ASME B31.3 Process Piping

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Piping Development Process

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

3. Materials

- Strength of Materials
- Bases for Design Stresses
- B31.3 Material Requirements
  - Listed and Unlisted Materials
  - Temperature Limits
  - Toughness Requirements
  - Deterioration in Service

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

Chapter II - Design

Chapter III - Materials

Appendix A - Allowable Stresses & Quality Factors – Metals

Appendix F - Precautionary Considerations

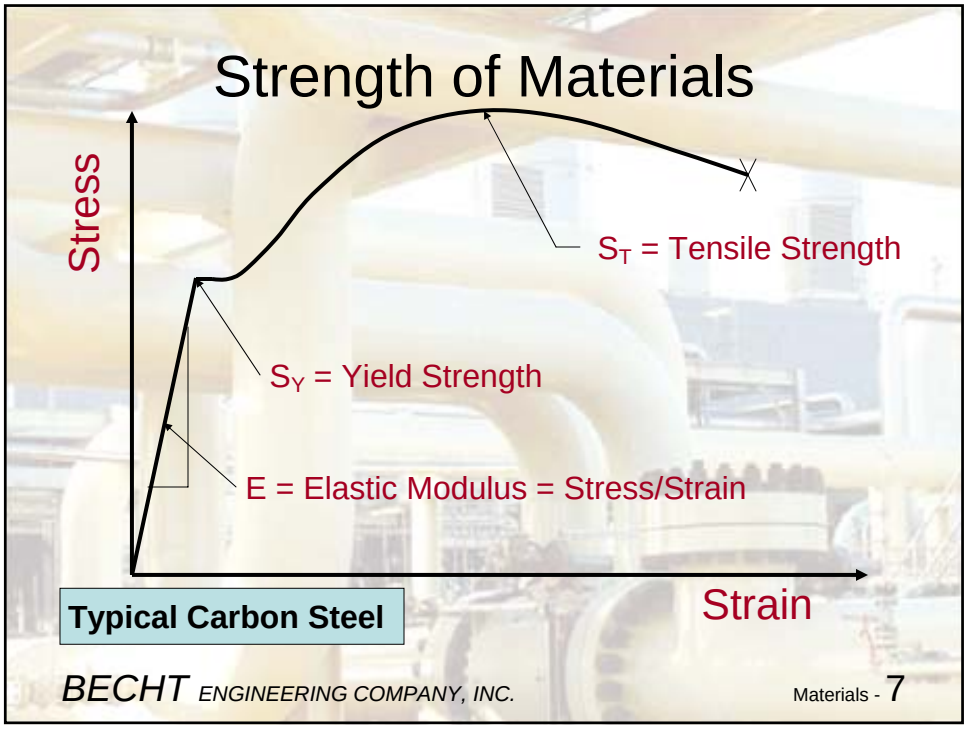
Strength of Materials

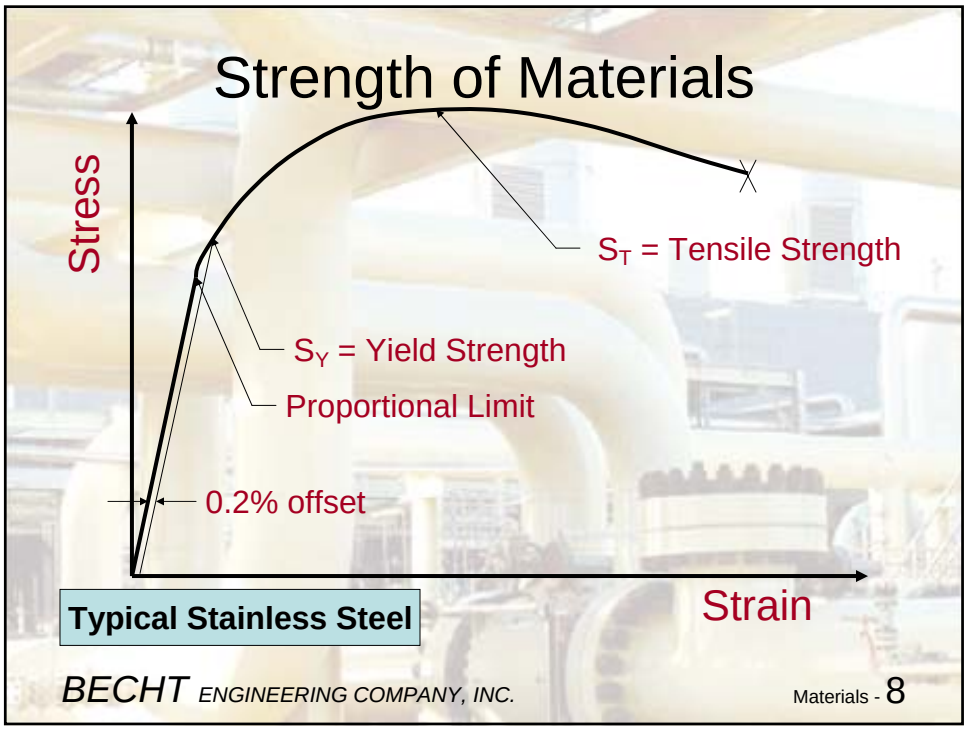
- Stress
- Strain
- Stress-Strain Diagram
  - Elastic Modulus
  - Yield Strength
  - Ultimate Strength
- Creep
- Fatigue
- Brittle versus Ductile Behavior

