | 31.1 | 245 | 45.6 |
| 12 | 12.750 | - | 5S | 0.156 | 12.438 | 21.0 | 52.7 | 122 | 19.2 |
| | | - | 10S | 0.180 | 12.390 | 24.1 | 52.2 | 140 | 22.0 |
| | | STD | - | 0.375 | 12.000 | 49.5 | 49.0 | 279 | 43.8 |
| | | - | 40 | 0.406 | 11.938 | 53.5 | 48.5 | 300 | 47.1 |
| | | XS | - | 0.500 | 11.750 | 65.3 | 47.0 | 362 | 56.7 |
| | | - | 80 | 0.688 | 11.374 | 88.5 | 44.0 | 476 | 74.6 |
| 14 | 14.000 | - | 5S | 0.156 | 13.688 | 23.0 | 63.8 | 163 | 23.2 |
| | | - | 10S | 0.188 | 13.624 | 27.7 | 63.2 | 195 | 27.8 |
| | | STD | - | 0.375 | 13.250 | 54.5 | 59.8 | 373 | 53.3 |
| | | - | 40 | 0.438 | 13.124 | 63.4 | 58.6 | 429 | 61.4 |
| | | XS | - | 0.500 | 13.000 | 72.0 | 57.5 | 484 | 69.1 |
| | | - | 80 | 0.750 | 12.500 | 106 | 53.2 | 687 | 98.2 |
| 16 | 16.000 | - | 5S | 0.165 | 15.670 | 27.9 | 83.6 | 257 | 32.2 |
| | | - | 10S | 0.188 | 15.624 | 31.7 | 83.1 | 292 | 36.5 |
| | | STD | - | 0.375 | 15.250 | 62.5 | 79.2 | 562 | 70.3 |
| | | XS | 40 | 0.500 | 15.000 | 82.7 | 76.6 | 732 | 91.5 |
| | | - | 80 | 0.844 | 14.312 | 136 | 69.7 | 1157 | 145 |
| 18 | 18.000 | - | 5S | 0.165 | 17.670 | 31.4 | 106 | 368 | 40.8 |
| | | - | 10S | 0.188 | 17.624 | 35.7 | 106 | 417 | 46.4 |
| | | STD | - | 0.375 | 17.250 | 70.5 | 101 | 807 | 89.6 |
| | | XS | - | 0.500 | 17.000 | 93.4 | 98.4 | 1053 | 117 |
| | | - | 40 | 0.562 | 16.876 | 105 | 96.9 | 1171 | 130 |
| | | - | 80 | 0.938 | 16.124 | 171 | 88.5 | 1835 | 204 |
| 20 | 20.000 | - | 5S | 0.188 | 19.624 | 39.7 | 131 | 574 | 57.4 |
| | | - | 10S | 0.218 | 19.564 | 46.0 | 130 | 663 | 66.3 |
| | | STD | - | 0.375 | 19.250 | 78.5 | 126 | 1113 | 111 |
| | | XS | - | 0.500 | 19.000 | 104 | 123 | 1457 | 146 |
| | | - | 40 | 0.594 | 18.812 | 123 | 120 | 1706 | 171 |
| 22 | 22.000 | - | 5S | 0.188 | 21.624 | 43.7 | 159 | 766 | 69.7 |

| NPS | OD, in. | ID | Schedule | Wall Thickness, in. | Inside Diameter, in. | Weight of Steel Pipe, lbm/ft | Weight of Water, lbm/ft | Moment of Inertia, in4 | Section Modulus, in3 |
|---|---|---|---|---|---|---|---|---|---|
| | | - | 10S | 0.218 | 21.564 | 50.7 | 158 | 885 | 80.4 |
| | | STD | - | 0.375 | 21.250 | 86.5 | 154 | 1490 | 135 |
| | | XS | - | 0.500 | 21.000 | 115 | 150 | 1952 | 177 |
| 24 | 24.000 | - | 5S | 0.218 | 23.564 | 55.3 | 189 | 1152 | 96.0 |
| | | - | 10S | 0.250 | 23.500 | 63.3 | 188 | 1315 | 110 |
| | | STD | - | 0.375 | 23.250 | 94.5 | 184 | 1942 | 162 |
| | | XS | - | 0.500 | 23.000 | 125 | 180 | 2549 | 212 |
| | | - | 40 | 0.688 | 22.624 | 171 | 174 | 3426 | 285 |
| 26 | 26.000 | STD | - | 0.375 | 25.250 | 103 | 217 | 2478 | 191 |
| | | XS | - | 0.500 | 25.000 | 136 | 213 | 3257 | 251 |
| 28 | 28.000 | STD | - | 0.375 | 27.250 | 111 | 253 | 3105 | 222 |
| | | XS | - | 0.500 | 27.000 | 147 | 248 | 4085 | 292 |
| 30 | 30.000 | - | 5S | 0.250 | 29.500 | 79.3 | 296 | 2585 | 172 |
| | | - | 10S | 0.312 | 29.376 | 98.8 | 294 | 3206 | 214 |
| | | STD | - | 0.375 | 29.250 | 119 | 291 | 3829 | 255 |
| | | XS | - | 0.500 | 29.000 | 157 | 286 | 5042 | 336 |

**PIPE DIMENSIONS AND PROPERTIES IN SI METRIC UNITS**

| NPS | DN | OD, mm | ID | Schedule | Wall Thickness, mm | Inside Diameter, mm | Weight of Steel Pipe, Kg/m | Weight of Water, Kg/m | Moment of Inertia, mm4 | Section Modulus, mm3 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1/8 | - | 10.3 | STD | 40 | 1.73 | 6.83 | 0.365 | 0.037 | 443 | 86.1 |
| | | 10.3 | XS | 80 | 2.41 | 5.46 | 0.469 | 0.023 | 506 | 98.4 |
| 1/4 | - | 13.7 | STD | 40 | 2.24 | 9.25 | 0.633 | 0.067 | 1379 | 201 |
| | | 13.7 | XS | 80 | 3.02 | 7.67 | 0.797 | 0.046 | 1567 | 229 |
| 3/8 | 10 | 17.1 | STD | 40 | 2.31 | 12.52 | 0.846 | 0.123 | 3035 | 354 |
| | | 17.1 | XS | 80 | 3.20 | 10.74 | 1.10 | 0.091 | 3587 | 418 |
| 1/2 | 15 | 21.3 | - | 10S | 2.11 | 17.12 | 1.00 | 0.230 | 5956 | 558 |
| | | 21.3 | STD | 40 | 2.77 | 15.80 | 1.27 | 0.196 | 7114 | 667 |
| | | 21.3 | XS | 80 | 3.73 | 13.87 | 1.62 | 0.151 | 8357 | 783 |
| | | 21.3 | - | 160 | 4.78 | 11.79 | 1.95 | 0.109 | 9225 | 865 |
| | | 21.3 | XXS | - | 7.47 | 6.40 | 2.55 | 0.032 | 1.009E+04 | 946 |
| 3/4 | 20 | 26.7 | - | 10S | 2.11 | 22.45 | 1.28 | 0.396 | 1.236E+04 | 927 |
| | | 26.7 | STD | 40 | 2.87 | 20.93 | 1.68 | 0.344 | 1.542E+04 | 1156 |
| | | 26.7 | XS | 80 | 3.91 | 18.85 | 2.20 | 0.279 | 1.864E+04 | 1398 |
| | | 26.7 | - | 160 | 5.56 | 15.54 | 2.90 | 0.190 | 2.197E+04 | 1647 |
| | | 26.7 | XXS | - | 7.82 | 11.02 | 3.64 | 0.095 | 2.411E+04 | 1808 |
| 1 | 25 | 33.4 | - | 10S | 2.77 | 27.86 | 2.09 | 0.610 | 3.151E+04 | 1887 |
| | | 33.4 | STD | 40 | 3.38 | 26.64 | 2.50 | 0.558 | 3.635E+04 | 2177 |
| | | 33.4 | XS | 80 | 4.52 | 24.36 | 3.22 | 0.466 | 4.381E+04 | 2624 |
| | | 33.4 | - | 160 | 6.35 | 20.70 | 4.24 | 0.337 | 5.208E+04 | 3119 |
| | | 33.4 | XXS | - | 9.09 | 15.21 | 5.45 | 0.182 | 5.846E+04 | 3501 |
| 1-1/4 | 32 | 42.2 | - | 10S | 2.77 | 36.63 | 2.69 | 1.05 | 6.680E+04 | 3169 |
| | | 42.2 | STD | 40 | 3.56 | 35.05 | 3.39 | 0.965 | 8.104E+04 | 3844 |

