STANDARDS FOR COILED TUBING – LIMITING THE GRADE SPREAD

Roderic K. Stanley, Ph. D., I. Eng
Coiled Tubing Resource Management.
API Co-chairman for Coiled Tubulars
API Standards for Coiled Tubulars

- **RP 5C7** is now withdrawn
- **5LCP** covers coiled line pipe mfr (X52C – X90C).
- **5ST** covers Coiled tubing mfr. (CT 70-CT110)
- **RP 16ST** covers well control equipment
- **Draft RP 5C8** (Care, Maintenance and Inspection of Coiled Tubing)
1. Chemical Analysis to cover **Cr, Mo, Cu, Nb, V, Ni, Ti, B & other elements added for other than de-oxidation**, and these are to be reported.
2. Two rechecks are permitted. 3. Master-coils can be rejected if they fail this analysis.
5ST PAPERWORK REQUIREMENTS -1

- **Mandatory Purchasers Requirements**
  - Grade
  - Method for YS (0.2% offset or 0.5% extn UL).
  - Length, diameter, wall thickness(s)
  - End fitting.
  - Product analysis.
  - Drying procedure.
  - Drift Ball material (e.g. carbon steel).
  - NDE Reference indicators for all NDE.
  - Retests (within 50-ft or original test).
  - Final (SR 37) NDE.
  - Shipping reels & delivery data.

- **Optional/Agreement Requirements**
  1. Additional NDE of SE & Butt welds.
  2. Alternate NDE reference indicators (notches, IQIs).
  4. Final string length profile.
  5. Additional hardness tests.
  6. Impact tests.
  7. Minimum acceptable remaining wall.
  8. Whether internal flash is to be removed.
  9. Alternate hydrotest pressure and time.
  10. A measurement of ovality $\Theta = \frac{200(D_{\text{max}} - D_{\text{min}})}{(D_{\text{max}} + D_{\text{min}})}$.
  11. Grain size measurement.
  12. Internal and external coatings.
  13. Markings in SI units.
  14. Documentation to be provided to the customer.
  15. Actual chemical composition.
PAPERWORK REQUIREMENTS-2

String Design

• The purchaser and the mill should design a string before manufacturing begins. The final design often depends on the material in stock, and where skelp-end welds need to be located with regard to working them over the guide-arch.

• Final design to be agreed between purchaser and manufacturer.

• Regard should be paid to **reel size** and **weight**, and to **transportation**.

<table>
<thead>
<tr>
<th>Table 1: Max thickness change between skelp</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>t/in.</td>
<td>t/mm</td>
</tr>
<tr>
<td>&lt; 0.110</td>
<td>&lt; 2.8</td>
</tr>
<tr>
<td>0.110 &lt; t &lt; 0.150</td>
<td>2.8 - 3.8</td>
</tr>
<tr>
<td>0.151 &lt; t &lt; 0.204</td>
<td>3.8 - 5.2</td>
</tr>
<tr>
<td>&gt; 0.205</td>
<td>&gt; 5.2</td>
</tr>
</tbody>
</table>

**Note max YS** for CT70, 80, 90

**Table 3: Tensile requirements**

<table>
<thead>
<tr>
<th>Grade</th>
<th>CT70</th>
<th>CT80</th>
<th>CT90</th>
<th>CT100</th>
<th>CT110</th>
</tr>
</thead>
<tbody>
<tr>
<td>YS(min) kPsi</td>
<td>70</td>
<td>80</td>
<td>90</td>
<td>100</td>
<td>110</td>
</tr>
<tr>
<td>MPa</td>
<td>483</td>
<td>551</td>
<td>620</td>
<td>689</td>
<td>758</td>
</tr>
<tr>
<td>YS(max) kPsi</td>
<td>80</td>
<td>90</td>
<td><strong>100</strong></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MPa</td>
<td>551</td>
<td>620</td>
<td>689</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TS(min) kPsi</td>
<td>80</td>
<td>88</td>
<td>97</td>
<td>108</td>
<td>115</td>
</tr>
<tr>
<td>MPa</td>
<td>551</td>
<td>607</td>
<td>669</td>
<td>758</td>
<td>793</td>
</tr>
<tr>
<td>HRC</td>
<td>max</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>28</td>
</tr>
</tbody>
</table>

1. **Tensile properties** required at “mill stops”, (results added), & at the ends of tbg.
2. Can use prior results from **same heat, size, grade, heat treatment**.
3. Two retests are possible. If end tests fail, take 2 more within 50-ft.
SKELP TESTS & BUTT WELDS

- **Skelp**: Skelp should be inspected for scabs, pits, laminations, etc., as a purchasing quality requirement, but neither 5ST nor 5LCP specify this. This is because the skelp is assumed to be compliant with the CT mill’s requirements.

