Casing Design Workshop: Casing and Connections

Part 2

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Casing Grade

- API Grades:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Min Yield</th>
<th>Max Yield</th>
<th>Min Tensile</th>
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<td>H-4</td>
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<td>80</td>
<td>60</td>
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<tr>
<td>J-55</td>
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<td>K-55</td>
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<tr>
<td>V-150</td>
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</table>

V-150 is non-API

Video #7—Stainless Steel Grades Overview

- https://www.youtube.com/watch?v=rZtscuoQDAE

- Stainless Steel Grades Explained

- Not all of the grades are used in casing and tubing, but most are used in gas processing and oil refining
Interference sealing
- Relies on thread lubricant for seal
- Not for high pressure applications
- Examples: ST&C, LT&C, Buttress

Metal-to-metal sealing
- Smooth metal surfaces in contact
- Higher pressure applications
- Examples: Tenaris-Hydril Blue, Wedge or VAM etc.
- Resilient rings: corrosion barriers

API recognizes three basic types:

- Coupling with rounded thread (long or short)
- Coupling with asymmetrical trapezoidal thread buttress
- Extreme-line casing with trapezoidal thread without coupling

Threads are used as mechanical means to hold the neighboring joints together during axial tension or compression. For all casing sizes, the threads are not intended to be leak resistant when made up. API Spec. 5C2, Performance Properties of Casing, Tubing, and Drillpipe, provides information on casing and tubing threads dimensions.
Common Interference Sealing Connections

- API 8 rd Connection
- API Buttress Connection

Interference Sealing

Most threads by themselves are interference sealing

Proprietary Connections

- Shouldered coupling
- Metal-to-metal sealing
- Tapered shoulder enhances sealing contact
- More complex thread forms
Proprietary Connections Conditions (BL)

Special connections are used to achieve gas-tight sealing reliability and 100% connection efficiency. Joint efficiency is defined as a ratio of joint tensile strength to pipe body tensile strength under more severe well conditions. Severe conditions include:

- High pressure (typically > 5,000 psi)
- High temperature (typically > 250°F)
- A sour environment
- Gas production
- High-pressure gas lift
- A steam well
- A large bend (horizontal well)

Also, efficiency in flush joint, integral joint or other special clearance applications improves connections. A large diameter (> 16 in.) pipe improves the stab-in and makeup characteristics; galling should be reduced (particularly in CRA applications and tubing strings that will be re-used); and connection failure under high torsional loads (e.g., while rotating pipe) should be prevented. API connections were not designed for pipe body strength compressive loads. Proprietary connections can address this.

Metal-to-Metal (No Shoulder)

Reverse Taper Thread
Interlocking Threads Metal-to-Metal Seal

Resilient Ring

Primarily a corrosion barrier

Make-Up Torque

- When to stop?

  Connection Make-up Indicators

<table>
<thead>
<tr>
<th>Torque Gage</th>
<th>Shoulder Stop</th>
<th>Make-up Mark</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>casing tongs</td>
<td>pin-to-pin</td>
<td>pipe body</td>
<td>rotation count with torque measure</td>
</tr>
<tr>
<td>coupling shoulder</td>
<td>coupling ring stop</td>
<td>Integral shoulder</td>
<td></td>
</tr>
</tbody>
</table>
Connection Design Limits (BL)

- The design limits of a connection are not only dependent upon its geometry and material properties, but are influenced by:
  - Surface treatment
  - Phosphating
  - Metal plating (copper, tin, or zinc)
  - Bead blasting
  - Thread compound
  - Makeup torque
  - Use of a resilient seal ring
  - Fluid to which connection is exposed (mud, clear brine, or gas)
  - Temperature and pressure cycling
  - Large bends (e.g., medium- or short-radius horizontal wells)

Casing Strength Properties

- Collapse Resistance:
  - External pressure that initiates collapse

- Internal Yield Pressure (“Burst”):
  - Internal pressure that initiates yield at the inner wall
  - Not the actual rupture pressure

- Pipe Body Yield
  - Axial tensile load at the yield strength of the tube

Strength Properties (cont.)

- Joint Tensile Strength
  - Tensile yield strength of the connection
  - Usually less than the pipe body yield strength for API connections (but not always)
  - Always use the lesser of Joint Tensile Strength or Pipe Body Yield in tensile design

- Coupling Leak Strength
  - Leak resistance of API couplings in API 5C2 examples in manual and formulas in Section 7 and textbook (also table in 5C2)
Internal Yield Pressure of Connection (BL)

The internal yield pressure is the pressure that initiates yield at the root of the coupling thread.

\[ P_{cy} = Y_c \left( \frac{W}{d_1} - 1 \right) \]

where

- \( P_{cy} \) = coupling internal yield pressure, psi,
- \( Y_c \) = minimum yield strength of coupling, psi,
- \( W \) = nominal outside diameter of coupling, in.,
- and
- \( d_1 \) = diameter at the root of the coupling thread in the power tight position, in.

This dimension is based on data given in API Spec. 5B, Threading, Gauging, and Thread Inspection of Casing, Tubing, and Line Pipe Threads and other thread geometry data. The coupling internal yield pressure is typically greater than the pipe body internal yield pressure.