| NPS | DN | OD, mm | ID | Schedule | Wall Thickness, mm | Inside Diameter, mm | Weight of Steel Pipe, Kg/m | Weight of Water, Kg/m | Moment of Inertia, mm4 | Section Modulus, mm3 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 42.2 | XS | 80 | 4.85 | 32.46 | 4.46 | 0.828 | 1.006E+05 | 4774 |
| | | 42.2 | - | 160 | 6.35 | 29.46 | 5.61 | 0.682 | 1.182E+05 | 5604 |
| | | 42.2 | XXS | - | 9.70 | 22.76 | 7.77 | 0.407 | 1.420E+05 | 6734 |
| 1-1/2 | 40 | 48.3 | - | 10S | 2.77 | 42.72 | 3.11 | 1.43 | 1.027E+05 | 4258 |
| | | 48.3 | STD | 40 | 3.68 | 40.89 | 4.05 | 1.31 | 1.290E+05 | 5346 |
| | | 48.3 | XS | 80 | 5.08 | 38.10 | 5.41 | 1.14 | 1.628E+05 | 6748 |
| | | 48.3 | - | 160 | 7.14 | 33.99 | 7.24 | 0.907 | 2.008E+05 | 8321 |
| | | 48.3 | XXS | - | 10.16 | 27.94 | 9.55 | 0.613 | 2.364E+05 | 9795 |
| 2 | 50 | 60.3 | - | 10S | 2.77 | 54.79 | 3.93 | 2.36 | 2.078E+05 | 6889 |
| | | 60.3 | STD | 40 | 3.91 | 52.50 | 5.44 | 2.16 | 2.771E+05 | 9187 |
| | | 60.3 | XS | 80 | 5.54 | 49.25 | 7.48 | 1.91 | 3.613E+05 | 1.198E+04 |
| | | 60.3 | - | 160 | 8.74 | 42.85 | 11.1 | 1.44 | 4.846E+05 | 1.607E+04 |
| | | 60.3 | XXS | - | 11.07 | 38.18 | 13.5 | 1.14 | 5.458E+05 | 1.810E+04 |
| 2-1/2 | 65 | 73.0 | - | 10S | 3.05 | 66.93 | 5.26 | 3.52 | 4.109E+05 | 1.125E+04 |
| | | 73.0 | STD | 40 | 5.16 | 62.71 | 8.63 | 3.09 | 6.366E+05 | 1.744E+04 |
| | | 73.0 | XS | 80 | 7.01 | 59.00 | 11.4 | 2.73 | 8.009E+05 | 2.194E+04 |
| | | 73.0 | - | 160 | 9.53 | 53.98 | 14.9 | 2.29 | 9.793E+05 | 2.682E+04 |
| | | 73.0 | XXS | - | 14.02 | 44.98 | 20.4 | 1.59 | 1.195E+06 | 3.273E+04 |
| 3 | 80 | 88.9 | - | 5S | 2.11 | 84.68 | 4.51 | 5.63 | 5.416E+05 | 1.218E+04 |
| | | 88.9 | - | 10S | 3.05 | 82.80 | 6.45 | 5.39 | 7.584E+05 | 1.706E+04 |
| | | 88.9 | STD | 40 | 5.49 | 77.93 | 11.3 | 4.77 | 1.256E+06 | 2.825E+04 |
| | | 88.9 | XS | 80 | 7.62 | 73.66 | 15.3 | 4.26 | 1.621E+06 | 3.647E+04 |
| | | 88.9 | - | 160 | 11.13 | 66.65 | 21.3 | 3.49 | 2.097E+06 | 4.719E+04 |
| | | 88.9 | XXS | - | 15.24 | 58.42 | 27.7 | 2.68 | 2.494E+06 | 5.611E+04 |
| 4 | 100 | 114.3 | - | 5S | 2.11 | 110.08 | 5.83 | 9.52 | 1.170E+06 | 2.046E+04 |
| | | 114.3 | - | 10S | 3.05 | 108.20 | 8.36 | 9.20 | 1.649E+06 | 2.886E+04 |
| | | 114.3 | STD | 40 | 6.02 | 102.26 | 16.1 | 8.21 | 3.010E+06 | 5.268E+04 |
| | | 114.3 | XS | 80 | 8.56 | 97.18 | 22.3 | 7.42 | 4.000E+06 | 6.999E+04 |
| 6 | 150 | 168.3 | - | 5S | 2.77 | 162.74 | 11.3 | 20.8 | 4.930E+06 | 5.860E+04 |
| | | 168.3 | - | 10S | 3.40 | 161.47 | 13.8 | 20.5 | 5.993E+06 | 7.122E+04 |
| | | 168.3 | STD | 40 | 7.11 | 154.05 | 28.3 | 18.6 | 1.171E+07 | 1.392E+05 |
| | | 168.3 | XS | 80 | 10.97 | 146.33 | 42.6 | 16.8 | 1.685E+07 | 2.003E+05 |
| 8 | 200 | 219.1 | - | 5S | 2.77 | 213.54 | 14.8 | 35.8 | 1.101E+07 | 1.005E+05 |
| | | 219.1 | - | 10S | 3.76 | 211.56 | 20.0 | 35.2 | 1.474E+07 | 1.346E+05 |
| | | 219.1 | STD | 40 | 8.18 | 202.72 | 42.5 | 32.3 | 3.017E+07 | 2.755E+05 |
| | | 219.1 | XS | 80 | 12.70 | 193.68 | 64.6 | 29.5 | 4.400E+07 | 4.017E+05 |
| 10 | 250 | 273.1 | - | 5S | 3.40 | 266.24 | 22.6 | 55.7 | 2.621E+07 | 1.920E+05 |
| | | 273.1 | - | 10S | 4.19 | 264.67 | 27.8 | 55.0 | 3.199E+07 | 2.343E+05 |
| | | 273.1 | STD | 40 | 9.27 | 254.51 | 60.3 | 50.9 | 6.690E+07 | 4.900E+05 |
| | | 273.1 | XS | - | 12.70 | 247.65 | 81.5 | 48.2 | 8.822E+07 | 6.462E+05 |
| | | 273.1 | - | 80 | 15.09 | 242.87 | 96.0 | 46.3 | 1.021E+08 | 7.475E+05 |
| 12 | 300 | 323.9 | - | 5S | 3.96 | 315.93 | 31.3 | 78.4 | 5.094E+07 | 3.146E+05 |
| | | 323.9 | - | 10S | 4.57 | 314.71 | 36.0 | 77.8 | 5.845E+07 | 3.610E+05 |
| | | 323.9 | STD | - | 9.53 | 304.80 | 73.8 | 73.0 | 1.163E+08 | 7.180E+05 |
| | | 323.9 | - | 40 | 10.31 | 303.23 | 79.7 | 72.2 | 1.250E+08 | 7.717E+05 |
| | | 323.9 | XS | - | 12.70 | 298.45 | 97.5 | 70.0 | 1.505E+08 | 9.294E+05 |
| | | 323.9 | - | 80 | 17.48 | 288.90 | 132 | 65.6 | 1.980E+08 | 1.223E+06 |

| NPS | DN | OD, mm | ID | Schedule | Wall Thickness, mm | Inside Diameter, mm | Weight of Steel Pipe, Kg/m | Weight of Water, Kg/m | Moment of Inertia, mm4 | Section Modulus, mm3 |
|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 350 | 355.6 | - | 5S | 3.96 | 347.68 | 34.4 | 94.9 | 6.766E+07 | 3.806E+05 |
| | | 355.6 | - | 10S | 4.78 | 346.05 | 41.3 | 94.1 | 8.098E+07 | 4.555E+05 |
| | | 355.6 | STD | - | 9.53 | 336.55 | 81.3 | 89.0 | 1.552E+08 | 8.726E+05 |
| | | 355.6 | - | 40 | 11.13 | 333.35 | 94.5 | 87.3 | 1.788E+08 | 1.005E+06 |
| | | 355.6 | XS | - | 12.70 | 330.20 | 107 | 85.6 | 2.014E+08 | 1.132E+06 |
| | | 355.6 | - | 80 | 19.05 | 317.50 | 158 | 79.2 | 2.861E+08 | 1.609E+06 |
| 16 | 400 | 406.4 | - | 5S | 4.19 | 398.02 | 41.6 | 124 | 1.071E+08 | 5.271E+05 |
| | | 406.4 | - | 10S | 4.78 | 396.85 | 47.3 | 124 | 1.215E+08 | 5.979E+05 |
| | | 406.4 | STD | - | 9.53 | 387.35 | 93.2 | 118 | 2.340E+08 | 1.151E+06 |
| | | 406.4 | XS | 40 | 12.70 | 381.00 | 123 | 114 | 3.047E+08 | 1.499E+06 |
| | | 406.4 | - | 80 | 21.44 | 363.52 | 204 | 104 | 4.818E+08 | 2.371E+06 |
| 18 | 450 | 457 | - | 5S | 4.19 | 448.82 | 46.8 | 158 | 1.530E+08 | 6.694E+05 |
| | | 457 | - | 10S | 4.78 | 447.65 | 53.3 | 157 | 1.737E+08 | 7.597E+05 |
| | | 457 | STD | - | 9.53 | 438.15 | 105 | 151 | 3.357E+08 | 1.469E+06 |
| | | 457 | XS | - | 12.70 | 431.80 | 139 | 146 | 4.384E+08 | 1.918E+06 |
| | | 457 | - | 40 | 14.27 | 428.65 | 156 | 144 | 4.876E+08 | 2.133E+06 |
| | | 457 | - | 80 | 23.83 | 409.55 | 255 | 132 | 7.638E+08 | 3.341E+06 |
| 20 | 500 | 508 | - | 5S | 4.78 | 498.45 | 59.3 | 195 | 2.390E+08 | 9.409E+05 |
| | | 508 | - | 10S | 5.54 | 496.93 | 68.6 | 194 | 2.759E+08 | 1.086E+06 |
| | | 508 | STD | - | 9.53 | 488.95 | 117 | 188 | 4.635E+08 | 1.825E+06 |
| | | 508 | XS | - | 12.70 | 482.60 | 155 | 183 | 6.064E+08 | 2.387E+06 |
| | | 508 | - | 40 | 15.09 | 477.82 | 183 | 179 | 7.102E+08 | 2.796E+06 |
| 22 | 550 | 559 | - | 5S | 4.78 | 549.25 | 65.2 | 237 | 3.189E+08 | 1.141E+06 |
| | | 559 | - | 10S | 5.54 | 547.73 | 75.6 | 236 | 3.683E+08 | 1.318E+06 |
| | | 559 | STD | - | 9.53 | 539.75 | 129 | 229 | 6.200E+08 | 2.219E+06 |
| | | 559 | XS | - | 12.70 | 533.40 | 171 | 223 | 8.127E+08 | 2.909E+06 |
| 24 | 600 | 610 | - | 5S | 5.54 | 598.53 | 82.5 | 281 | 4.793E+08 | 1.573E+06 |
| | | 610 | - | 10S | 6.35 | 596.90 | 94.5 | 280 | 5.475E+08 | 1.796E+06 |
| | | 610 | STD | - | 9.53 | 590.55 | 141 | 274 | 8.084E+08 | 2.652E+06 |
| | | 610 | XS | - | 12.70 | 584.20 | 187 | 268 | 1.061E+09 | 3.481E+06 |
| | | 610 | - | 40 | 17.48 | 574.65 | 255 | 259 | 1.426E+09 | 4.678E+06 |
| 26 | 650 | 660 | STD | - | 9.53 | 641.35 | 153 | 323 | 1.032E+09 | 3.124E+06 |
| | | 660 | XS | - | 12.70 | 635.00 | 203 | 317 | 1.356E+09 | 4.106E+06 |
| 28 | 700 | 711 | STD | - | 9.53 | 692.15 | 165 | 376 | 1.292E+09 | 3.635E+06 |
| | | 711 | XS | - | 12.70 | 685.80 | 219 | 369 | 1.700E+09 | 4.781E+06 |
| 30 | 750 | 762 | - | 5S | 6.35 | 749.30 | 118 | 441 | 1.076E+09 | 2.824E+06 |
| | | 762 | - | 10S | 7.92 | 746.15 | 147 | 437 | 1.335E+09 | 3.503E+06 |
| | | 762 | STD | - | 9.53 | 742.95 | 177 | 434 | 1.594E+09 | 4.184E+06 |
| | | 762 | XS | - | 12.70 | 736.60 | 235 | 426 | 2.099E+09 | 5.508E+06 |

**PIPING MATERIAL SPECIFICATION WORKSHOP**

Develop a piping material specification for styrene monomer.
Design conditions are from Problems 1 and 2 on page 25.

- Condition 1: _____________ psi (bar) at _____________ ºF (ºC)
- Condition 2: 50 psi (3.5 bar) at 735ºF (390ºC)
- Pipe wall thicknesses are as determined from calculations on page 32.

