Common Natural Gas Engineering Problems – And Solutions

Ohio Gas Association
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DISCLAIMER

Some portions of 49 CFR Part 192 are open to interpretation and federal or state regulators may not agree with the opinions expressed in this seminar. Attendees are urged to research the facts and arrive at their own conclusions.
Steel Pipe Design:

- Design formula for steel pipe
- Other design considerations
- Additional design requirements for using an alternate MAOP
- Specifications when ordering steel pipe
- Record keeping for steel pipe
- Double stamped pipe
Tensile Stress:

- A force that attempts to pull apart or stretch a material

Tensile Strength:

- A material's ability to resist tensile stress
Barlow’s formula: $P = 2St/D$

Tells us that the Tensile Stress (which is also called the Hoop Stress) on the pipe = Pressure $\times$ Outside Diameter / $2 \times$ Thickness, i.e. $S = PD/(2t)$

SO,

1000 psig $\times$ 10.75 in / (2 x 0.250 in) = 21,500 psig tensile stress
2000 psig $\times$ 10.75 in / (2 x 0.250 in) = 43,000 psig tensile stress

And yes, size does matter!!

2000 psig $\times$ 20.00 in / (2 x 0.250 in) = 80,000 psig tensile stress
How much tensile stress can we put on pipe?

For our purposes:

- Maximum tensile/hoop stress allowed in pipe ≈ Yield Strength “S”, or Specified Minimum Yield Strength, “SMYS”
  - Grade A = 25,000 psi
  - Grade B = 35,000 psi
  - API 5L X-42 = 42,000 psi
  - API 5L X-52 = 52,000 psi
  - API 5L X-60 = 60,000 psi
  - API 5L X-65 = 65,000 psi

- Pipe used for projects regulated under Part 192 must be a listed specification in 192.7
192.105 Design Formula for Steel Pipe

\[ P = \frac{(2St)}{D} \times F \times E \times T \]

- Design Pressure “P”
- Yield Strength (or SMYS) “S”
- Nominal Wall Thickness “t”
- Nominal Outside Diameter “D”
- Design Factor “F”
- Longitudinal Joint Factor “E”
- Temperature De-rating Factor “T”

Design Factor “F” is our safety factor
192.105 Design Formula for Steel Pipe

\[ P = \left( \frac{2St}{D} \right) \times F \times E \times T \]

- Step 1: Choose a pipe and enter “S” (Yield Strength), “t” (Wall Thickness), and “D” (Outside Diameter)
  - For new pipe this should be straightforward
  - For existing pipe, you need to rely on existing records. If “S” is unknown, use 24,000 psi or determine “S” in accordance with Section II-D of Appendix B
  - If “t” is unknown, it must be determined in accordance with 192.109
P = (2St/D) x F x E x T

- **Step 2: Determine the Design Factor “F”**
  - Class 1 Locations, F = 0.72
  - Class 2 Locations, F = 0.60
  - Class 3 Locations, F = 0.50
  - Class 4 Locations, F = 0.40
  - Exceptions: 0.60 for pipe in Class 1 Locations that (1) Cross the right-of-way of an unimproved public road without casing; (2) Crosses without a casing, or makes a parallel encroachment on, the right-of-way of either a hard surfaced road, a highway, a public street, or a railroad; (3) Is supported by a vehicular, pedestrian, railroad, or pipeline bridge.
\[ P = (2St/D) \times F \times E \times T \]

- **Step 2: Determine the Design Factor “F”**
  - Class 1 Locations, \( F = 0.72 \)
  - Exception: 0.60 for pipe in Class 1 Locations that (4) Is used in a fabricated assembly, (including separators, mainline valve assemblies, cross-connections, and river crossing headers) or is used within five pipe diameters in any direction from the last fitting of a fabricated assembly, other than a transition piece or an elbow used in place of a pipe bend which is not associated with a fabricated assembly.
P = (2St/D) x F x E x T

- Step 2: Determine the Design Factor “F”
  - Class 1 Locations, F = 0.72
  - Class 2 Locations, F = 0.60
  - Exception: For Class 2 locations, a design factor of 0.50, or less, must be used … for uncased steel pipe that crosses the right-of-way of a hard surfaced road, a highway, a public street, or a railroad.
  - Exception: For Class 1 and Class 2 locations, a design factor of 0.50, or less, must be used … in a compressor station, regulating station, or measuring station
\[ P = (2St/D) \times F \times E \times T \]