Strength of Materials

Stress (S): force (F) divided by area (A) over which force acts, pounds force/inch^2 (psi), Pascals (Newtons/meter^2)

Strain (ε): change in length (ΔL) divided by the original length (L)


Strength of Materials
Stress
S_T = Tensile Strength
S_Y = Yield Strength
E = Elastic Modulus = Stress/Strain
Strain
Typical Carbon Steel
BECHT ENGINEERING COMPANY, INC.
Materials - 7

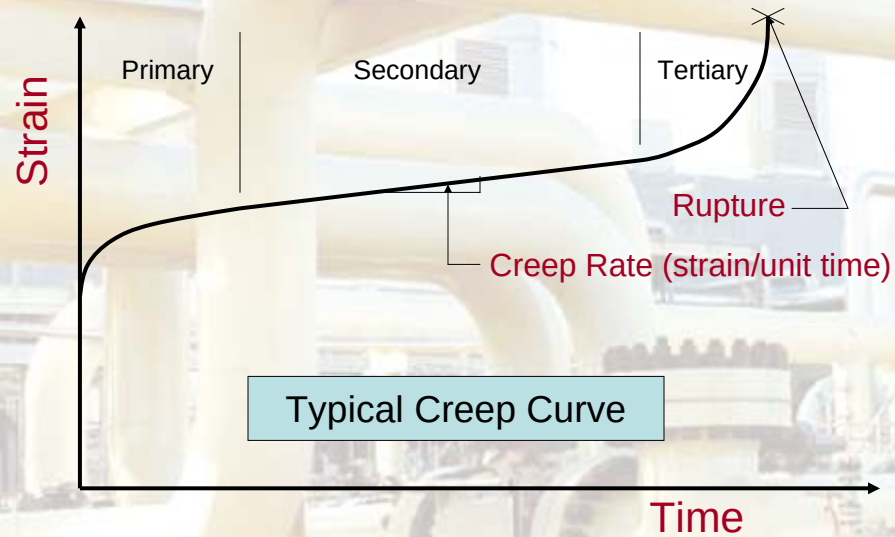

Strength of Materials
Stress
S_T = Tensile Strength
S_Y = Yield Strength
Proportional Limit
0.2% offset
Strain
Typical Stainless Steel
BECHT ENGINEERING COMPANY, INC.
Materials - 8

Strength of Materials

Creep: progressive permanent deformation of material subjected to constant stress, AKA time dependent behavior. Creep is of concern for