Pressure Class ____**300**_________

| Item | NPS Range | Sch/Rating | Description |
|---|---|---|---|
| Pipe | **¾** | **160** | **Seamless carbon steel pipe, ASTM A106 Gr B, ASTM A53 Type S Gr B, or API 5L Gr B** |
| | **1 – 2** | **XS** | **Seamless carbon steel pipe, ASTM A106 Gr B, ASTM A53 Type S Gr B, or API 5L Gr B** |
| | **3 - 12** | **STD** | **Seamless carbon steel pipe, ASTM A106 Gr B, ASTM A53 Type S Gr B, or API 5L Gr B** |
| Nipples | **¾ - 1½** | **160** | **Seamless carbon steel pipe, ASTM A106 Gr B, ASTM A53 Type S Gr B, or API 5L Gr B** |
| Fittings | | | |
| | **¾** | **6000** | **Forged carbon steel, ASTM A105, ASME B16.11, socket weld 90 EL, 45 EL, TEE, PLUG, COUPLING, CAP, AND REDUCER. UNIONS are prohibited.** |
| | **1 - 1 ½** | **3000** | **Forged carbon steel, ASTM A105, ASME B16.11, socket weld 90 EL, 45 EL, TEE, PLUG, COUPLING, CAP, AND REDUCER. UNIONS are prohibited.** |
| | **2 – 12** | **Match pipe** | **Wrought carbon steel, ASTM A234, ASME B16.9, buttweld 90 LR EL, 45 LR EL, TEE, CAP AND REDUCER** |
| Flanges | **¾ - 1 ½** | **300** | **Forged carbon steel, ASTM A105, ASME B16.5 socket welding raised face** |
| | **2 - 12** | **300** | **Forged carbon steel, ASTM A105, ASME B16.5 welding neck raised face, bore to match pipe** |
| Gaskets | **¾ - 12** | **300** | **Spiral wound ASME B16.20 with 304 SS windings (yellow centering ring), flexible graphite filler (gray stripe) and standard inner ring NPS 10 and larger** |
| Bolting | **¾ - 12** | **-** | **Low alloy steel bolting, ASTM A193 Gr B7 stud with 2 ASTM A194 Gr 2H nuts** |

What should be used for branch construction? [Note that the answer will different for different size combinations.]

**Sample from Process Industry Practices (PIP) PN03CS1S01**

90° BRANCH CONNECTION
Legend and Chart

| BRANCH SIZE \ HEADER SIZE | 48 | 42 | 36 | 30 | 24 | 20 | 18 | 16 | 14 | 12 | 10 | 8 | 6 | 4 | 3 | 2 | 1-1/2 | 1 | 3/4 | 1/2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 48 | T | | | | | | | | | | | | | | | | | | | |
| 42 | P | T | | | | | | | | | | | | | | | | | | |
| 36 | P | P | T | | | | | | | | | | | | | | | | | |
| 30 | P | P | P | T | | | | | | | | | | | | | | | | |
| 24 | P | P | P | P | T | | | | | | | | | | | | | | | |
| 20 | P | P | P | P | P | T | | | | | | | | | | | | | | |
| 18 | P | P | P | P | P | P | T | | | | | | | | | | | | | |
| 16 | P | P | P | P | P | P | P | T | | | | | | | | | | | | |
| 14 | P | P | P | P | P | P | P | P | T | | | | | | | | | | | |
| 12 | P | P | P | P | P | P | P | P | P | T | | | | | | | | | | |
| 10 | W | W | W | W | W | W | W | W | W | W | T | | | | | | | | | |
| 8 | W | W | W | W | W | W | W | W | W | W | W | T | | | | | | | | |
| 6 | W | W | W | W | W | W | W | W | W | W | W | W | T | | | | | | | |
| 4 | W | W | W | W | W | W | W | W | W | W | W | W | W | T | | | | | | |
| 3 | W | W | W | W | W | W | W | W | W | W | W | W | W | W | T | | | | | |
| 2 | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | T | | | | |
| 1-1/2 | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | E | T | | | |
| 1 | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | E | E | T | | |
| 3/4 | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | E | E | E | T | |
| 1/2 | S | S | S | S | S | S | S | S | S | S | S | S | S | S | S | E | E | E | E | T |

E Reducing Tee
P Branch Weld w/ Reinforcing Pad (Pad thickness equals run pipe thickness. Pad width equals 1/2 branch OD.)
S Sockolet
T Tee
W Weldolet (Note 05)

**Note that when branch connection fittings (Weldolet) are specified, the requirements for these components should be described as well, e.g., "Forged carbon steel ASTM A105, MSS SP-97". When ordering buttweld branch connection fittings, both the header and branch wall thicknesses should be specified.**

Sample Notes:

NOTES:
01 The pipe and fittings are adequate for the full flange rating.
02 All buttwelding component thicknesses shall match pipe thicknesses.
03 Threaded joints are permitted only at outlet of vent and drain valves, at hydrostatic connections, at outlet of instrument take-off valves, and to match equipment.
05 Integrally reinforced branch connections are permitted outside the sizes shown in the branch connection table.
13 Welding neck flanges shall be used against buttweld fittings.
19 Sch 160 pipe and pipe nipples shall be used for threaded connections for sizes NPS 1/2 – 1-1/2.
26 To be used only when indicated on the P&ID.
27 Pipe and pipe components thicker than 1/2-inch may require impact tested materials when the minimum design metal temperature is below 100F (38C) (See ASME B31.3, paragraph 323.2.2).
136 Sch XS pipe shall be used for threaded connections for NPS 2.

**MEAN THERMAL EXPANSION COEFFICIENT BETWEEN 70ºF AND THE INDICATED TEMPERATURE ($1 \times 10^{-6}$/ºF)**

| Temp, ºF | Carbon Steels | Stainless Steels | Copper & its Alloys | Aluminum | Ni-Fe-Cr | Ni-Cr-Fe |
|---|---|---|---|---|---|---|
| -300 | 5.07 | 8.21 | 7.94 | 10.04 | | |
| -250 | 5.21 | 8.34 | 8.26 | 10.33 | | |
| -200 | 5.35 | 8.47 | 8.51 | 10.61 | | |
| -150 | 5.50 | 8.54 | 8.72 | 10.90 | | |
| -100 | 5.65 | 8.66 | 8.89 | 11.25 | | |
| -50 | 5.80 | 8.90 | 9.04 | 11.60 | | |
| 0 | 5.90 | 8.98 | 9.17 | 11.86 | | |
| 50 | 6.01 | 9.07 | 9.28 | 12.12 | | |
| 100 | 6.13 | 9.16 | 9.39 | 12.39 | | 7.20 |
| 150 | 6.25 | 9.25 | 9.48 | 12.67 | | 7.30 |
| 200 | 6.38 | 9.34 | 9.56 | 12.95 | 7.90 | 7.40 |
| 250 | 6.49 | 9.41 | 9.64 | 13.12 | 8.01 | 7.48 |
| 300 | 6.60 | 9.47 | 9.71 | 13.28 | 8.35 | 7.56 |
| 350 | 6.71 | 9.53 | 9.78 | 13.44 | 8.57 | 7.63 |
| 400 | 6.82 | 9.59 | 9.84 | 13.60 | 8.80 | 7.70 |
| 450 | 6.92 | 9.65 | 9.89 | 13.75 | 8.85 | 7.75 |
| 500 | 7.02 | 9.70 | 9.94 | 13.90 | 8.90 | 7.80 |
| 550 | 7.12 | 9.76 | 9.99 | 14.05 | 8.95 | 7.85 |
| 600 | 7.23 | 9.82 | 10.04 | 14.02 | 9.00 | 7.90 |
| 650 | 7.33 | 9.87 | | | 9.05 | 7.95 |
| 700 | 7.44 | 9.92 | | | 9.10 | 8.00 |
| 750 | 7.54 | 9.99 | | | 9.15 | 8.05 |
| 800 | 7.65 | 10.05 | | | 9.20 | 8.10 |
| 850 | 7.75 | 10.11 | | | 9.25 | |
| 900 | 7.84 | 10.16 | | | 9.30 | |
| 950 | 7.91 | 10.23 | | | 9.35 | |
| 1000 | 7.97 | 10.29 | | | 9.40 | |
| 1050 | 8.05 | 10.34 | | | 9.45 | |
| 1100 | 8.12 | 10.39 | | | 9.50 | |
| 1150 | 8.16 | 10.44 | | | 9.55 | |
| 1200 | 8.19 | 10.48 | | | 9.60 | |
| 1250 | 8.24 | 10.51 | | | 9.68 | |
| 1300 | 8.28 | 10.54 | | | 9.75 | |
| 1350 | 8.32 | 10.57 | | | 9.83 | |
| 1400 | 8.36 | 10.60 | | | 9.90 | |
| 1450 | | 10.68 | | | 9.98 | |
| 1500 | | 10.77 | | | 10.05 | |

**TOTAL THERMAL EXPANSION BETWEEN 70ºF AND THE INDICATED TEMPERATURE (IN/100 FT)**

| Temp, ºF | Carbon Steels | Stainless Steels | Copper & its Alloys | Aluminum | Ni-Fe-Cr | Ni-Cr-Fe |
|---|---|---|---|---|---|---|
| -300 | -2.25 | -3.65 | -3.53 | -4.46 | | |
| -250 | -2.00 | -3.20 | -3.17 | -3.97 | | |
| -200 | -1.73 | -2.74 | -2.76 | -3.44 | | |
| -150 | -1.45 | -2.25 | -2.30 | -2.88 | | |
| -100 | -1.15 | -1.77 | -1.81 | -2.30 | | |
| -50 | -0.84 | -1.28 | -1.30 | -1.67 | | |
| 0 | -0.50 | -0.75 | -0.77 | -1.00 | | |
| 50 | -0.14 | -0.22 | -0.22 | -0.29 | | |
| 100 | 0.22 | 0.33 | 0.34 | 0.45 | | 0.26 |
| 150 | 0.60 | 0.89 | 0.91 | 1.22 | | 0.70 |
| 200 | 1.00 | 1.46 | 1.49 | 2.02 | 1.23 | 1.15 |
| 250 | 1.40 | 2.03 | 2.08 | 2.83 | 1.73 | 1.62 |
| 300 | 1.82 | 2.61 | 2.68 | 3.67 | 2.30 | 2.09 |
| 350 | 2.25 | 3.20 | 3.29 | 4.52 | 2.88 | 2.56 |
| 400 | 2.70 | 3.80 | 3.90 | 5.39 | 3.48 | 3.05 |
| 450 | 3.16 | 4.40 | 4.51 | 6.27 | 4.04 | 3.53 |
| 500 | 3.62 | 5.01 | 5.13 | 7.17 | 4.59 | 4.02 |
| 550 | 4.10 | 5.62 | 5.75 | 8.09 | 5.16 | 4.52 |
| 600 | 4.60 | 6.25 | 6.39 | 8.92 | 5.72 | 5.02 |
| 650 | 5.10 | 6.87 | | | 6.30 | 5.53 |
| 700 | 5.62 | 7.50 | | | 6.88 | 6.05 |
| 750 | 6.15 | 8.15 | | | 7.47 | 6.57 |
| 800 | 6.70 | 8.80 | | | 8.06 | 7.10 |
| 850 | 7.25 | 9.46 | | | 8.66 | |
| 900 | 7.81 | 10.12 | | | 9.26 | |
| 950 | 8.35 | 10.80 | | | 9.87 | |
| 1000 | 8.89 | 11.48 | | | 10.49 | |
| 1050 | 9.47 | 12.16 | | | 11.11 | |
| 1100 | 10.04 | 12.84 | | | 11.74 | |
| 1150 | 10.58 | 13.53 | | | 12.38 | |
| 1200 | 11.11 | 14.21 | | | 13.02 | |
| 1250 | 11.67 | 14.88 | | | 13.71 | |
| 1300 | 12.22 | 15.56 | | | 14.39 | |
| 1350 | 12.78 | 16.24 | | | 15.10 | |
| 1400 | 13.34 | 16.92 | | | 15.80 | |
| 1450 | | 17.69 | | | 16.53 | |
| 1500 | | 18.48 | | | 17.25 | |

