

API STANDARD 5ST **SPECIFICATION FOR COILED** **TUBING**

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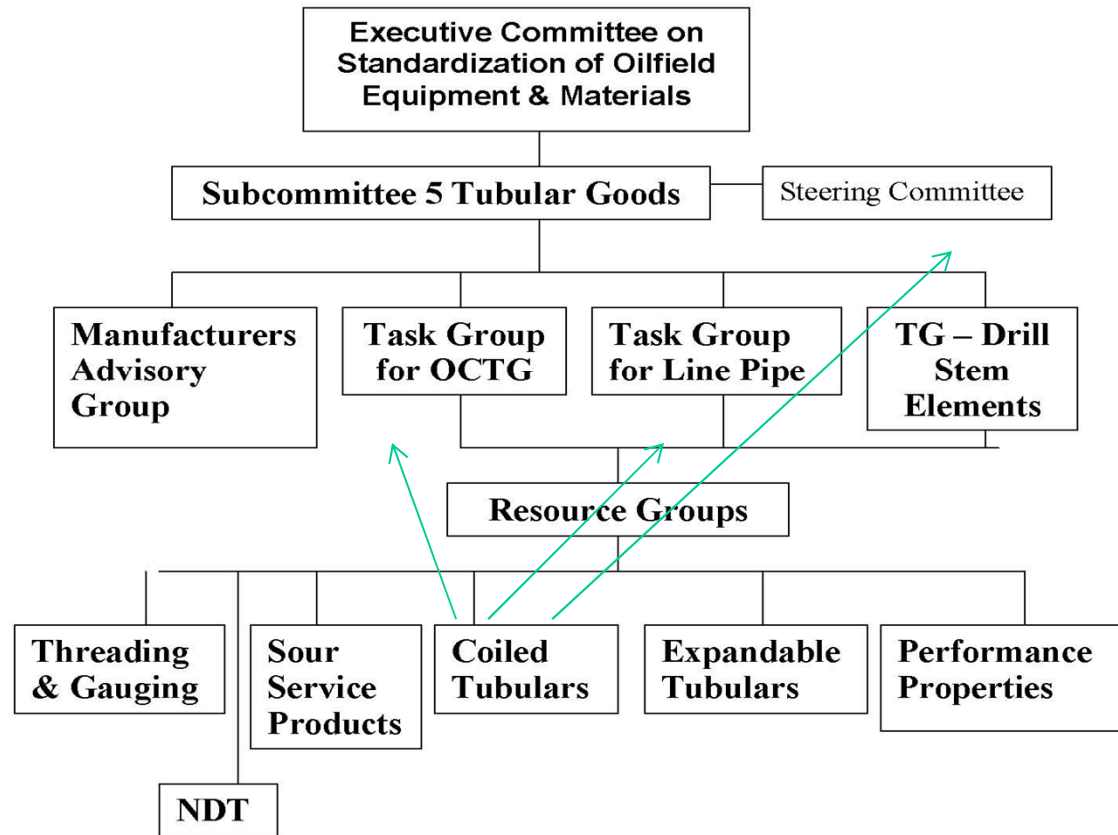
API Co-chairman for Coiled Tubulars



API Tubular Committee Structure

- Coiled Tubulars reports upwards to the TGOCTG (for RP 5C7, RP 5C8, **Spec 5ST**) or TGLP (for Spec 5LCP).
- Co-chm now vote on MAG, TGOCTG & TGLP.
- We sit on Subcommittee 5 Steering committee.