- **Step 3: Longitudinal Joint Factor “E”**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Pipe Class</th>
<th>Longitudinal Joint Factor (E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM A53/A53M</td>
<td>Seamless</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Electric Resistance</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Welded</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Furnace Butt Welded</td>
<td>0.60</td>
</tr>
<tr>
<td>ASTM A106</td>
<td>Seamless</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>~</td>
<td>~</td>
</tr>
<tr>
<td>API 5L</td>
<td>Seamless</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Electric Resistance</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Welded</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electric Flash Welded</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Submerged Arc</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Welded</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Furnace Butt Welded</td>
<td>0.60</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>Pipe over 4 inches</td>
<td>0.80</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>Pipe 4 inches and less</td>
<td>0.60</td>
</tr>
</tbody>
</table>
P = \((2St/D) \times F \times E \times T\)

- **Step 4: Temperature De-rating Factor “T”**
  
  - For gas temperature below 250° F = 1.000
  - For gas temperature above 250° F, see 192.115
Examples

What’s the design pressure for 12”, API 5L X-42, 0.250w, ERW, in a Class 3 location?

\[
P = (2St/D) \times F \times E \times T
\]
\[
P = 2 \times 42,000 \times 0.250 / 12.75 \times 0.50 \times 1.00 \times 1.00
\]
\[
P = 823.53 \text{ psig}←
\]

What wall thickness do I need for a 20”, API 5L X-52, ERW, Class 1 road crossing if I want a 1000 psig MAOP?

\[
P = 2 \times 52,000 \times 0.250 / 20.00 \times 0.60 \times 1.00 \times 1.00 = 780 \text{ psig}
\]
\[
P = 2 \times 52,000 \times 0.320512821 / 20.00 \times 0.60 \times 1.00 \times 1.00 = 1000 \text{ psig}
\]
\[
P = 2 \times 52,000 \times 0.375 / 20.00 \times 0.60 \times 1.00 \times 1.00 = 1170 \text{ psig}←
\]

For other pipe besides road crossings and valve settings:
\[
P = 2 \times 60,000 \times 0.250 / 20.00 \times 0.72 \times 1.00 \times 1.00 = 1080 \text{ psig}←
\]
• Other Considerations

- Distribution vs. Transmission (need to keep below 20% SMYS)

How do I calculate 20% SMYS?

12”, API 5L X-42, 0.250w, ERW. SMYS = 42,000

20% of 42,000 = 0.2 x 42,000 = 8400 psi

Use Barlow’s formula:  \( P = \frac{2S \cdot t}{D} \) (do NOT use E, F, or T)

\[ P = 2 \times 8400 \times 0.250 / 12.75 = 329.41 \text{ psig} \]

Class 3 design = 2 x 42,000 x 0.250 / 12.75 x 0.50 x 1 x 1 = 823 psig
But anything over 329 MAOP will cause it to be a transmission line
• Other Considerations

- Availability of fittings
- Future Class location changes
- Road, railroad crossings
- Bridges
- Compressor, regulator/meter stations, valve settings, other above ground facilities
- Damage prevention
- Corrosion allowance
- Ohio Power Siting Requirements
- External loading

External loading on the pipe is additive and must be considered separately using API 1102 or other external loading calculations.
Additional requirements for alternative MAOP

- Allows for Design Factor “F” up to 0.80 in Class 1, 0.67 in Class 2, and 0.56 in Class 3
- Significant additional requirements for almost every aspect, including pipe manufacturing, design, construction, testing, and operations and maintenance
- See 192.112 for further details
Specifications for ordering steel pipe

• Diameter
• Pipe manufacturing specifications
• Grade
• Wall thickness
• Product Specification Level (PSL) for API 5L pipe