**MEAN THERMAL EXPANSION COEFFICIENT BETWEEN 20ºC AND THE INDICATED TEMPERATURE ($1 \times 10^{-6}$/ºC)**

| Temp, ºC | Carbon Steels | Stainless Steels | Copper & its Alloys | Aluminum | Ni-Fe-Cr | Ni-Cr-Fe |
|---|---|---|---|---|---|---|
| -175 | 2.86 | 4.58 | 4.36 | 5.62 | | |
| -150 | 2.89 | 4.66 | 4.63 | 5.78 | | |
| -125 | 2.97 | 4.71 | 4.74 | 5.89 | | |
| -100 | 3.06 | 4.78 | 4.84 | 6.06 | | |
| -75 | 3.14 | 4.86 | 4.94 | 6.25 | | |
| -50 | 3.22 | 4.94 | 5.02 | 6.44 | | |
| -25 | 3.25 | 4.98 | 5.08 | 6.56 | | |
| 0 | 3.31 | 5.02 | 5.14 | 6.67 | | |
| 25 | 3.37 | 5.06 | 5.18 | 6.80 | | 3.96 |
| 50 | 3.77 | 5.11 | 5.24 | 6.96 | | 4.03 |
| 75 | 3.51 | 5.15 | 5.28 | 7.06 | | 4.07 |
| 100 | 3.56 | 5.19 | 5.32 | 7.22 | 4.42 | 4.12 |
| 125 | 3.61 | 5.23 | 5.36 | 7.29 | 4.51 | 4.16 |
| 150 | 3.67 | 5.26 | 5.39 | 7.38 | 4.64 | 4.20 |
| 175 | 3.73 | 5.29 | 5.44 | 7.47 | 4.76 | 4.24 |
| 200 | 3.79 | 5.32 | 5.46 | 7.54 | 4.88 | 4.28 |
| 225 | 3.83 | 5.35 | 5.48 | 7.62 | 4.91 | 4.29 |
| 250 | 3.88 | 5.38 | 5.51 | 7.69 | 4.93 | 4.32 |
| 275 | 3.93 | 5.41 | 5.54 | 7.77 | 4.96 | 4.34 |
| 300 | 3.98 | 5.44 | 5.61 | 7.85 | 4.98 | 4.38 |
| 325 | 4.03 | 5.46 | | | 5.01 | 4.39 |
| 350 | 4.09 | 5.49 | | | 5.03 | 4.42 |
| 375 | 4.14 | 5.51 | | | 5.06 | 4.44 |
| 400 | 4.19 | 5.55 | | | 5.08 | 4.47 |
| 425 | 4.25 | 5.58 | | | 5.11 | 4.50 |
| 450 | 4.3 | 5.61 | | | 5.13 | |
| 475 | 4.34 | 5.63 | | | 5.16 | |
| 500 | 4.38 | 5.67 | | | 5.18 | |
| 525 | 4.41 | 5.70 | | | 5.21 | |
| 550 | 4.45 | 5.73 | | | 5.23 | |
| 575 | 4.48 | 5.75 | | | 5.26 | |
| 600 | 4.52 | 5.78 | | | 5.28 | |
| 625 | 4.53 | 5.80 | | | 5.31 | |
| 650 | 4.55 | 5.82 | | | 5.33 | |
| 675 | 4.58 | 5.84 | | | 5.38 | |
| 700 | 4.60 | 5.86 | | | 5.41 | |
| 725 | 4.62 | 5.87 | | | 5.45 | |
| 750 | 4.63 | 5.88 | | | 5.48 | |
| 775 | | 5.91 | | | 5.52 | |
| 800 | | 5.96 | | | 5.56 | |

**TOTAL THERMAL EXPANSION BETWEEN 20ºC AND THE INDICATED TEMPERATURE (mm/m)**

| Temp, ºC | Carbon Steels | Stainless Steels | Copper & its Alloys | Aluminum | Ni-Fe-Cr | Ni-Cr-Fe |
|---|---|---|---|---|---|---|
| -175 | -0.56 | -0.89 | -0.85 | -1.10 | | |
| -150 | -0.49 | -0.79 | -0.79 | -0.98 | | |
| -125 | -0.43 | -0.68 | -0.69 | -0.85 | | |
| -100 | -0.37 | -0.57 | -0.58 | -0.73 | | |
| -75 | -0.30 | -0.46 | -0.47 | -0.59 | | |
| -50 | -0.23 | -0.35 | -0.35 | -0.45 | | |
| -25 | -0.15 | -0.22 | -0.23 | -0.30 | | |
| 0 | -0.07 | -0.10 | -0.10 | -0.13 | | |
| 25 | 0.02 | 0.03 | 0.03 | 0.03 | | |
| 50 | 0.10 | 0.15 | 0.16 | 0.21 | | |
| 75 | 0.19 | 0.28 | 0.29 | 0.39 | | |
| 100 | 0.28 | 0.42 | 0.43 | 0.58 | 0.35 | 0.33 |
| 125 | 0.38 | 0.55 | 0.56 | 0.77 | 0.47 | 0.44 |
| 150 | 0.48 | 0.68 | 0.70 | 0.96 | 0.60 | 0.55 |
| 175 | 0.58 | 0.82 | 0.84 | 1.16 | 0.74 | 0.66 |
| 200 | 0.68 | 0.96 | 0.98 | 1.36 | 0.88 | 0.77 |
| 225 | 0.79 | 1.10 | 1.12 | 1.56 | 1.01 | 0.88 |
| 250 | 0.89 | 1.24 | 1.27 | 1.77 | 1.13 | 0.99 |
| 275 | 1.00 | 1.38 | 1.41 | 1.98 | 1.26 | 1.11 |
| 300 | 1.11 | 1.52 | 1.57 | 2.20 | 1.39 | 1.23 |
| 325 | 1.23 | 1.67 | | | 1.53 | 1.34 |
| 350 | 1.35 | 1.81 | | | 1.66 | 1.46 |
| 375 | 1.47 | 1.96 | | | 1.80 | 1.58 |
| 400 | 1.59 | 2.11 | | | 1.93 | 1.70 |
| 425 | 1.72 | 2.26 | | | 2.07 | 1.82 |
| 450 | 1.85 | 2.41 | | | 2.21 | |
| 475 | 1.97 | 2.56 | | | 2.35 | |
| 500 | 2.10 | 2.72 | | | 2.49 | |
| 525 | 2.23 | 2.88 | | | 2.63 | |
| 550 | 2.36 | 3.04 | | | 2.77 | |
| 575 | 2.49 | 3.19 | | | 2.92 | |
| 600 | 2.62 | 3.35 | | | 3.06 | |
| 625 | 2.74 | 3.51 | | | 3.21 | |
| 650 | 2.87 | 3.67 | | | 3.36 | |
| 675 | 3.00 | 3.83 | | | 3.52 | |
| 700 | 3.13 | 3.98 | | | 3.68 | |
| 725 | 3.26 | 4.14 | | | 3.84 | |
| 750 | 3.38 | 4.29 | | | 4.00 | |
| 775 | | 4.46 | | | 4.17 | |
| 800 | | 4.65 | | | 4.34 | |

**SPRING HANGAR LOAD TABLE FROM ANVIL INTERNATIONAL, INC. (Part 1)**

## Spring Hanger Size and Series Selection

### How to use hanger selection table:

In order to choose a proper size hanger, it is necessary to know the actual load which the spring is to support and the amount and direction of the pipe line movement from the cold to the hot position.

Find the actual load of the pipe in the load table. As it is desirable to support the actual weight of the pipe when the line is hot, the actual load is the hot load. To determine the cold load, read the spring scale, up or down, for the amount of expected movement.

The chart must be read opposite from the direction of the pipe's movement. The load arrived at is the cold load.

If the cold load falls outside of the working load range of the hanger selected, relocate the actual or hot load in the adjacent column and find the cold load. When the hot and cold loads are both within the working range of a hanger, the size number of that hanger will be found at the top of the column.

**Load Table (lbs) for Selection of Hanger Size** (sizes 10 through 22 on next page)

| Working Range (in) Shaded Rows Show Overtravel | | | | | Hanger size | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Figure No. | | | | | B-268 Only | | Fig. 82, Fig. B-268, Fig. 98, Triple & Quadruple Spring | | | | | | | | | |
| Quad. | Triple | 98 | B-268 | 82 | 000 | 00 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 2 | 1½ | 1 | ½ | ¼ | 7 | 19 | 43 | 63 | 81 | 105 | 141 | 189 | 252 | 336 | 450 | 600 |
| | | | | | 7 | 20 | 44 | 66 | 84 | 109 | 147 | 197 | 263 | 350 | 469 | 625 |
| | | | | | 8 | 22 | 46 | 68 | 88 | 114 | 153 | 206 | 273 | 364 | 488 | 650 |
| | | | | | 9 | 24 | 48 | 71 | 91 | 118 | 159 | 213 | 284 | 378 | 506 | 675 |
| 0 | 0 | 0 | 0 | 0 | 10 | 26 | 50 | 74 | 95 | 123 | 165 | 221 | 294 | 392 | 525 | 700 |
| | | | | | 11 | 28 | 52 | 76 | 98 | 127 | 170 | 228 | 305 | 406 | 544 | 725 |
| | | | | | 12 | 30 | 54 | 79 | 101 | 131 | 176 | 236 | 315 | 420 | 563 | 750 |
| | | | | | 12 | 31 | 56 | 81 | 105 | 136 | 182 | 244 | 326 | 434 | 581 | 775 |
| 2 | 1½ | 1 | ½ | ¼ | 14 | 34 | 58 | 84 | 108 | 140 | 188 | 252 | 336 | 448 | 600 | 800 |
| | | | | | 14 | 35 | 59 | 87 | 111 | 144 | 194 | 260 | 347 | 462 | 619 | 825 |
| | | | | | 15 | 38 | 61 | 89 | 115 | 149 | 200 | 268 | 357 | 476 | 638 | 850 |
| | | | | | 16 | 40 | 63 | 92 | 118 | 153 | 206 | 276 | 368 | 490 | 656 | 875 |
| 4 | 3 | 2 | 1 | ½ | 17 | 41 | 65 | 95 | 122 | 158 | 212 | 284 | 378 | 504 | 675 | 900 |
| | | | | | 18 | 43 | 67 | 97 | 125 | 162 | 217 | 291 | 389 | 518 | 694 | 925 |
| | | | | | 19 | 45 | 69 | 100 | 128 | 166 | 223 | 299 | 399 | 532 | 713 | 950 |
| | | | | | 20 | 47 | 71 | 102 | 132 | 171 | 229 | 307 | 410 | 546 | 731 | 975 |
| 6 | 4½ | 3 | 1½ | ¾ | 21 | 49 | 73 | 105 | 135 | 175 | 235 | 315 | 420 | 560 | 750 | 1,000 |
| | | | | | 21 | 50 | 74 | 108 | 138 | 179 | 241 | 323 | 431 | 574 | 769 | 1,025 |
| | | | | | 22 | 53 | 76 | 110 | 142 | 184 | 247 | 331 | 441 | 588 | 788 | 1,050 |
| | | | | | 23 | 55 | 78 | 113 | 145 | 188 | 253 | 339 | 452 | 602 | 806 | 1,075 |
| 8 | 6 | 4 | 2 | 1 | 24 | 56 | 80 | 116 | 149 | 193 | 258 | 347 | 462 | 616 | 825 | 1,100 |
| | | | | | 25 | 58 | 82 | 118 | 152 | 197 | 264 | 354 | 473 | 630 | 844 | 1,125 |
| | | | | | 26 | 60 | 84 | 121 | 155 | 201 | 270 | 362 | 483 | 644 | 863 | 1,150 |
| | | | | | 27 | 62 | 86 | 123 | 159 | 206 | 276 | 370 | 494 | 658 | 881 | 1,175 |
| 10 | 7½ | 5 | 2½ | 1¼ | 28 | 64 | 88 | 126 | 162 | 210 | 282 | 378 | 504 | 672 | 900 | 1,200 |
| 2 | 1½ | 1 | ½ | ¼ | 28 | 66 | 89 | 129 | 165 | 214 | 288 | 386 | 515 | 686 | 919 | 1,225 |
| | | | | | 29 | 68 | 91 | 131 | 169 | 219 | 294 | 394 | 525 | 700 | 938 | 1,250 |
| | | | | | 30 | 70 | 93 | 134 | 172 | 223 | 300 | 402 | 536 | 714 | 956 | 1,275 |
| | | | | | 31 | 72 | 95 | 137 | 176 | 228 | 306 | 410 | 546 | 728 | 975 | 1,300 |
| | | | | | Spring Rate (lbs/In) | | | | | | | | | | | |
| | | | | 82 | – | – | 30 | 42 | 54 | 70 | 94 | 126 | 168 | 224 | 300 | 400 |
| | | | | B-268 | 7 | 15 | 15 | 21 | 27 | 35 | 47 | 63 | 84 | 112 | 150 | 200 |
| | | | | 98 | – | – | 7 | 10 | 13 | 17 | 23 | 31 | 42 | 56 | 75 | 100 |
| | | | | Triple | – | – | 5 | 7 | 9 | 12 | 16 | 21 | 28 | 37 | 50 | 67 |
| | | | | Quadruple | – | – | 4 | 5 | 7 | 9 | 12 | 16 | 21 | 28 | 38 | 50 |