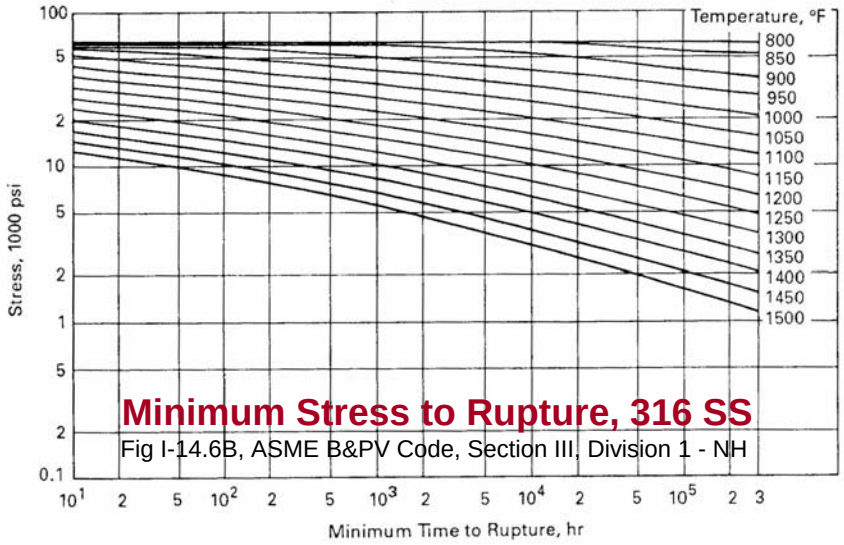
- Carbon steels above ~700ºF (~370ºC)
- Stainless steels above ~950ºF (~510ºC)
- Aluminum alloys above ~300ºF (~150ºC)

Strength of Materials



Typical Creep Curve

Strength of Materials

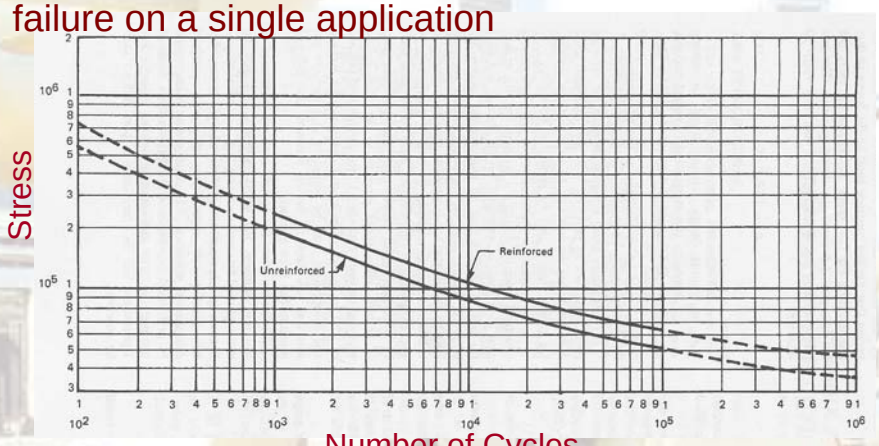


Minimum Stress to Rupture, 316 SS

Fig I-14.6B, ASME B&PV Code, Section III, Division 1 - NH

Strength of Materials

Fatigue failure: a failure which results from a repetitive load lower than that required to cause failure on a single application



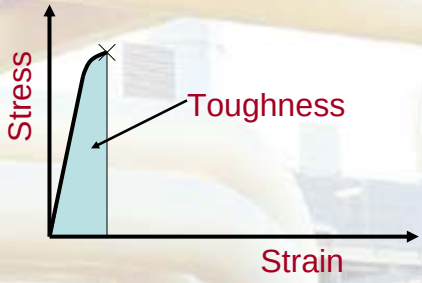
Strength of Materials

Brittle failure:

Ductile deformation:

Strength of Materials

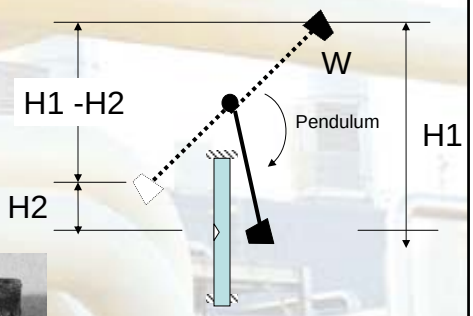
Brittle failure:

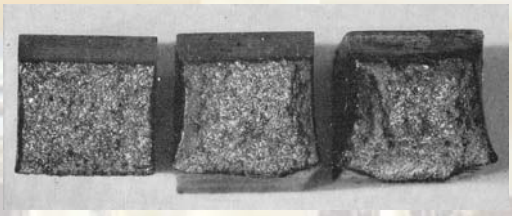


Ductile failure:

Strength of Materials

Measuring Toughness using a Charpy impact test





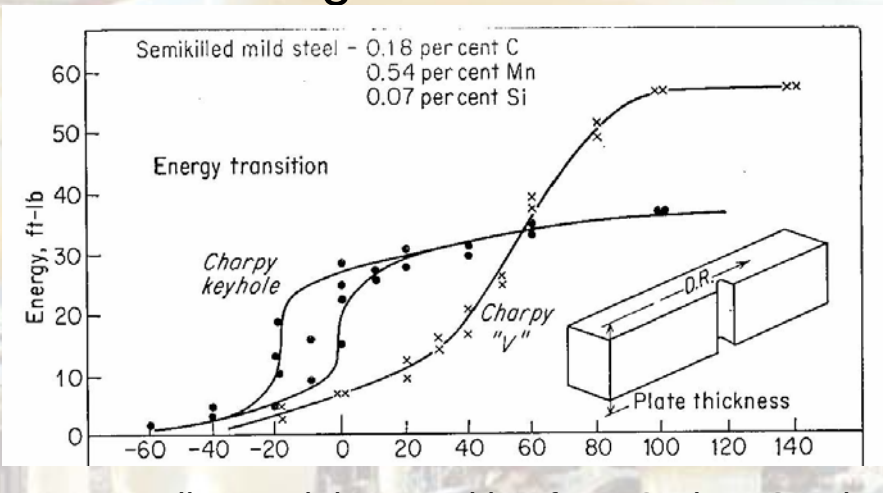
Specimens tested at 40, 100 and 212ºF (4, 38 and 100ºC)

Charpy Impact Test

C_v = W(H1 - H2)

= Energy Absorbed

Strength of Materials



Ductile to Brittle Transition for a Carbon Steel

Bases for Design Stresses

Most Materials – (materials other than gray iron, malleable iron and bolting) below the creep range, the lowest of (302.3.2)

- 1/3 of specified minimum tensile strength (S_T)
- 1/3 of tensile strength at temperature
- 2/3 of specified minimum yield strength (S_Y)
- 2/3 of yield strength at temperature; except for austenitic stainless steels and nickel alloys with similar behavior, 90% of yield strength at temperature

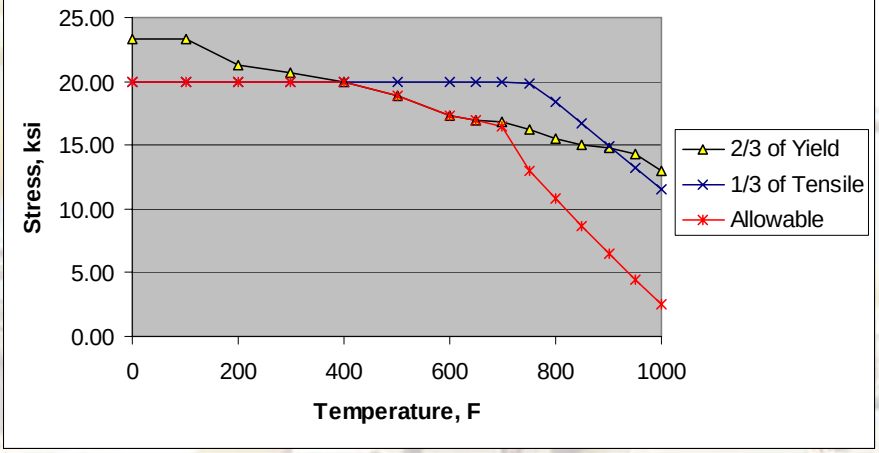
Bases for Design Stresses

Most Materials – additional bases in the creep range, the lowest of (302.3.2)

- 100% of the average stress for a creep rate of 0.01% per 1000 hours
- 67% of the average stress for rupture at the end of 100,000 hours
- 80% of the minimum stress for rupture at the end of 100,000 hours