### Summary of Differences Between PSL 1 and PSL 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PSL1</th>
<th>PSL2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade range</td>
<td>A25 through X70</td>
<td>B through X80</td>
</tr>
<tr>
<td>Size range</td>
<td>0.405 through 80</td>
<td>4.5 through 80</td>
</tr>
<tr>
<td>Type of pipe ends</td>
<td>Plain-end, threaded end</td>
<td>Plain-end</td>
</tr>
<tr>
<td>Seam welding</td>
<td>All methods: continuous welding limited to Grade A25</td>
<td>All methods except continuous and laser welding</td>
</tr>
<tr>
<td>Electric welds: welder frequency</td>
<td>No minimum</td>
<td>100kHz minimum</td>
</tr>
<tr>
<td>Heat treatment of electric welds</td>
<td>Required for grades &gt; X42</td>
<td>Required for all grades (B through X80)</td>
</tr>
<tr>
<td>Chemistry: max C for seamless pipe</td>
<td>0.28% for grades &gt;= B</td>
<td>0.24%</td>
</tr>
<tr>
<td>Chemistry: max C for welded pipe</td>
<td>0.26% for grades &gt;= B</td>
<td>0.22%</td>
</tr>
<tr>
<td>Chemistry: max P</td>
<td>0.030% for grades &gt;= A</td>
<td>0.025%</td>
</tr>
<tr>
<td>Chemistry: max S</td>
<td>0.030%</td>
<td>0.015%</td>
</tr>
<tr>
<td>Carbon equivalent</td>
<td>Only when purchaser specifies SR18</td>
<td>Maximum required for each grade</td>
</tr>
<tr>
<td>Yield Strength, maximum</td>
<td>None</td>
<td>Maximum required for each grade</td>
</tr>
<tr>
<td>UTS, maximum</td>
<td>None</td>
<td>Maximum required for each grade</td>
</tr>
<tr>
<td>Fracture toughness</td>
<td>None required</td>
<td>Required for all grades</td>
</tr>
<tr>
<td>Nondestructive inspection of seamless</td>
<td>Only when purchaser specifies SR4</td>
<td>SR4 mandatory</td>
</tr>
<tr>
<td>Repair by welding of pipe body, plate by skelp</td>
<td>Permitted</td>
<td>Prohibited</td>
</tr>
<tr>
<td>Repair by welding of weld seams without filler metal</td>
<td>Permitted by agreement</td>
<td>Prohibited</td>
</tr>
<tr>
<td>Certification</td>
<td>Certificates when specified per SR15</td>
<td>Certificates (SR 15.1) mandatory</td>
</tr>
<tr>
<td>Traceability</td>
<td>Traceable only until all tests are passed, unless SR15 is specified</td>
<td>Traceable after completion of tests (SR 15.2) mandatory</td>
</tr>
</tbody>
</table>
Record Keeping for Steel Pipe

- Purchase orders (vs. phone call)
- Invoice
- Shipping receipt/bill of lading
- Mill test report (MTR’s)
- Documentation on where pipe was actually installed

MTR’s should be requested and retained whenever possible
# Certificate of Testing

**Company:** IPSCO Tubulars (KY) Inc

**Document Number:** 184425-4

**Date:** Friday, February 18, 2011, 10:34:38 AM

**Material Data:**
- **Grade:** X42, X52-2M
- **Outside Diameter:** 18.00 in
- **Wall Thickness:** 0.376 in
- **Customer PC:**

**Material Identification:**
- **Specification:** API 5L, FORTY-FOURTH EDITION, GRADINGS X42, X52, COMPLIANCE WITH STOCK PSL2.

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Orientation</th>
<th>Width (in)</th>
<th>YS (psi)</th>
<th>UTS (psi)</th>
<th>Elong% (2 in)</th>
<th>V/F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
<td>I</td>
<td>P</td>
<td>S</td>
<td>Cu</td>
<td>Ni</td>
</tr>
<tr>
<td>Proven</td>
<td>0.06</td>
<td>1.12</td>
<td>0.0011</td>
<td>0.0004</td>
<td>0.72</td>
<td>0.07</td>
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<tr>
<td>870B</td>
<td>0.006</td>
<td>1.12</td>
<td>0.0011</td>
<td>0.0004</td>
<td>0.72</td>
<td>0.07</td>
</tr>
<tr>
<td>Mill Control</td>
<td>0.006</td>
<td>1.12</td>
<td>0.0011</td>
<td>0.0004</td>
<td>0.72</td>
<td>0.07</td>
</tr>
<tr>
<td>Pipe</td>
<td>0.006</td>
<td>1.12</td>
<td>0.0011</td>
<td>0.0004</td>
<td>0.72</td>
<td>0.07</td>
</tr>
<tr>
<td>TPA</td>
<td>0.006</td>
<td>1.12</td>
<td>0.0011</td>
<td>0.0004</td>
<td>0.72</td>
<td>0.07</td>
</tr>
<tr>
<td>TWA</td>
<td>0.006</td>
<td>1.12</td>
<td>0.0011</td>
<td>0.0004</td>
<td>0.72</td>
<td>0.07</td>
</tr>
</tbody>
</table>