**Note:** General rule for series selection use Fig. 82 for up to ½" of movement up to 1" use Fig. B-268, up to 2" use Fig. 98, up to 3" use a Triple, up to 4" use a Quadruple. Double check to assure desired variability is achieved.

## SPRING HANGAR LOAD TABLE FROM ANVIL INTERNATIONAL, INC. (Part 2)

### Spring Hanger Size and Series Selection

#### How to use hanger selection table (cont.):

Should it be impossible to select a hanger in a particular series such that both loads occur within the working range, consideration should be given to a variable spring hanger with a wider working range or a constant support hanger.

The cold load is calculated by adding (for up movement) or subtracting (for down movement) the product of spring rate times movement to or from the hot load.

**Cold load = (hot load) ± (movement) x (spring rate)**

A key criteria in selecting the size and series of a variable spring is a factor known as variability. This is a measurement of the percentage change in supporting force between the hot and cold positions of a spring and is calculated from the formula:

**Variability = (Movement) x (Spring Rate) / (Hot Load)**

If an allowable variability is not specified, good practice would be to use 25% as recommended by MSS-SP-58.

**Load Table (lbs) for Selection of Hanger Size** (Cont. from previous page)

| Hanger size: Fig. 82, Fig. B-268, Fig. 98, Triple & Quadruple Spring | | | | | | | | | | | | | Working Range (in) — Shaded Rows Show Overtravel: Figure No. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 82 | B-268 | 98 | Triple | Quad |
| 780 | 1,020 | 1,350 | 1,800 | 2,400 | 3,240 | 4,500 | 6,000 | 7,990 | 10,610 | 14,100 | 18,750 | 25,005 | | | | | |
| 813 | 1,063 | 1,406 | 1,875 | 2,500 | 3,375 | 4,688 | 6,250 | 8,322 | 11,053 | 14,588 | 19,531 | 26,047 | ¼ | ½ | 1 | 1½ | 2 |
| 845 | 1,105 | 1,463 | 1,950 | 2,600 | 3,510 | 4,875 | 6,500 | 8,655 | 11,495 | 15,275 | 20,313 | 27,089 | | | | | |
| 878 | 1,148 | 1,519 | 2,025 | 2,700 | 3,645 | 5,063 | 6,750 | 8,987 | 11,938 | 15,863 | 21,094 | 28,131 | | | | | |
| 910 | 1,190 | 1,575 | 2,100 | 2,800 | 3,780 | 5,250 | 7,000 | 9,320 | 12,380 | 16,450 | 21,875 | 29,173 | 0 | 0 | 0 | 0 | 0 |
| 943 | 1,233 | 1,631 | 2,175 | 2,900 | 3,915 | 5,438 | 7,250 | 9,652 | 12,823 | 17,038 | 22,656 | 30,215 | | | | | |
| 975 | 1,275 | 1,688 | 2,250 | 3,000 | 4,050 | 5,625 | 7,500 | 9,985 | 13,265 | 17,625 | 23,438 | 31,256 | | | | | |
| 1,008 | 1,318 | 1,744 | 2,325 | 3,100 | 4,185 | 5,813 | 7,750 | 10,317 | 13,708 | 18,213 | 24,219 | 32,298 | | | | | |
| 1,040 | 1,360 | 1,800 | 2,400 | 3,200 | 4,320 | 6,000 | 8,000 | 10,650 | 14,150 | 18,800 | 25,000 | 33,340 | ¼ | ½ | 1 | 1½ | 2 |
| 1,073 | 1,403 | 1,856 | 2,475 | 3,300 | 4,455 | 6,188 | 8,250 | 10,982 | 14,592 | 19,388 | 25,781 | 34,382 | | | | | |
| 1,105 | 1,445 | 1,913 | 2,550 | 3,400 | 4,590 | 6,375 | 8,500 | 11,315 | 15,035 | 19,975 | 26,563 | 35,424 | | | | | |
| 1,138 | 1,488 | 1,969 | 2,625 | 3,500 | 4,725 | 6,563 | 8,750 | 11,647 | 15,477 | 20,563 | 27,344 | 36,466 | | | | | |
| 1,170 | 1,530 | 2,025 | 2,700 | 3,600 | 4,860 | 6,750 | 9,000 | 11,980 | 15,920 | 21,150 | 28,125 | 37,508 | ½ | 1 | 2 | 3 | 4 |
| 1,203 | 1,573 | 2,081 | 2,775 | 3,700 | 4,995 | 6,938 | 9,250 | 12,312 | 16,362 | 21,738 | 28,906 | 38,549 | | | | | |
| 1,235 | 1,615 | 2,138 | 2,850 | 3,800 | 5,130 | 7,125 | 9,500 | 12,645 | 16,805 | 22,325 | 29,688 | 39,591 | | | | | |
| 1,268 | 1,658 | 2,194 | 2,925 | 3,900 | 5,265 | 7,313 | 9,750 | 12,977 | 17,247 | 22,913 | 30,469 | 40,633 | | | | | |
| 1,300 | 1,700 | 2,250 | 3,000 | 4,000 | 5,400 | 7,500 | 10,000 | 13,310 | 17,690 | 23,500 | 31,250 | 41,675 | ¾ | 1½ | 3 | 4½ | 6 |
| 1,333 | 1,743 | 2,306 | 3,075 | 4,100 | 5,535 | 7,688 | 10,250 | 13,642 | 18,132 | 24,088 | 32,031 | 42,717 | | | | | |
| 1,365 | 1,785 | 2,363 | 3,150 | 4,200 | 5,670 | 7,875 | 10,500 | 13,975 | 18,575 | 24,675 | 32,813 | 43,759 | | | | | |
| 1,398 | 1,828 | 2,419 | 3,225 | 4,300 | 5,805 | 8,063 | 10,750 | 14,307 | 19,017 | 25,263 | 33,594 | 44,801 | | | | | |
| 1,430 | 1,870 | 2,475 | 3,300 | 4,400 | 5,940 | 8,250 | 11,000 | 14,640 | 19,460 | 25,850 | 34,375 | 45,843 | 1 | 2 | 4 | 6 | 8 |
| 1,463 | 1,913 | 2,531 | 3,375 | 4,500 | 6,075 | 8,438 | 11,250 | 14,972 | 19,902 | 26,438 | 35,156 | 46,885 | | | | | |
| 1,495 | 1,955 | 2,588 | 3,450 | 4,600 | 6,210 | 8,625 | 11,500 | 15,305 | 20,345 | 27,025 | 35,938 | 47,926 | | | | | |
| 1,528 | 1,998 | 2,644 | 3,525 | 4,700 | 6,345 | 8,813 | 11,750 | 15,637 | 20,787 | 27,613 | 36,719 | 48,968 | | | | | |
| 1,560 | 2,040 | 2,700 | 3,600 | 4,800 | 6,480 | 9,000 | 12,000 | 15,970 | 21,230 | 28,200 | 37,500 | 50,010 | 1¼ | 2½ | 5 | 7½ | 10 |
| 1,593 | 2,083 | 2,756 | 3,675 | 4,900 | 6,615 | 9,188 | 12,250 | 16,302 | 21,672 | 28,788 | 38,281 | 51,052 | | | | | |
| 1,625 | 2,125 | 2,813 | 3,750 | 5,000 | 6,750 | 9,375 | 12,500 | 16,635 | 22,115 | 29,375 | 39,063 | 52,094 | ¼ | ½ | 1 | 1½ | 2 |
| 1,658 | 2,168 | 2,869 | 3,825 | 5,100 | 6,885 | 9,563 | 12,750 | 16,967 | 22,557 | 29,963 | 39,844 | 53,136 | | | | | |
| 1,690 | 2,210 | 2,925 | 3,900 | 5,200 | 7,020 | 9,750 | 13,000 | 17,300 | 23,000 | 30,550 | 40,625 | 54,178 | | | | | |
| **Spring Rate (lbs/in)** | | | | | | | | | | | | | | | | | |
| 520 | 680 | 900 | 1,200 | 1,600 | 2,160 | 3,000 | 4,000 | 5,320 | 7,080 | 9,400 | 12,500 | 16,670 | 82 | | | | |
| 260 | 340 | 450 | 600 | 800 | 1,080 | 1,500 | 2,000 | 2,660 | 3,540 | 4,700 | 6,250 | 8,335 | B-268 | | | | |
| 130 | 170 | 225 | 300 | 400 | 540 | 750 | 1,000 | 1,330 | 1,770 | 2,350 | 3,125 | 4,167 | 98 | | | | |
| 87 | 113 | 150 | 200 | 267 | 360 | 500 | 667 | 887 | 1,180 | 1,567 | 2,083 | 2,778 | Triple | | | | |
| 65 | 85 | 113 | 150 | 200 | 270 | 375 | 500 | 665 | 885 | 1,175 | 1,563 | 2,084 | Quadruple | | | | |

**Note:** General rule for series selection use Fig. 82 for up to ½" of movement up to 1" use Fig. B-268, up to 2" use Fig. 98, up to 3" use a Triple-, up to 4" use a Quadruple. Double check to assure desired variability is achieved.