  **Skelp-End Welds**: These must be manufactured to written procedures, which should include NDE.
  - **Friction-stir welding** is included.
  - The finished SE welds must be flush with the wall surfaces, & polished.
  - **Radiography** (RT) is mandated for CT and CLP. (As a minimum, an ASTM 2T hole, or specified wire image quality indicator is used. The sensitivity may be modified by agreement).
  - **Ultrasonic Shear wave** (UTSW) is a customer call, with its reference indicators specified in 5ST.
  - **Surface hardness tests** must also be conducted and be in compliance with the table.

- **Butt Welds**: Customers determine whether a certified butt weld is permitted. In many strings, they are not a problem. External weld flash must be removed so that there is not more than 1/32-in. excess.
  
  They must be made to a written procedure and NDE-tested at least by RT.

  - The customer can require additional UT. (In some situations, we require UTSW after a weld has passed RT, because of RT’s inability to find 2-dimensional defects).

  Surface hardness tests must be conducted at the weld, the HAZ and the parent metal.
FLATTENING, FLARING, VISUAL, HARDNESS

<table>
<thead>
<tr>
<th>Grade</th>
<th>D/t Ratio</th>
<th>Max Distance between plates</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT70</td>
<td>7/23</td>
<td>D(1.074 – 0.0194 D/t)</td>
</tr>
<tr>
<td>CT80</td>
<td>7/23</td>
<td>D(1.074 – 0.0194 D/t)</td>
</tr>
<tr>
<td>CT90</td>
<td>7/23</td>
<td>D(1.080 – 0.0178 D/t)</td>
</tr>
<tr>
<td>CT100</td>
<td>7/23</td>
<td>D(1.080 – 0.0178 D/t)</td>
</tr>
<tr>
<td>CT110</td>
<td>All</td>
<td>D(1.086 – 0.0163 D/t)</td>
</tr>
</tbody>
</table>

b. If the test fails at 0 or 180°, the test shall continue until the remaining portion fails of the specimen fails at the 90° or 270° position. Premature failure at 12 o’clock or 6 o’clock positions shall not be considered basis for rejection.
c. Flattening shall be at least 0.85D.

- To ASTM 450 at each end of continuously milled lengths, mill stops.
- Flare over 60 deg mandrel
- CT90 & below IDf = 1.25 x ID.
- CT100 & higher IDf = 1.21 x D.
- Retests: 2 additional tests
- One more within 50-ft.

Retests: One set of retests is permitted. If high readings occur, the strip from which the tube is made is rejected.
IMPACT TESTS, HYDRO TEST

Table 5: Charpy V-notch Minimum requirements

<table>
<thead>
<tr>
<th>Directn</th>
<th>Avge of 3</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trnsvrse</td>
<td>20 ft-lb, 27 J</td>
<td>15 ft-lb, 20 J</td>
</tr>
<tr>
<td>Lngtdnl</td>
<td>30 ft-lb, 41 J</td>
<td>20 ft-lb, 27 J</td>
</tr>
</tbody>
</table>

Impact Tests (32°F/0°C): Where size permits, impact tests and retests can be called out by the customer. Minimum requirements are (table 5):

Retests: Two sets of retests are permitted within the 50-ft rule above.

- The Hydro test is mandated to be a minimum of $1.6S_yt/D$ for 15 min. at constant pressure for the thinnest section of a string.
- Customers can require higher pressures or longer times at pressure. (Esp. on 5LCP material)
- Recall that a mill hydrotest is a proof test of the seam weld on the reel.
- What pressures people do in field use is their own problem.
INLINE & OFFLINE NDT

- **Inline:** The tube is assessed in-line by electro-magnetic or ultrasonic methods. Reference standards shall contain longitudinal **10% deep** notches [minimum depth 0.015-in. (0.38 mm)] and drilled holes [(1/32-nd in. (0.8 mm) or 1/16-th –in. (1.6 mm)] that can be partially or entirely through the wall.
- The customer may require to observe the set up tests.

- **Offline:** Re-inspection after the hydrotest. [customer call]
- Reference standards for the equipment are OD and ID (where possible) EDM notches of **length 0.500** (LID, LOD), **0.250-in.** (TID, TOD), **depth 10%** of specified wall (thick end), min depth 0.015-in, maximum width 0.020-in., and a **1/32**" through drilled hole (TDH).
- Reference indicators must be detected clearly in 4 quadrants before and after the string is inspected.
- This inspection is being called out more and more for “critical” strings
- **Chafing marks** from the sides of the reel, and **internal spume** are being found.