API SUBCOMMITTEE 5 ORGANIZATION STRUCTURE



**Recommended Practice for
Coiled Tubing Operations in
Oil and Gas Well Services**

API RECOMMENDED PRACTICE 5C7
FIRST EDITION, DECEMBER 1996



MINIMUM CHEMICAL REQUIREMENTS

TABLE 2: Chemical requirements (mass %)

Grade	Carbon (Max)	Manganese (Max)	Phosphorus (Max)	Sulphur (Max)	Silicon (max)
CT70	0.16	1.20	0.025	0.005	0.50
CT80	0.16	1.20	0.020	0.005	0.50
CT90	0.16	1.20	0.020	0.005	0.50
CT100	0.16	1.65	0.025	0.005	0.50
CT110	0.16	1.65	0.025	0.005	0.50

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

API SPECIFICATION 5ST

- Spec 5ST Took 12 years to get into print.
- Grades CT70, CT80, CT90, CT100, CT110.
- Sizes 0.750 - 3.500-in.
- Does not contain information about (a) use in **sour** service or (b) **fatigue** models/life.
- (These would be better suited to *recommended practices*)

Specification for Coiled Tubing

U.S. Customary and SI Units

Upstream Segment

API SPECIFICATION 5ST
FIRST EDITION, APRIL 2010

EFFECTIVE DATE: OCTOBER 1, 2010



5LCP & 5ST are *MANUFACTURING* documents, and contain no information about service-related problems.



5 ST DOCUMENT LAYOUT

1. Scope
2. References
3. Definitions
4. Information to be Supplied by the Purchaser
 - Mandatory
 - Optional
5. Processes of manufacture
6. Material requirements
7. Dimensions, masses/Unit Length, Defects, End Finishes.
8. Testing
9. Test methods
10. Nondestructive Inspection
11. Invalidation of tests
12. Retests
13. Marking
14. Coating and Protection
15. Document Control & Retention
16. Certification.

Annexes

- A – Tables (Normative).
- B - Tube-to-tube Welding (Normative).
- C – Skelp-End & Tube-Tube Procedure Specifications (Normative).
- D - Supplementary Requirements (Normative).
- E - Purchaser Inspection (Normative).
- F - Use of Monograph by API Licencees (Informative).
- G – Shipping/Service reels (Informative).
- H - SI Conversions (Normative).

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).
3. Demonstrations of NDE reference standards.
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 [$\Theta = 200 (D_{max} - D_{min}) / (D_{max} + D_{min})$].
11. Grain size measurement.
12. Internal and external coatings.
13. Markings in SI units.
14. Documentation to be provided to the customer.
14. 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.
- Regard should be paid to **reel size** and **weight**, and to **transportation**.

WALL THICKNESS CHANGES BETWEEN SKELPS

TABLE 1: **Max thickness change** between skelps

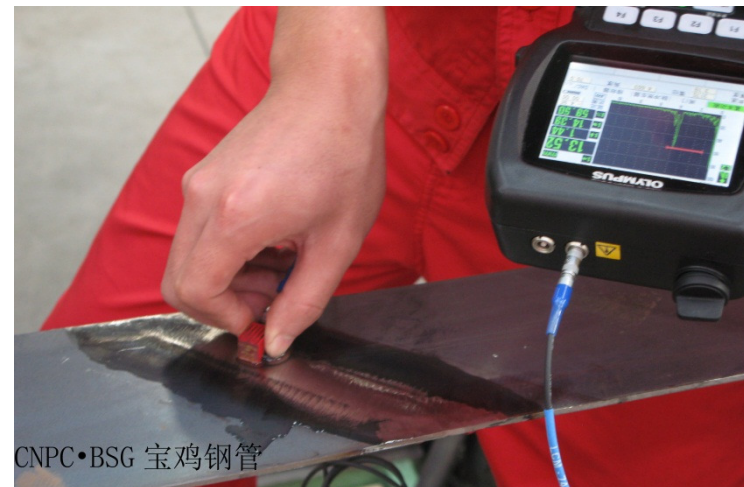
t/in.	t/mm	Δt /in.	Δt /mm.
< 0.110	< 2,8	0.008	0,2
0.110 < t < 0.150	2,8 - 3,8	0.011	0,3
0.151 < t < 0.204	3,8 - 5,2	0.020	0,5
> 0.205	> 5,2	0.031	0,8

Alternatively, one mill uses **continuous tapering** within strips, with no thickness change at the ends.