## Fig. 82, Fig. B-268, Fig. 98, Triple Spring, and Quadruple Spring
## Fig. C-82, Fig. C-268, Fig. C-98, Triple-CR, and Quadruple-CR Spring (Corrosion Resistant)

### Design features:

- Precompression.
  Precompressing the spring into the hanger casing provides the following advantages:
  (1) Saves up to 50% in headroom by reducing the length of the hanger.
  (2) Reduces the installed height of the overall hanger assembly.
  (3) Prevents the spring supporting force from exceeding the normal safe limits of variations.
  (4) Saves valuable erection time because spring is precompressed close to ½" of the working range.
- Calibration: all Anvil Variable Spring Hangers and supports are calibrated for accurate loading conditions.
- Load indicator is clearly seen in the slot, simplifying reading of the scale plate. Load is read from bottom of indicator.
- Cold set at the factory upon request.
- Spring and casing are fabricated of steel and are rugged and compact.
- Piston cap serves as a centering device or guide maintaining spring alignment.
- Casing protects the spring from damage and weather conditions.

**Standard Finish:** Painted with semi-gloss primer.

### Corrosion Resistant:

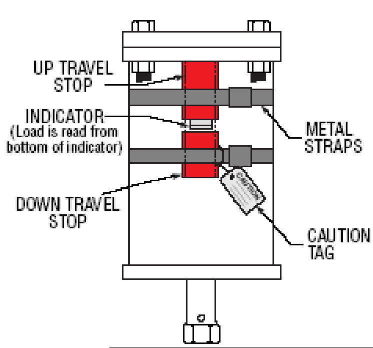
Anvil offers corrosion-resistant and weather-resistant Variable Spring Hangers to fill vital needs in the chemical and refinery industries as well as in modern outdoor power plant construction.
For protection against severe weather conditions or moderate corrosive conditions, the parts of the hanger are galvanized per ASTM A-153, except the spring which has a protective coating and the load column for Type F which is electro-galvanized.

### Advantages of a Protective Coating:

- Protects from a wide range of corrosives.
- Does not affect the flex life of the spring.
- Recommended for ambient temperatures up to 200° F

### Travel stop:

The functional design of the pre-compressed variable spring hanger permits the incorporation of a two-piece travel stop that locks the hanger spring against upward or downward movement for temporary conditions of underload or overload. The complete travel stop, the up travel stop only for cold set purposes or the down travel stop only which may be employed during erection, hydrostatic test (Anvil permits a hydrostatic test load of 2 times the normal operating load for the spring hanger) or chemical cleanout will be furnished only when specified. The travel stop is painted red and is installed at the factory with a caution tag attached calling attention that the device must be removed before the pipe line is put in service. Permanently attached travel stops available upon request.





**Approvals:** WW-H-171E (Types 51, 56 and 57) and MSS-SP-69 (Types 51, 52 and 53).

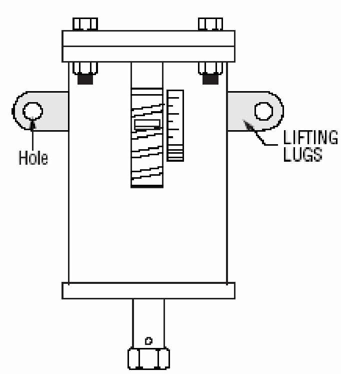
**Specifications:** Anvil Variable Spring Hangers are welded in strict accordance with ASME Section IX.

**Size Range:** The Anvil Variable Spring Hanger in five series and seven types is offered in twenty-three sizes (Fig. B-268 only is offered in twenty-five sizes). The hanger can be furnished to take loads 10 lbs. to 50,000 lbs.

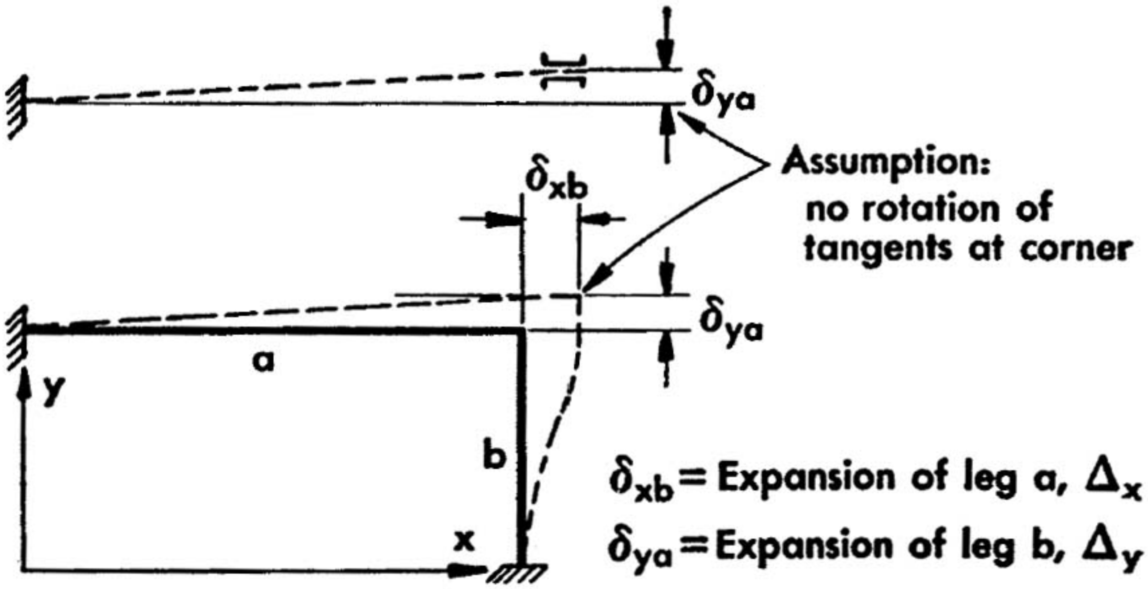
### Ordering:

(1) Size
(2) Type
(3) Figure number
(4) Product name
(5) Desired supporting force in operating position
(6) Calculated amount and direction of pipe movement from installed to operating position.
(7) Customer's identification number (if any)
(8) When ordering Type F spring specify if roller or guided, load column is to be furnished.
(9) When ordering Type G, specify total load and load per spring plus center to center rod dimensions.
(10) If required, specify with travel stop
(11) When ordering corrosion resistant, specify C-268, C-82, C-98, Triple-CR, or Quadruple-CR " completely galvanized except coated spring coil".

**Note:** To help alleviate the problem of lifting large size spring hangers into position for installation, this product is available with lifting lugs (if required) on sizes weighing one hundred pounds or more.



**GUIDED CANTILEVER METHOD – KELLOGG**

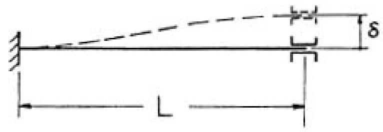



$\delta = 48L^2S_A/E_aD$

Where:

| | | |
|---|---|---|
| $\delta$ | = | maximum permissible displacement |
| D | = | pipe outside diameter |
| $E_a$ | = | elastic modulus of pipe material |
| L | = | length of leg under consideration |
| $S_A$ | = | allowable stress range |

**GUIDED CANTILEVER CHART – KELLOGG**



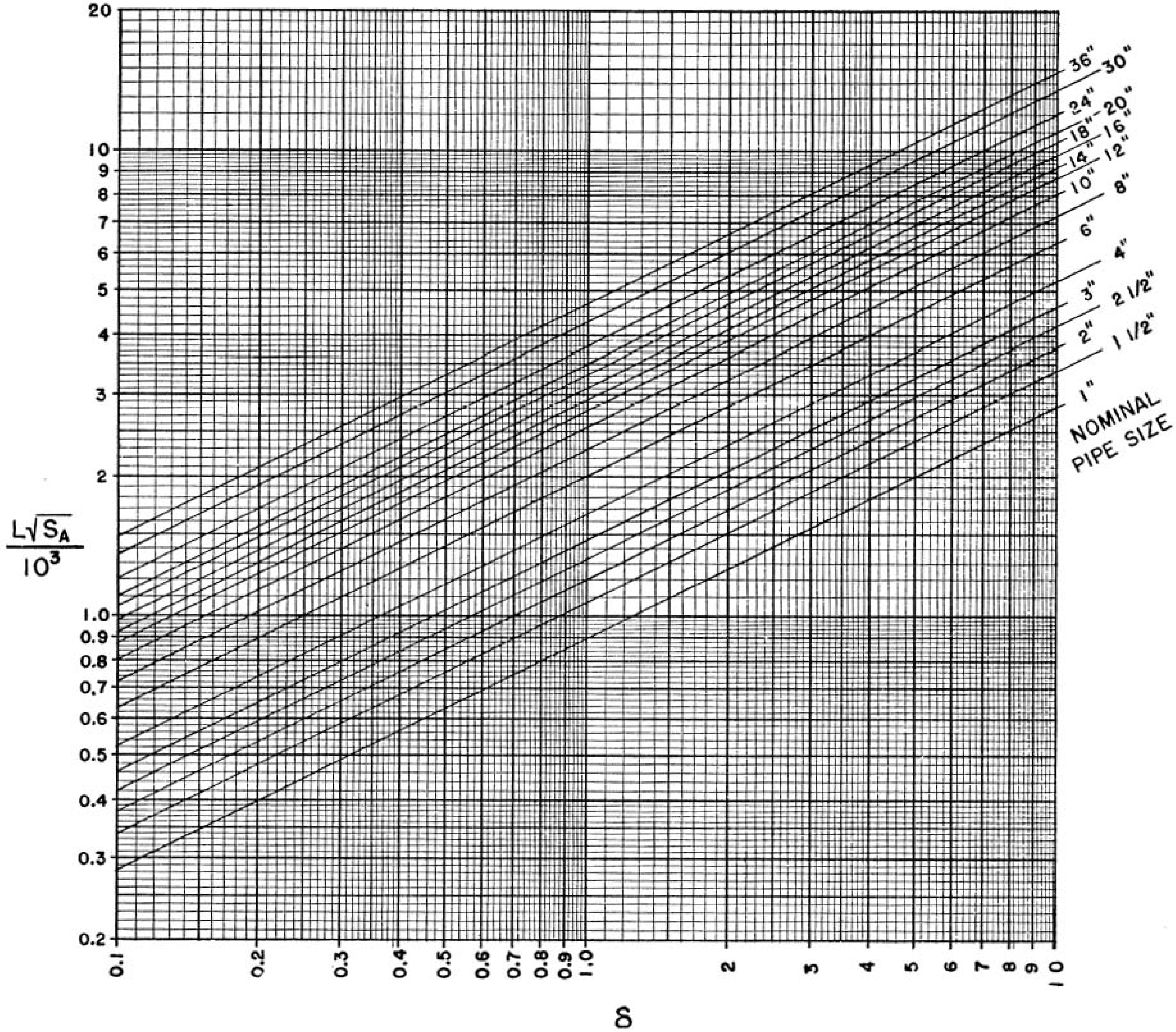

Assumed mode of deflection of guided cantilever.

$L$ = Length of leg, ft.

$\delta$ = Lateral deflection, in.

Value of $E$ used = $29 \times 10^6$ psi.

$S_A$ = Code allowable stress range psi.