Internal Pressure Leak Resistance (BL)

The internal pressure leak resistance is based on the interface pressure between the pipe and coupling threads because of makeup.

\[ P_{plr} = \frac{E T N}{p_t} \left( 1 + \frac{d_1}{2Es} \right) \]

where

- \( P_{plr} \) = coupling internal pressure leak resistance, psi,
- \( E \) = modulus of elasticity, (3.0 × 10^7 psi for steel)
- \( T \) = thread taper, in.,
- \( N \) = a function of the number of thread turns from hand-tight to power-tight position, as given in API Spec. 5B, Threading, Gauging, and Thread Inspection of Casing, Tubing, and Line Pipe Threads,
- \( p_t \) = thread pitch, in.,
- \( E_s \) = pitch diameter at plane of seal, in., as given in API Spec. 5B, Threading, Gauging, and Thread Inspection of Casing, Tubing, and Line Pipe Threads.

This equation accounts only for the contact pressure on the thread flanks as a sealing mechanism and ignores the long helical leak paths filled with thread compound that exist in all API connections.

Leak Pressure of Couplings

- From API 5C2 (may be less than pipe internal body yield or coupling yield)
### Round Thread Casing-Joint Strength (BL)

The round-thread casing-joint strength is given as the lesser of the fracture strength of the pin and the jump-out strength. The fracture strength is given by

\[
 F_f = 0.95 F_p \left[ 0.74 \sqrt{E_p} R_p - 0.32 \sqrt{E_p} R_p + 0.26 \sqrt{E_p} R_p - 0.14 \sqrt{E_p} R_p \right]
\]

where

- \( F_f \) = minimum joint strength, lbf,
- \( A_{jp} \) = cross-sectional area of the pipe wall, in.\(^2\),
- \( d \) = nominal inside diameter of pipe, in.,
- \( D \) = nominal outside diameter of pipe, in.,
- \( G_s \) = ultimate tensile strength of pipe, psi,
- \( K_l \) = engaged thread length, as given in API Spec. 5B, Threading, Gauging, and Thread Inspection of Casing, Tubing, and Line Pipe Threads,
- \( L \) = engaged thread length, in.2

The jump-out strength is given by

\[
 F_j = 0.95 A_{jp} \left[ 0.74 \sqrt{E_p} R_p - 0.32 \sqrt{E_p} R_p + 0.26 \sqrt{E_p} R_p - 0.14 \sqrt{E_p} R_p \right]
\]

These equations are based on tension tests to failure on 162 round-thread test specimens. Both are theoretically derived and adjusted using statistical methods to match the test data. For standard coupling dimensions, round threads are pin weak (i.e., the coupling is not critical in determining joint strength).

### Buttress Thread Casing-Joint Strength (BL)

The buttress thread casing-joint strength is given as the lesser of the fracture strength of the pipe body (the pin) and the coupling (the box). Pipe thread strength is given by

\[
 F_p = 0.95 A_p \left[ 0.74 \sqrt{E_p} R_p - 0.32 \sqrt{E_p} R_p + 0.26 \sqrt{E_p} R_p - 0.14 \sqrt{E_p} R_p \right]
\]

Coupling thread strength is given by

\[
 F_c = 0.95 A_c \left[ 0.74 \sqrt{E_p} R_p - 0.32 \sqrt{E_p} R_p + 0.26 \sqrt{E_p} R_p - 0.14 \sqrt{E_p} R_p \right]
\]

where

- \( U_p \) = minimum ultimate tensile strength of coupling, psi,
- \( A_p \) = cross-sectional area of plain-end pipe, in.\(^2\),
- \( A_c \) = cross-sectional area of coupling, in.\(^2\),
- \( W \) = pipe wall thickness, in.,
- \( d_1 \) = pipe outside diameter, in.,
- \( d_2 \) = pipe inside diameter, in.,
- \( d_3 \) = pipe outside diameter, in.,
- \( Y_p \) = minimum yield strength of pipe, psi.

These equations are based on tension tests to failure on 151 buttress-thread test specimens. They are theoretically derived and adjusted using statistical methods to match test data.

### XL API Casing-Joint Strength (BL)

Extreme-line casing-joint strength is calculated as

\[
 F_{j} = A_{cr} U_p
\]

where

- \( F_j \) = minimum joint strength, lbf,
- \( A_{cr} \) = critical section area of box, pin, or pipe, whichever is least, in.\(^2\).

When performing casing design, it is very important to note that the API joint-strength values are a function of the ultimate tensile strength. This is a different criterion from that used to define the axial strength of the pipe body, which is based on the yield strength. If care is not taken, this approach can lead to a design that inherently does not have the same level of safety for the connections as for the pipe body. This is not good practice, particularly in light of the fact that most casing failures occur at connections. This discrepancy can be countered by using a higher design factor when performing connection axial design with API connections.
Large Diameter Conductor

- API Casing
  - Standard API casing connections, grades, weights
  - Diameters: 16, 18-5/8, 20 inch
- API Line Pipe
  - Connections: welded or weld-on thread connections
  - Yield strengths: 25 to 100 ksi
  - Wall thicknesses: many up to 1.5 inch
  - Diameters: 16 up to 48 inch
- Non-API (ASTM, etc)
  - Wall thicknesses: many up to 2.00 inch
  - Diameters 16 to 72 inch

Large Diameter Connections

- Large diameter casing is difficult to thread
- Butt welding on location is slow for thick wall pipe
- Weld-on threads reduce make-up time and problems on location

Weld-on Connectors

- Eliminate welding time on location
- Some have both tension and compression enhancements
- Some can be used on drive pipe
Conductor Pipe References

- API 5L – Line Pipe Specifications
- Line pipe and caisson manufacturers
- Weld-on connection makers

Closure

- We have acquired a basic overview of casing and casing performance
- Next: We begin the casing design process