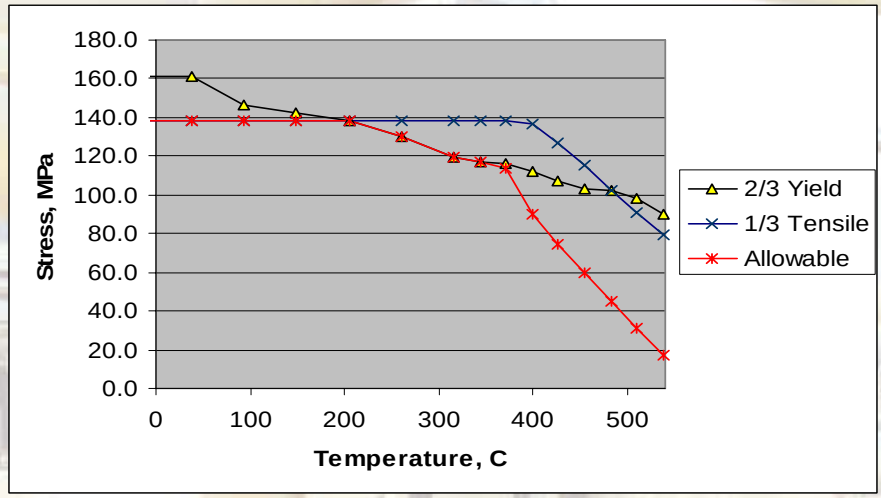
Bases for Design Stresses

ASTM A106 Grade B Carbon Steel (US Customary Units)



Bases for Design Stresses

ASTM A106 Grade B Carbon Steel (Metric Units)



Bases for Design Stresses

Additional Notes

- For structural grade materials, design stresses are 0.92 times the value determined for most materials (302.3.2)
- Stress values above 2/3 S_Y are not recommended for flanged joints and other components in which slight deformation can cause leakage or malfunction (302.3.2)
- Design stresses for temperatures below the minimum are the same as at the minimum

B31.3 Material Requirements

- Listed and Unlisted Materials
- Temperature Limits
- Impact Test Methods & Acceptance
- Toughness Requirements
- Deterioration in Service

Listed and Unlisted Materials

- ***Listed Material:*** a material that conforms to a specification in Appendix A or to a standard in Table 326.1 – may be used (323.1.1)
- ***Unlisted Material:*** a material that is not so listed – may be used under certain conditions (323.1.2)
- ***Unknown Material:*** may not be used (323.1.3)

Listed and Unlisted Materials

An unlisted material may be used if (323.1.2)

- It conforms to a published specification covering chemistry, mechanical properties, method of manufacture, heat treatment, and quality control
- Otherwise meets the requirements of the Code
- Allowable stresses are determined in accordance with Code bases, and
- Qualified for service…all temperatures (323.2.3)

Temperature Limits

Listed materials may be used above the maximum described in the Code if (323.2.1)

- There is no prohibition in the Code
- The designer verifies serviceability of the material, considering the quality of mechanical property data used to determine allowable stresses and resistance of the material to deleterious effects in the planned fluid service (323.2.4)

Temperature Limits

Listed materials may be used within the temperature range described in the Code if (323.2.2)

- The base metal, weld deposits and heat affected zone (HAZ) are qualified in accordance with Column A of Table 323.2.2.

Table 323.2.2

Requirements for Low Temperature Toughness Tests

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
1 Gray cast iron	A-1 No additional requirements		B-1 No additional requirements
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)]	
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 at [illegible] design minimum temperature is −29°C (−20°F), [illegible] 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)].

See page 20 of the supplement.

Temperature Limits

Listed materials may be used <u>below</u> the minimum described in the Code if (323.2.2)

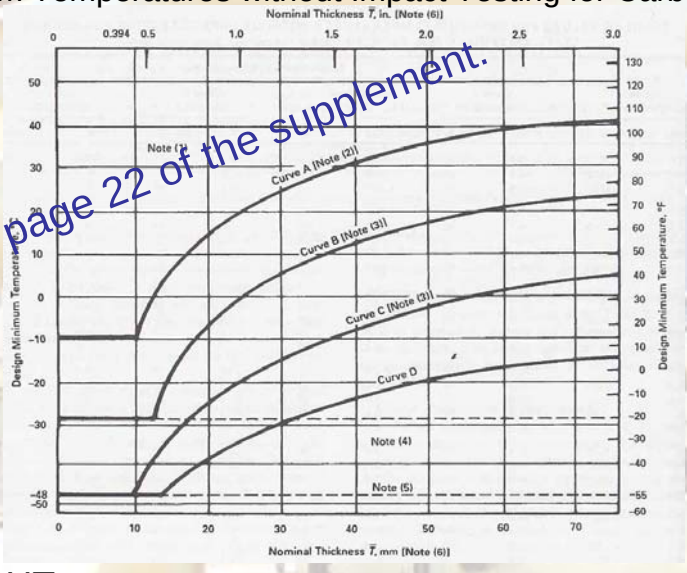
- There is no prohibition in the Code
- The base metal, weld deposits and heat affected zone (HAZ) are qualified in accordance with Column B of Table 323.2.2.