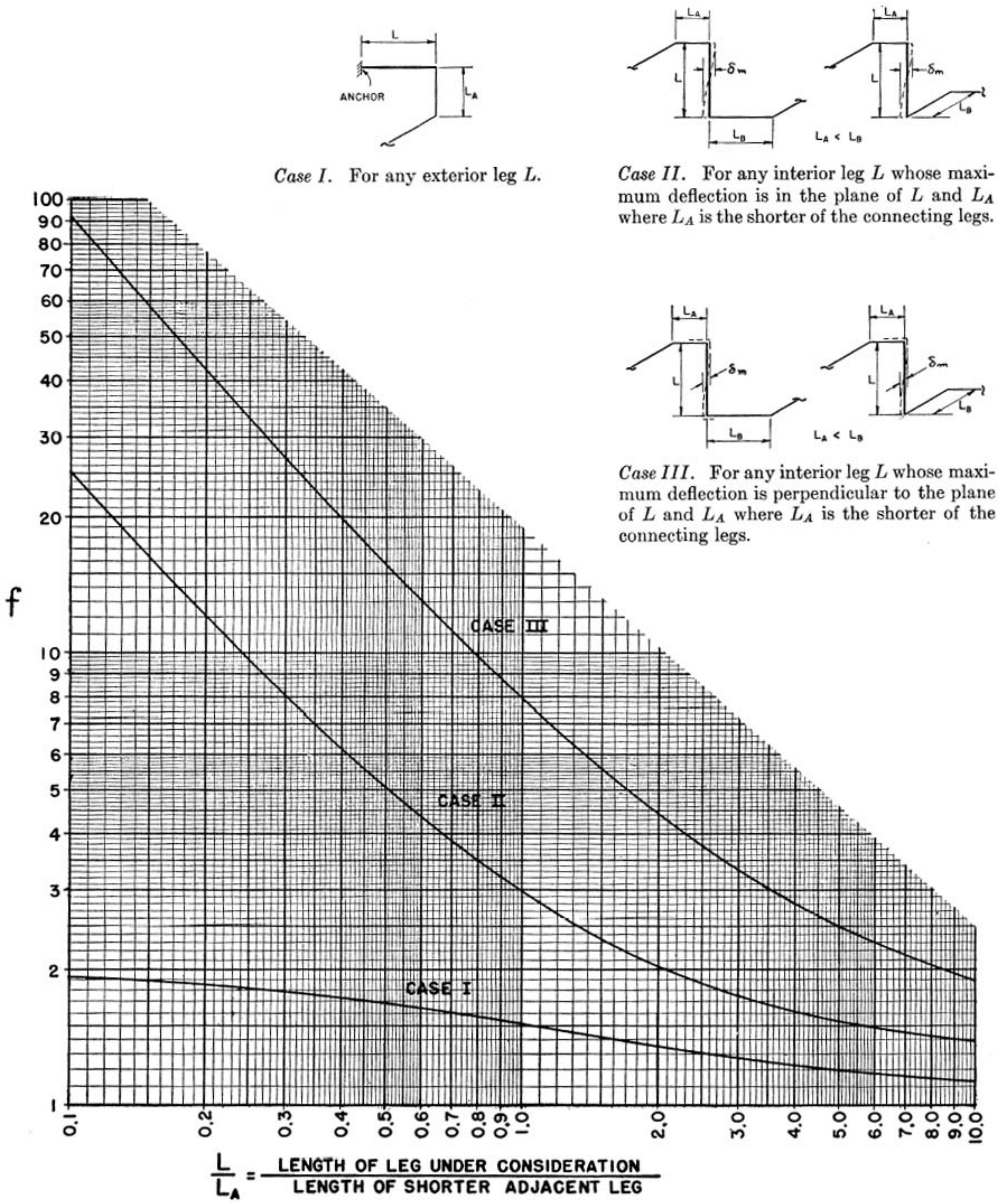



*Instructions:* Determine value of $L\sqrt{S_A}/10^3$. Enter with this value of ordinate scale and read over to line for proper nominal pipe size. Read down to abscissa scale. The value obtained will be the permissible lateral deflection for leg.

**GUIDED CANTILEVER CORRECTION FACTORS – KELLOGG**

Multiply f times δ to get the maximum permissible displacement for the geometry under consideration.

**Correction Factor *f*, Guided Cantilever Method**

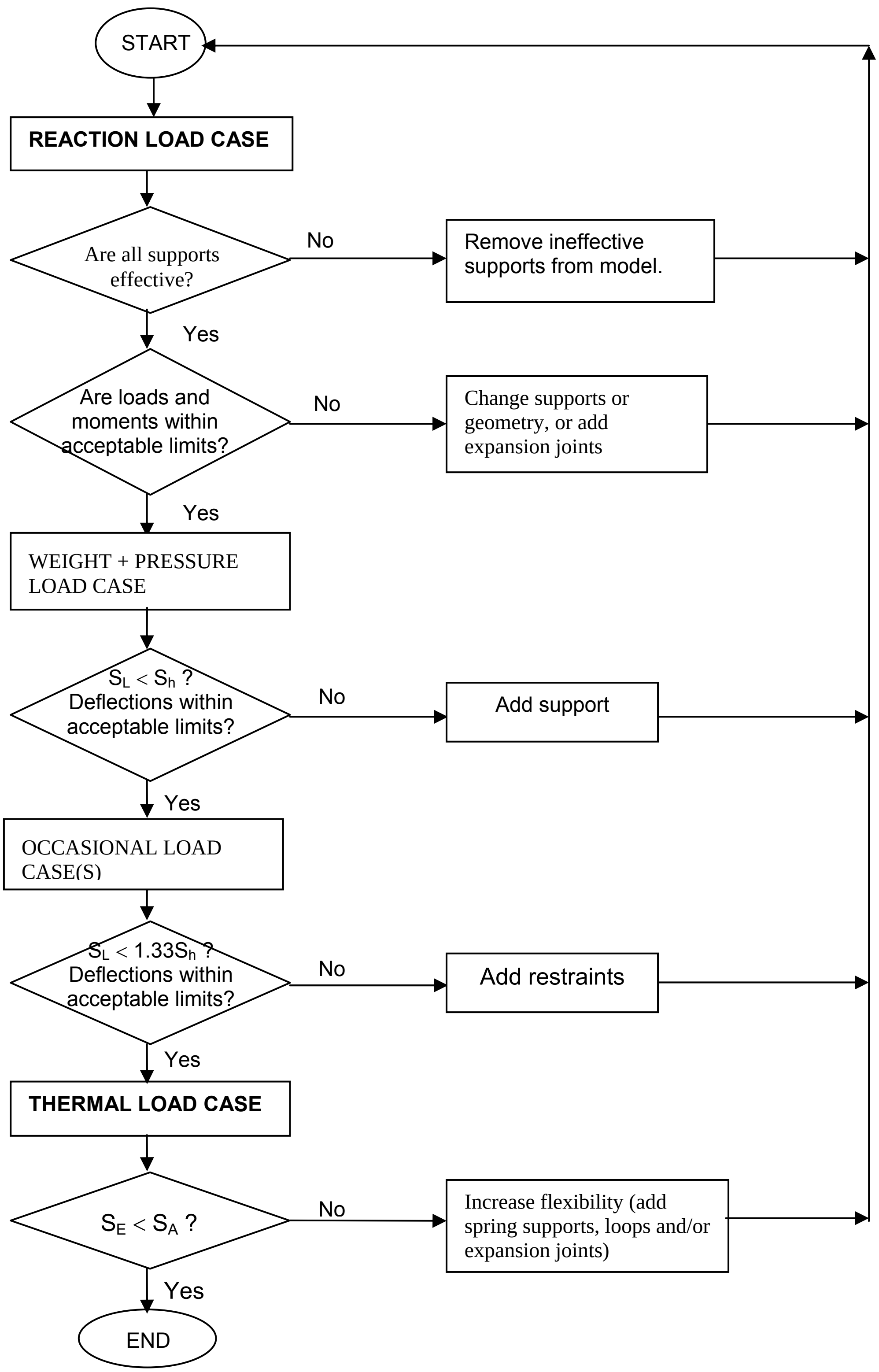



*Case I.* For any exterior leg $L$.

*Case II.* For any interior leg $L$ whose maximum deflection is in the plane of $L$ and $L_A$ where $L_A$ is the shorter of the connecting legs.

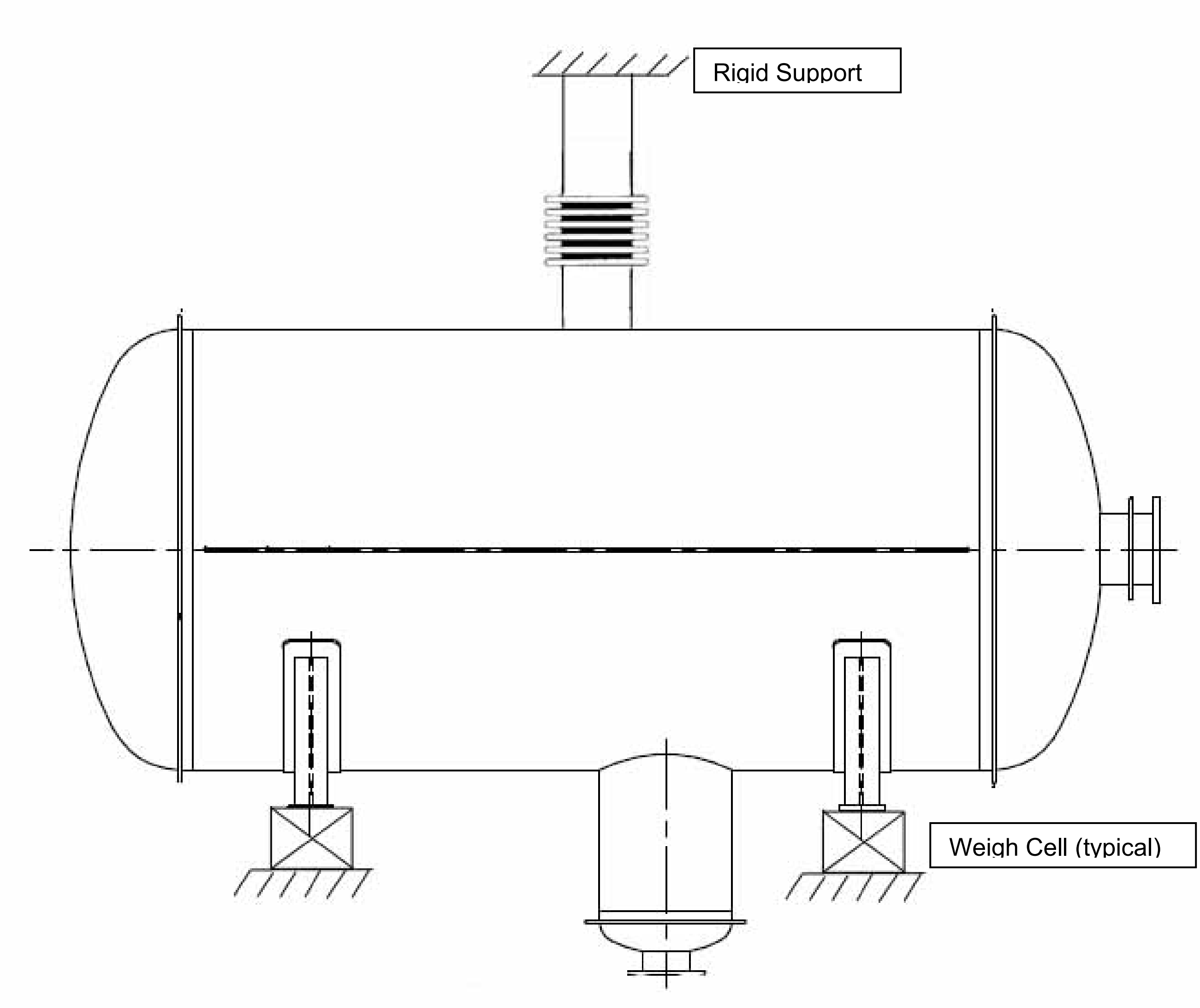
*Case III.* For any interior leg $L$ whose maximum deflection is perpendicular to the plane of $L$ and $L_A$ where $L_A$ is the shorter of the connecting legs.