SKELP TESTS

- **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*.
- **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 notch reference indicators specified in 5ST.
- **Surface hardness tests** must also be conducted and be in compliance with the table.



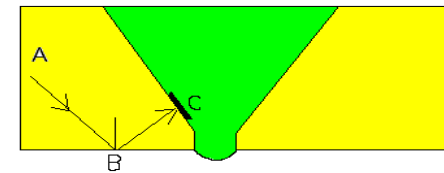
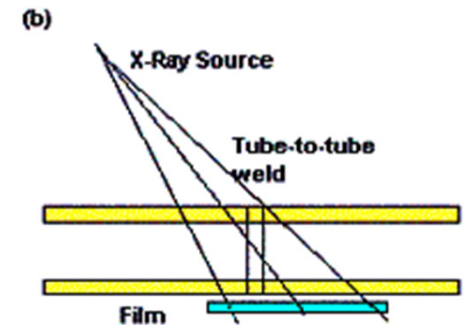
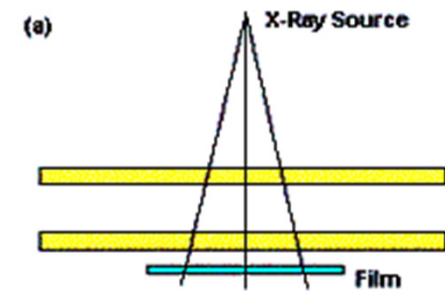
Strip Inspection



CNPC • BSG 宝鸡钢管

BUTT WELDS

- **Butt Welds:** Customers determine whether a butt weld is permitted. In many strings, they are not a problem.
- External weld crown 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.



TENSILE TESTING REQUIREMENTS

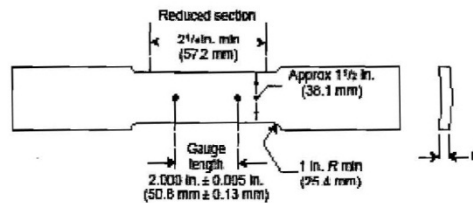


Figure 2—Strip Specimen

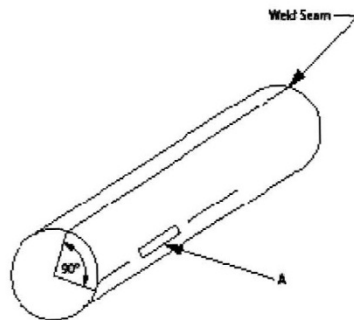


Figure 3—Orientation of Tensile Test Strip Specimen

TABLE 3: Tensile requirements

Grade		CT70	CT80	CT90	CT100	CT110
YS(min)	kPsi	70	80	90	100	110
	MPa	483	551	620	689	758
YS(max)	kPsi	80	90	100	-	-
	MPa	551	620	689	-	-
TS(min)	kPsi	80	88	97	108	115
	MPa	551	607	669	758	793
HRC	max	22	22	22	28	30

1. Taken at ends and at “**mill stops**”. Add “mill stop” results in if (2) is used.
2. Can use prior results from sale heat, size, grade, heat treatment.
3. Two retests possible. If end tests fail, take 2 more within 50-ft.