Certified inspectors are needed.
## TYPICAL DEFECTS

<table>
<thead>
<tr>
<th>Dents</th>
<th>Cracks</th>
<th>Leaks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laminations</td>
<td><strong>Undercut at tube-tube welds</strong></td>
<td></td>
</tr>
<tr>
<td>Inclusions exceeding NDT reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Radial offset</strong> exceeding greater of <strong>0.010-in</strong> or <strong>0.05t</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midwall Imperfections within 1/16-in. (1.6 mm) of seam that reduce wall to &lt; <strong>90% t</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other imperfections having depth &gt; <strong>10%t</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- MT and PT are to be used to investigate indications found during in- or off-line NDE, such as might originate from open/partial/incomplete/intermittent welds, cracks, seams, overlaps, and slivers.
- These are then explored for depth, and may be fully removed.
- **Customer** sets requirements for remaining minimum wall thickness.
WALL TOLERANCES, OVALITY, DRIFTING

Table 6

<table>
<thead>
<tr>
<th>Specified Wall thickness (t)</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 0.110-in. (2.8 mm)</td>
<td>-0.005-in (-0.1 mm) to +0.010-in (+0.2mm)</td>
</tr>
<tr>
<td>0.110-in (2.8 mm) - 0.175-in. (4.4 mm)</td>
<td>-0.008-in (-0.2 mm) to +0.012-in. (+0.3 mm)</td>
</tr>
<tr>
<td>0.176-in (4.5 mm) t-0.250-in (6.4 mm)</td>
<td>-0.012 in. (-0.3 mm) to +0.012-in. (+0.3 mm)</td>
</tr>
<tr>
<td>≥ 0.251-in (6.4, mm)</td>
<td>-0.015 in. (-0.4 mm) to +0.015 in. (+0.4 mm)</td>
</tr>
</tbody>
</table>

These are for unrepaired areas of the tubing wall

Ovality: The tolerance is ±0.010-in. from specified diameter (D), which is generally measured at the ends of the tubing. The customer can call for additional ovality measurements. Ovality is also measured after OD flaw removal as part of a SR 37 inspection.

- Drift ball sizes are given in 5ST, the ball material (nylon, steel, other) being specified.
- Wiper and drift balls often help to clean out spume, and assure a minimum ID.
- For “flash-in” tubing, the flash column at the seam shall not be more than 0.090-in. (2.3 mm) from the original inside surface.

• The OD surface can be repaired by removing chafing marks, gouges, etc, and finishing with 400-600 grit-size sandpaper. Length or removal should be at least 2 x diameter of tube.
• It is recommended that not more than 10% of the specified wall thickness is removed. This often occurs during the SR 37 inspection.
MARKING, COATINGS

- CT that meets **all requirements** shall be marked (a) **on the reel** and (b) **durably on a tag** with the following:
  - **Manufacturer, Spool number, “Spec 5ST,”, OD, Grade (e.g. CT80), Tested xxxxx psi, NDE SR37 (if performed).**
  - The **length** shall be paint-stencilled on the reel.

- **Unless otherwise specified**, CT shall be given a protective coating. The purchase agreement shall state if special coatings are required.
  - Uncoated tubing shall be protected from water ingress by placing them under cover.
  - **By agreement**, the tube shall be filled with a **dry non-reactive gas**, and the **ends sealed**.
  - **By agreement**, the internal surface shall be protected with a **corrosion inhibitor approved by the customer**.

Baoji Steel, 1025, CT90, 1.750, Tested 15000 psi, NDE SR37
At least the following documents shall be kept by the mfr. for each string.

When specified by the customer, the following shall be supplied.

- A certificate stating the API Spec and revision date.
- Diameter, wall thickness(es) and grade.
- Chemical analysis (heat, product if required) showing mass per-cents as elucidated in 5ST.
- All tensile and hardness test data.
- All weld locations, measured from the reference end.
- Test pressure and duration string is held at pressure.
- Inline NDT method, & reference indicators.
- Type/size of all IQIs & other reference standards.
- Fracture toughness tests (type, sample size, orientation, location), if applicable.
- Results of supplementary tests required by purchaser (eg: SR37)
- Spool size and # of times spooled.
- Certification of drying procedure.

The spool documentation above shall be kept for at least 5 years, along with tester charts, radiographs and other NDE data, and NDE personnel qualification and certifications.