Carbon Steel Lower Temperature Limits

- Most carbon steels have a letter designation in the column for minimum temperature in Appendix A
- See page 25 of the supplement
- For those that do, the minimum temperature is defined by Figure 323.2.2A

Figure 323.2.2A

Minimum Temperatures without Impact Testing for Carbon Steel



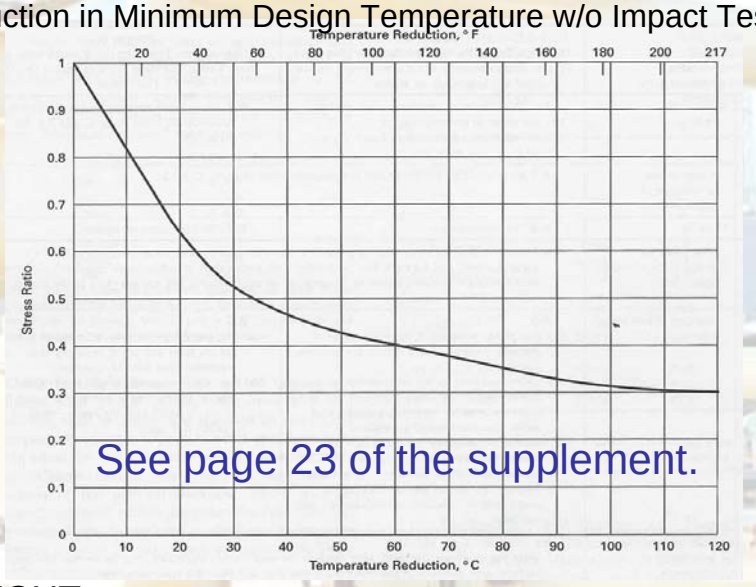
See page 22 of the supplement.

Carbon Steel Lower Temperature Limits

- Impact testing is not required down to -55ºF (-48ºC) if stress ratio does not exceed the value defined by Figure 323.2.2B
- Impact testing is not required down to -155ºF (-104ºC) if stress ratio does not exceed 0.3

Fig.323.2.2B

Reduction in Minimum Design Temperature w/o Impact Testing



See page 23 of the supplement.

Carbon Steel Lower Temperature Limits

Fig.323.2.2B provides a further basis for use of carbon steel without impact testing. If used:

- Hydrotesting is required
- Safeguarding is required for components with wall thicknesses greater than ½ in. (13 mm)

Stress Ratio is the largest of

- Nominal pressure stress / S
- Pressure / pressure rating
- Combined longitudinal stress / S

Carbon Steel Lower Temperature Limits

650 psig (45 bar) steam superheated to 735°F (390°C). Relief pressure is 725 psig (50 bar). Pipe material is ASTM A53 Gr B seamless.

What options are available to deal with expected ambient temperatures down to -30°F (-34°C)?

NPS	Nominal WT in (mm)	Stress Ratio
1	0.178 (4.52)	0.71
4	0.237 (6.02)	0.74
12	0.500 (12.70)	0.86
30	1.000 (25.40)	0.97

Deterioration in Service

- Selection of material to resist deterioration in service is not within the scope of the Code. (323.5)
- Recommendations for material selection are presented in Appendix F.
  - General considerations
  - Specific material considerations

Deterioration in Service

- General considerations
  - Fire resistance
  - Possibility of brittle fracture
  - Susceptibility to crevice corrosion
  - Possibility of galvanic corrosion
  - Chilling effect of the loss of pressure
  - Compatibility of materials such as
    - Packing
    - Gaskets
    - Thread sealants

Deterioration in Service

- Specific material considerations
  - Carbon and low alloy steel
  - High alloy steel
  - Nickel and nickel alloys
  - Aluminum and aluminum alloys
  - Copper and copper alloys
  - And more…