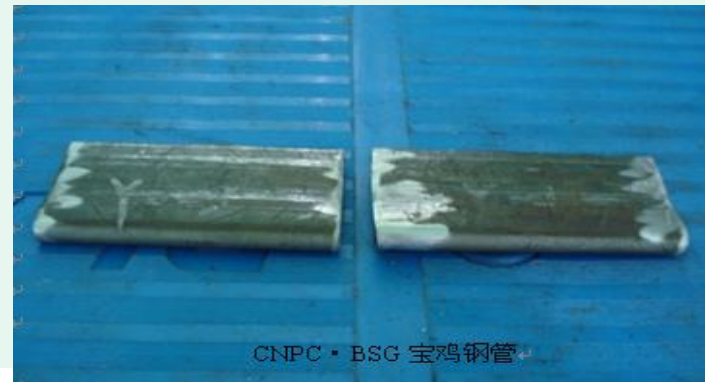
FLATTENING REQUIREMENTS

TABLE 4: Flattening requirements

Grade	D/t Ratio	Max Distance between plates
CT70	7/23	$D(1.074 - 0.0194 D/t)$
CT80 ^b	7/23	$D(1.074 - 0.0194 D/t)$
CT90 ^b	7/23	$D(1.080 - 0.0178 D/t)$
CT100 ^b	7/23	$D(1.080 - 0.0178 D/t)$
CT110 ^c	All	$D(1.086 - 0.0163 D/t)$

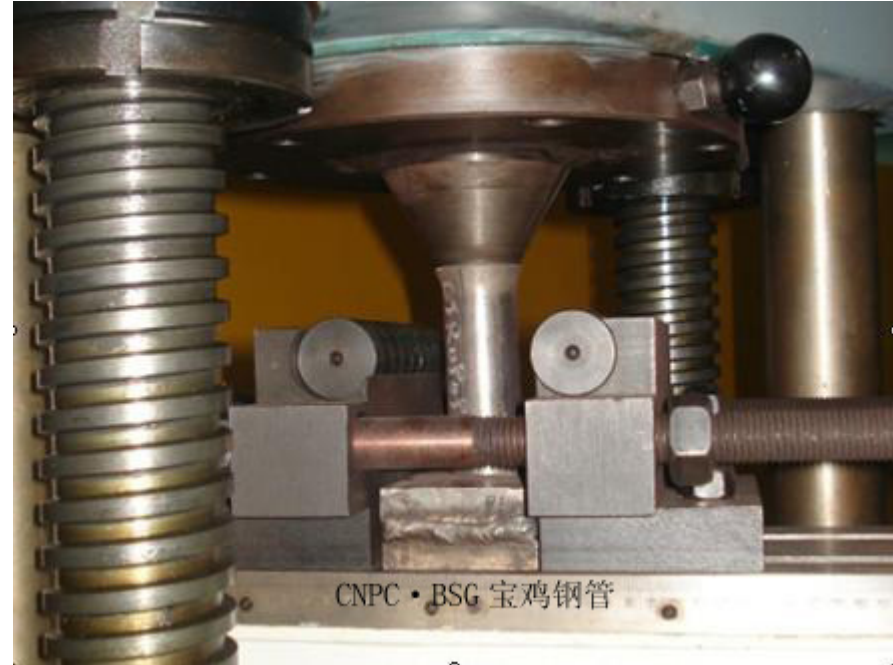
b. If the test fails at 0 or 180°, the test shall continue until the remaining portion fails of the specimen fails at the 90° or 270° position. Premature fail occurring at 12 o'clock or 6 o'clock positions shall not be considered basis for rejection.

c. Flattening shall be at least 0.85D.



FLARING REQUIREMENTS

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



IMPACT TESTS

TABLE 5: Charpy V-notch Minimum requirements

Direction	Average of 3	Minimum
Transverse	20 ft-lb, 27 J	15 ft-lb, 20 J
Longitudinal	30 ft-lb, 41 J	20 ft-lb, 27 J

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):