**Additional Information:**
- **Heat:** B115441
- **Product ID:** 970, 870B
- **Test Details:**
  - **Location:** C | I | P | S | Cu | Ni | Cr | Mo | Sn | Al | V | E | Cb | Ti | B | Y/F
  - **Results:**
    - **YS:** 5000 psi
    - **UTS:** 57500 psi
    - **Elongation:** 0.84

**Certification Statement:**
We certify that the product described above has been manufactured, sampled, inspected, and tested in accordance with the referenced specification. The product has been found to be in compliance with all requirements.
Double Stamped Pipe

- Why double stamped pipe?
The most common dual grade product has been Grade B/X42, but other common dual-grades are:

X-42/X-46
Grade B/X-42/X-46
X-42/X-52
X-60/X-65
X-60/X-65/X-70

UTI’s policy is to design to any single chosen grade but to weld to the highest stamped grade.
Steel Pipe Test Question #1

What is a reasonable 4” pipe to select for a Class 3 distribution system with a MAOP of 400 psig?

(1) 4”, API 5-L Gr B, 0.120w, ERW
(2) 4”, API 5-L Gr B, 0.188w, ERW
(3) 4”, API 5-L X-42, 0.237w, ERW
Steel Pipe Test Question #1

What is a reasonable 4” pipe to select for a Class 3 distribution system with a MAOP of 400 psig?

(1) 4”, API 5-L Gr B, 0.120w, ERW
(2) 4”, API 5-L Gr B, 0.188w, ERW
(3) 4”, API 5-L X-42, 0.237w, ERW

Solution (using Barlow’s Formula to limit at 20% SMYS)

(1) 4”, API 5-L Gr B, 0.120w, ERW
   • \[ P = 2 \times (35,000 \times 0.20) \times 0.120 / 4.5 = 373 \text{ psig} \]
(2) 4”, API 5-L Gr B, 0.188w, ERW
   • \[ P = 2 \times (35,000 \times 0.20) \times 0.188 / 4.5 = 584 \text{ psig} \leftarrow \text{ My Choice} \]
(3) 4”, API 5-L X-42, 0.237w, ERW
   • \[ P = 2 \times (42,000 \times 0.20) \times 0.237 / 4.5 = 884 \text{ psig} \]
Steel Pipe Test Question #2

I have an 8”, 0.188w, unknown grade transmission pipe in a Class 3 location with a 575 psig MAOP. Is it OK from a pipe design standpoint?
Steel Pipe Test Question #2

I have an 8”, 0.188w, unknown grade transmission pipe in a Class 3 location with a 575 psig MAOP. Is it OK from a pipe design standpoint?

Solution (using Design Formula)

\[ P = \frac{2 \times 24,000 \times 0.188}{8.625 \times 0.50 \times 1.00 \times 1.00} = 523 \text{ psig} \quad \text{NOPE} \]
Steel Pipe Test Question #3

What is 50% SMYS in a Class 1 location for 16”, API 5L X-52, 0.250w, Butt Welded pipe?
Steel Pipe Test Question #3

What is 50% SMYS in a Class 1 location for 16”, API 5L X-52, 0.250w, Butt Welded pipe?

Solution (using Barlow’s Formula)

\[ P = 2 \times (52,000 \times 0.50) \times 0.250 / 16 = 812 \text{ psig} \]

NOTE: 812 psig of internal pressure will create 50% SMYS for 16” API 5L X-52, 0.250w pipe regardless of class location, seam type, or temperature.
Steel Pipe Test Question #4

Is 12”, API 5L GR B, 0.250w, ERW pipe suitable for a 300 psig MAOP Class 3 distribution pipeline?
Steel Pipe Test Question #4

Is 12”, API 5L GR B, 0.250w, ERW pipe suitable for a 300 psig MAOP Class 3 distribution pipeline?

Solution (using Design Formula)

\[ P = 2 \times \frac{35,000 \times 0.250}{12.75 \times 0.50 \times 1.00 \times 1.00} = 686.3 \text{ psig} \]

However, since distribution piping is limited to 20% SMYS, calculate “P” at 20% SMYS using Barlow’s formula:

\[ P = 2 \times \frac{(35,000 \times 0.20) \times 0.250}{12.75} = 274.5 \text{ psig} \]

This pipe is suitable for a Class 3 design but is NOT suitable for a distribution pipeline since it would exceed 20% SMYS at 300 psig (causing it to be a transmission line)