## THE PIPING FLEXIBILITY ANALYSIS PROCESS



**EXPANSION JOINT PRESSURE THRUST WORKSHOP**

What is the apparent change in the weight of the vessel caused by increasing the pressure by 100 psig (700 kPa)?




The pitch diameter of the bellows is 6.87 in. (175 mm).

## TYPES OF EXAMINATION

Visual examination means using the unaided eye (except for corrective lenses) to inspect the exterior and readily accessible internal surface areas of piping assemblies or components. It does not include nor require remote examination such as by use of boroscopes. Visual examination is used to check materials and components for conformance to specifications and freedom from defects; fabrication including welds, assembly of threaded bolted and other joints; piping during erection; and piping after erection. Further, visual examination can be substituted for radiography, as described later, which is called in-process examination. Requirements for visual examination are provided in the ASME B&PV Code, Section V, Article 9. Records of visual examinations are not required other than those of in-process examination.

Radiographic Examination means using X ray or gamma ray radiation to produce a picture of the subject part, including subsurface features, on radiographic film for subsequent interpretation. It is a volumetric examination procedure that provides a means of detecting defects that are not observable on the surface of the material. Radiographic examination is used to inspect welds and, in some circumstances, castings. Requirements for radiographic examination of welds are provided in the ASME B&PV Code, Section V, Article 2.

Ultrasonic Examination means detecting subsurface defects using high-frequency sound impulses. The defects are detected by the reflection of sound waves from them. It is also a volumetric examination method that can be used to detect subsurface defects. It can be used as an alternative to radiography for weld examination. The requirements for ultrasonic examination of welds are provide in the ASME B&PV Code, Section V, Article 5, with an alternative for basic calibration blocks provided in para. 344.6.

In-Process Examination is a visual examination of the entire joining process, as described in para. 344.7. It is applicable to welding and brazing for metals, and bonding for non-metals. Since radiographic examination is not considered to provide useful results in brazing and bonding, in-process examination is used for these instead of radiography. For welding, it is permitted as a substitute for radiographic examination if specified in the engineering design or specifically authorized by the Inspector. This is not as effective a quality control procedure as random radiography and should only be considered for welds when special circumstances warrant.

Liquid Penetrant Examination means detecting surface defects by spreading a liquid dye penetrant on the surface, removing the dye after sufficient time has passed for the dye to penetrate into any surface discontinuity, and applying a thin coat of developer to the surface which draws the dye from defects. The defects are observable by the contrast between the color of the dye penetrant and the color of the developer. It is used to detect surface defects, and is used for examination of socket welds and branch connections in severe cyclic service than cannot be radiographed, and for all welds including structural attachment welds that are not radiographed when the alternative leak test (para. 345.9) is used. Further, liquid penetrant examination of metallic bellows is required by Appendix X, para. X302.2.2. The requirements for liquid penetrant examination of welds and components other than castings are provided in the ASME B&PV Code, Section V, Article 6.

Magnetic Particle Examination employs either electric coils wound around the part or prods to create a magnetic field. A magnetic powder is applied to the surface and defects are revealed by patterns the powder forms in response to the magnetic field disturbances caused by defects. This technique reveals surface and shallow subsurface defects. As such, it can provide more information than liquid penetrant examination. However, its use is limited to magnetic materials. It is an alternative to liquid penetrant examination wherever such an examination is required in ASME B31.3 (except in the case of metallic bellows). The requirements for magnetic particle examination of welds and components other than castings are provided in the ASME B&PV Code, Section V, Article 7.

Hardness Testing is required after heat treatment under some circumstances, as specified in Table 331.1.1. Hardness testing is not required for carbon steel (P-1), ferritic and austenitic stainless steel (P-7 & P-8), high nickel alloys (P-9A & P-9B), as well as some less commonly used alloys. For welds, the hardness check includes both the weld and the heat affected zone.

## WELD ACCEPTANCE CRITERIA

### TABLE 341.3.2
### ACCEPTANCE CRITERIA FOR WELDS AND EXAMINATION METHODS FOR EVALUATING WELD IMPERFECTIONS

| Criteria (A to M) for Types of Welds and for Service Conditions [Note (1)] | | | | | | | | | | | | | | Examination Methods | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Normal and Category M Fluid Service | | | | Severe Cyclic Conditions | | | | Category D Fluid Service | | | | | | | | | | |
| Type of Weld | | | | Type of Weld | | | | Type of Weld | | | | | | | | | | |
| Girth, Miter Groove & Branch Connection [Note (4)] | Longitudinal Groove [Note (2)] | Fillet [Note (3)] | | Girth, Miter Groove & Branch Connection [Note (4)] | Longitudinal Groove [Note (2)] | Fillet [Note (3)] | | Girth and Miter Groove | Longitudinal Groove [Note (2)] | Fillet [Note (3)] | Branch Connection [Note (4)] | | Weld Imperfection | Visual | Radiography | | Magnetic Particle | Liquid Penetrant |
| A | A | A | . . . | A | A | A | . . . | A | A | A | A | | Crack | ✓ | ✓ | . . . | ✓ | ✓ |
| A | A | A | . . . | A | A | A | . . . | C | A | N/A | A | . . . | Lack of fusion | ✓ | ✓ | . . . | . . . | . . . |
| B | A | N/A | . . . | A | A | N/A | . . . | C | A | N/A | B | . . . | Incomplete penetration | ✓ | ✓ | . . . | . . . | . . . |
| E | E | N/A | . . . | D | D | N/A | . . . | N/A | N/A | N/A | N/A | . . . | Internal porosity | . . . | ✓ | . . . | . . . | . . . |
| G | G | N/A | . . . | F | F | N/A | . . . | N/A | N/A | N/A | N/A | . . . | Internal slag inlcusion, tungsten inclusion, or elongated indication | . . . | ✓ | . . . | . . . | . . . |
| H | A | H | . . . | A | A | A | . . . | I | A | H | H | . . . | Undercutting | . . . | ✓ | . . . | . . . | . . . |
| A | A | A | . . . | A | A | A | . . . | A | A | A | A | . . . | Surface porosity or exposed slug inclusion [Note (6)] | ✓ | . . . | . . . | . . . | . . . |
| N/A | N/A | N/A | . . . | J | J | J | . . . | N/A | N/A | N/A | N/A | . . . | Surface finish | ✓ | . . . | . . . | . . . | . . . |
| K | K | N/A | . . . | K | K | N/A | . . . | K | K | N/A | K | . . . | Concave root surface (suck up) | ✓ | ✓ | . . . | . . . | . . . |
| L | L | L | . . . | L | L | L | . . . | M | M | M | M | . . . | Weld reinforcement or internal protrusion | ✓ | . . . | . . . | . . . | . . . |

GENERAL NOTES:
(a) Weld imperfections are evaluated by one or more of the types of examination methods given, as specified in paras. 341.4.1, 341.4.2, 341.4.3 and M341.4, or by the engineering design.
(b) N/A the Code does not establish acceptance criteria or does not require evaluation of this kind of imperfection for this type of yield.
(c) * Alternative Leak Test requires examination of these welds, see para. 345.9
(d) ✓ examination method generally used for evaluating this kind of weld imperfection
(e) . . . examination method not generally used for evaluating this kind and weld imperfection.

## Criterion Value Notes for Table 341.3.2

| Criterion | | Acceptable Value Limits [Note (6)] | |
|---|---|---|---|
| Symbol | Measure | | |
| A | Extent of imperfection | Zero (no evident imperfection) | |
| B | Depth of incomplete penetration<br>Cumulative length of incomplete penetration | ≤ 1 mm ($^1/_{32}$ in.) and ≤ $0.2\overline{T}_w$<br>≤ 38 mm (1.5 in.) in any 150 mm (6 in.) weld length | |
| C | Depth of lack of fusion and incomplete penetration<br>Cumulative length of lack of fusion and incomplete penetration [Note (7)] | ≤ $0.2\overline{T}_w$<br>≤ 38 mm (1.5 in.) in any 150 mm (6 in.) weld length | |
| D | Size and distribution of internal porosity | See BPV Code, Section VIII, Division 1, Appendix 4 | |
| E | Size and distribution of internal porosity | For $\overline{T}_w$ ≤ 6 mm ($^1/_4$ in.), limit is same as D<br>For $\overline{T}_w$ > 6 mm ($^1/_4$ in.), limit is 1.5 × D | |
| F | Slag inclusion, tungsten inclusion, or elongated indication<br>Individual length<br>Individual width<br>Cumulative length | <br>≤ $\overline{T}_w/3$<br>≤ 2.5 mm ($^3/_{32}$ in.) and ≤ $\overline{T}_w/3$<br>≤ $\overline{T}_w$ in any $12\overline{T}_w$ weld length | |
| G | Slag inclusion, tungsten inclusion, or elongated indication<br>Individual length<br>Individual width<br>Cumulative length | <br>≤ $2\overline{T}_w$<br>≤ 3 mm ($^1/_8$ in.) and ≤ $\overline{T}_w/2$<br>≤ $4\overline{T}_w$ in any 150 mm (6 in.) weld length | |
| H | Depth of undercut | ≤ 1 mm ($^1/_{32}$ in.) and ≤ $\overline{T}_w/4$ | |
| I | Depth of undercut | ≤ 1.5 mm ($^1/_{16}$ in.) and ≤ [$\overline{T}_w/4$ or 1 mm ($^1/_{32}$ in.)] | |
| J | Surface roughness | ≤ 500 min. Ra per ASME B46.1 | |
| K | Depth of root surface concavity | Total joint thickness, incl. weld reinf., ≥ $\overline{T}_w$ | |
| L | Height of reinforcement or internal protrusion [Note (8)] in any plane through the weld shall be within limits of the applicable height value in the tabulation at right, except as provided in Note (9). Weld metal shall merge smoothly into the component surfaces. | For $\overline{T}_w$, mm (in.)<br>≤ 6 ($^1/_4$)<br>> 6 ($^1/_4$), ≤ 13 ($^1/_2$)<br>> 13 ($^1/_2$), ≤ 25 (1)<br>> 25 (1) | Height, mm (in.)<br>≤ 1.5 ($^1/_{16}$)<br>≤ 3 ($^1/_8$)<br>≤ 4 ($^5/_{32}$)<br>≤ 5 ($^3/_{16}$) |
| M | Height of reinforcement or internal protrusion [Note (8)] as described in L. Note (9) does not apply. | Limit is twice the value applicable for L above | |

X = required examination NA = not applicable . . . = not required

*Notes follow on next page*