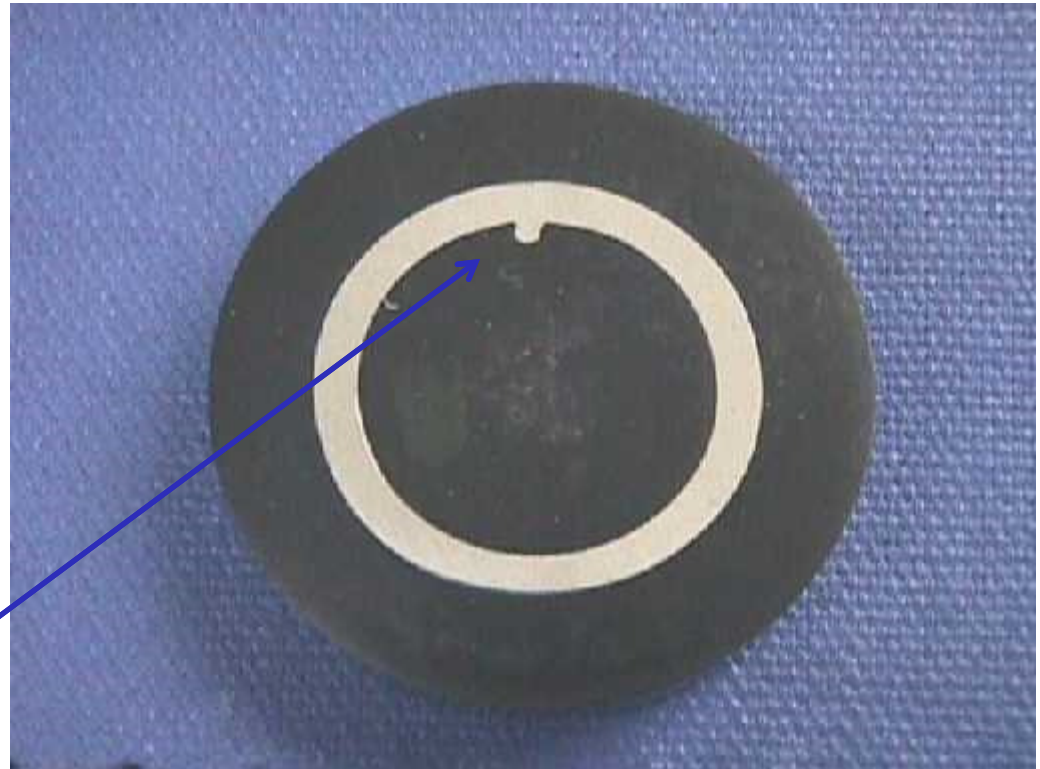
Retests: Two sets of retests are permitted within the 50-ft rule above.

We are aware of impact tests being performed regularly on bias welds, seam welds, butt welds, and in the body of the material from low to high temperatures and after strain aging for CLP, but only rarely for CT.



THE SEAM WELD VISUAL

- **Metallurgical Examination:**
Specimens are to be ground, polished and etched so that the microstructure can be viewed. In the case of “*flash-in*” tubing, the weld root shall show that it is **continuous** with **smooth curves** **blending into the inside diameter** of the tubing.

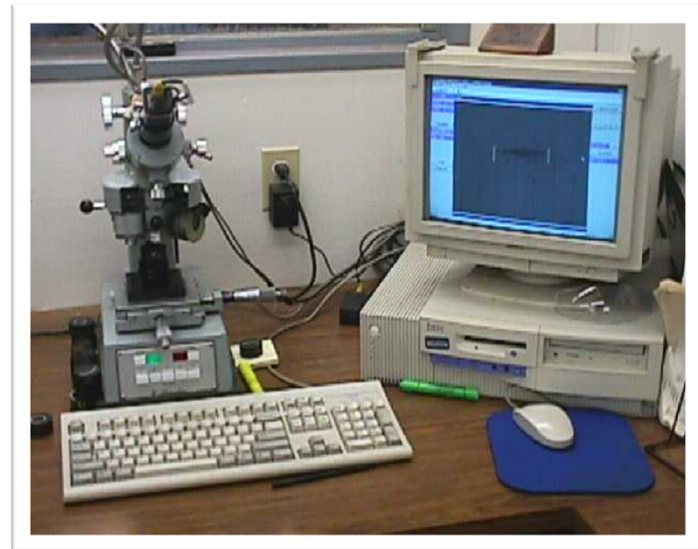


HARDNESS/MICROHARDNESS TESTS

Skelp-End Welds and Butt Welds:

The minimum requirement is for external surface measurements on each weld, HAZ & strip.

- Scans through welds must be performed as part of the welding procedure qualifications. (done with a micro-hardness tester).
- Customer can request more readings.



MICROHARDNESS AT SEAM WELD

Seam Welds: Using material taken next to the tensile test material, standard microhardness tests are taken close to the in the seam weld, the HAZ and the parent tube wall **close to the ID**, **midwall**, and **close to OD** (9 readings in all). The customer can request more readings. All readings must be within the limits of the table.

- **Retests:** One set of retests is permitted. If high readings occur, the *strip* from which the tube is made is rejected.

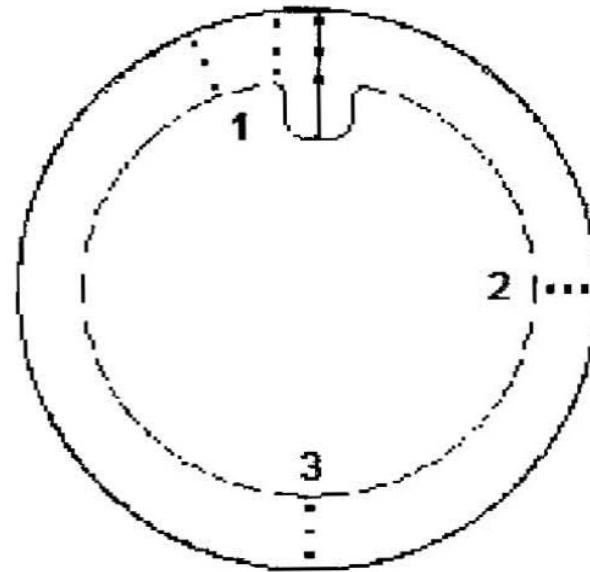


Figure 4—Through-wall Hardness Test Impression Locations

THE HYDROSTATIC TEST

- This is mandated to be a minimum of $1.6S_y t/D$ for **15 min.** at constant pressure for the thinnest section of a string.
- Customers can require **higher pressures** or **longer times** at pressure.
- Recall that a mill hydrotest is a **proof test** of the seam weld on the reel.
- What people do in field use is their own problem.

IN-LINE NDT

- 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 1/16th -in. (1.6 mm)] that **can be partially or entirely through the wall**. *So the customer and the manufacturer must agree on the reference indicator(s) during contract review.*
- The customer may require to observe the set up tests.

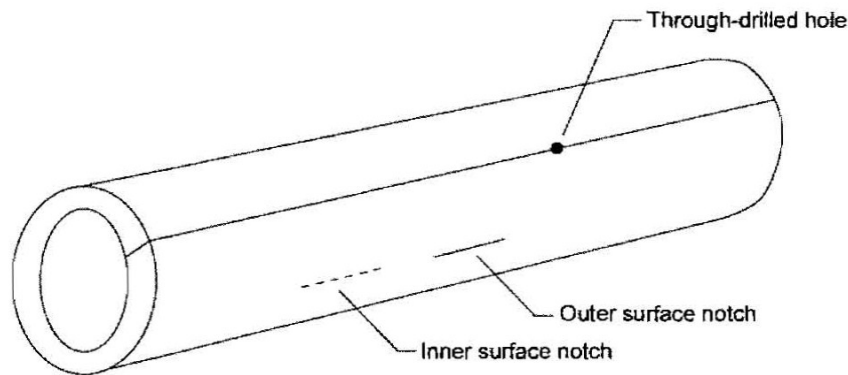
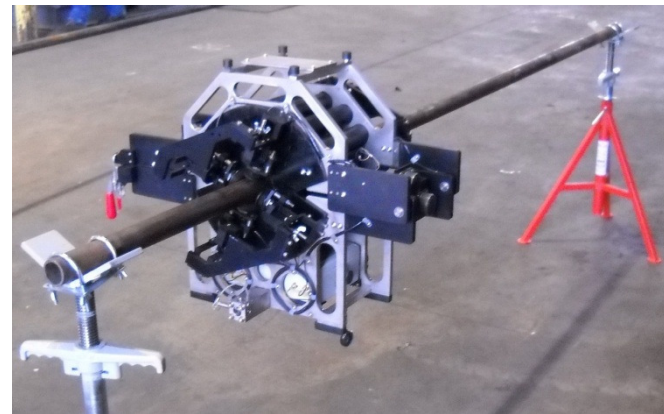


Figure 5—NDT Reference Indicators



OFF-LINE NDE (SR 37)

- 5ST allows the customer to call for an off-
- line re-inspection *after* the hydrotest SR37).
- The 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), minimum depth 0.015-in, **maximum width 0.020-in.**, and a 1/32nd in. through drilled hole (TDH).
- These reference indicators must be detected clearly in 4 quadrants before and after the string is inspected.
- **Inspection personnel MUST be suitably *qualified and certified.***
- This inspection is being called out more and more for strings that are destined for Europe, for offshore Newfoundland and the GoM.
- **Chafing marks** from the sides of the reel, and internal spume are being found.



TYPICAL DEFECTS

Dents

Cracks

Leaks

Laminations

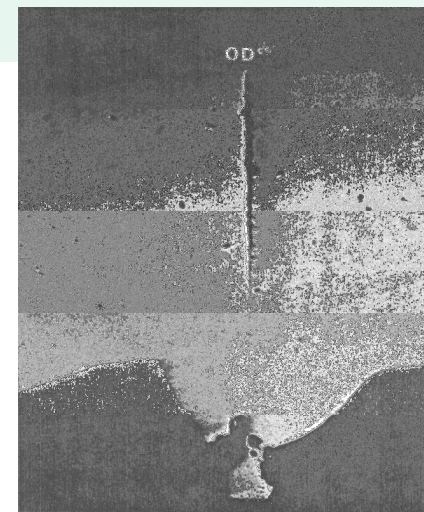
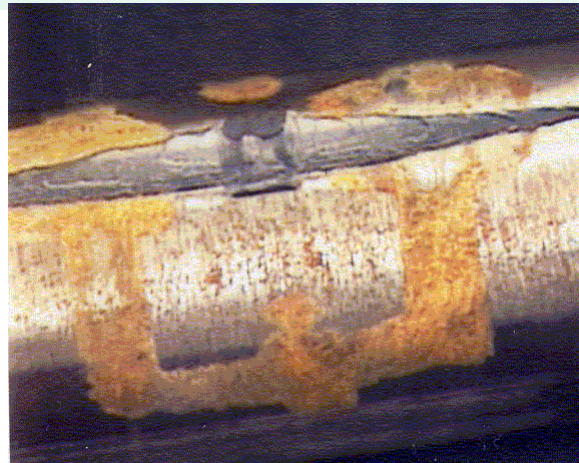
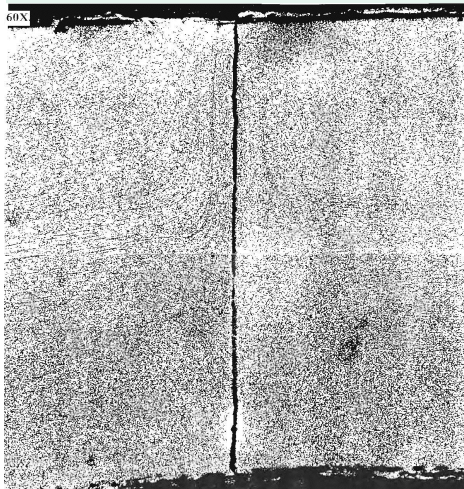
Undercut at tube-tube welds

Inclusions exceeding NDT reference

Radial offset exceeding greater of 0.010-in. or 0.05t

Midwall Imperfections within 1/16-in. (1.6 mm) of seam that reduce wall to $< 90\% t$

Other imperfections having depth $> 10\%t$



WALL TOLERANCES

Table 6

Specified Wall thickness (t)	Tolerance
Below 0.110-in. (2,8 mm)	-0.005-in (-0,1 mm) to +0.010-in (+0.2mm)
0.110-in (2,8 mm) to 0.175-in. (4.4 mm)	-0.008-in (-0,2 mm) to +0.012-in. (+0,3 mm)
0.176-in (4,5 mm) to 0.250-in (6,4 mm)	-0.012 in. (-0,3 mm) to +0.012-in. (+0,3 mm)
≥ 0.251-in (6,4, mm)	-0.015 in. (-0,4 mm) to + 0.015 in. (+0,4 mm)

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.

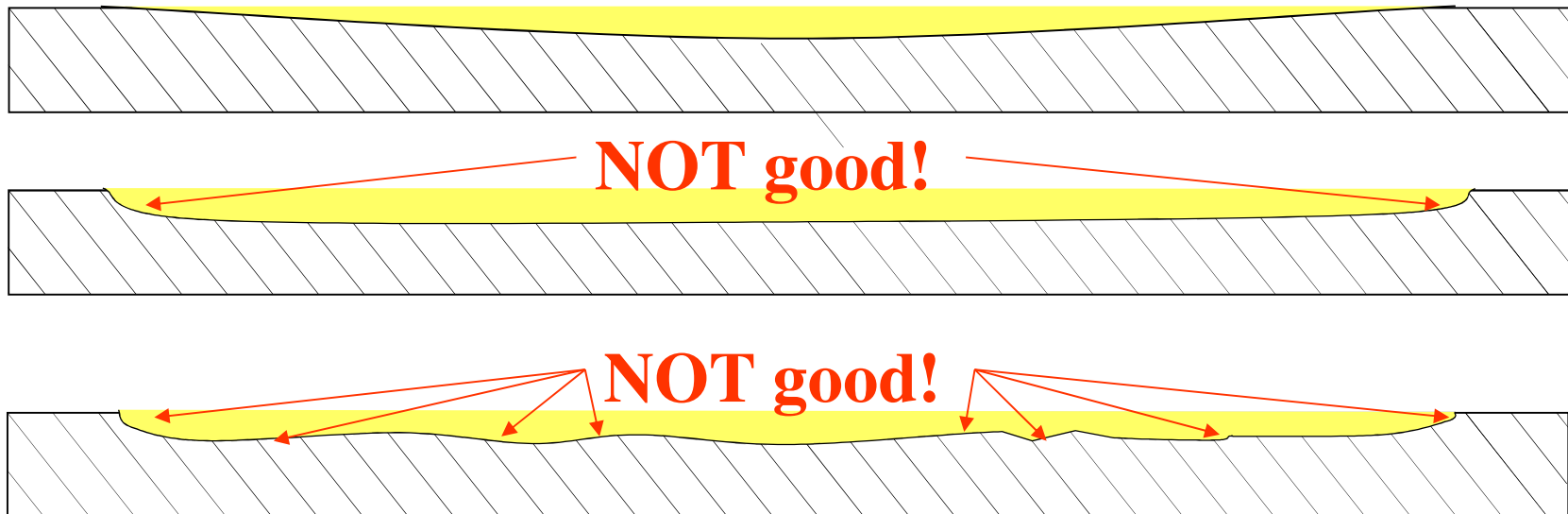
The customer can call for additional ovality measurements.

Ovality is also measured after OD flaw removal as part of a SR 37 inspection.

OD SURFACE FLAW REPAIR

- The OD surface can be repaired by removing chafing marks, gouges, etc, and finishing with 400-600 grit-size sandpaper.
- It is recommended that *not more than 10%* of the specified wall thickness is removed. This often occurs during the SR 37 inspection.

Length or removal should be at least 2 x diameter of tube



DRIFTING THE TUBING

- 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.

MARKING

- 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,” (Comparable standard), OD, Grade (e.g. CT80), Tested xxxxx psi, NDE SR37 (if performed).**
- The length shall be paint-stencilled on the reel.

COATINGS & PROTECTION

- *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.

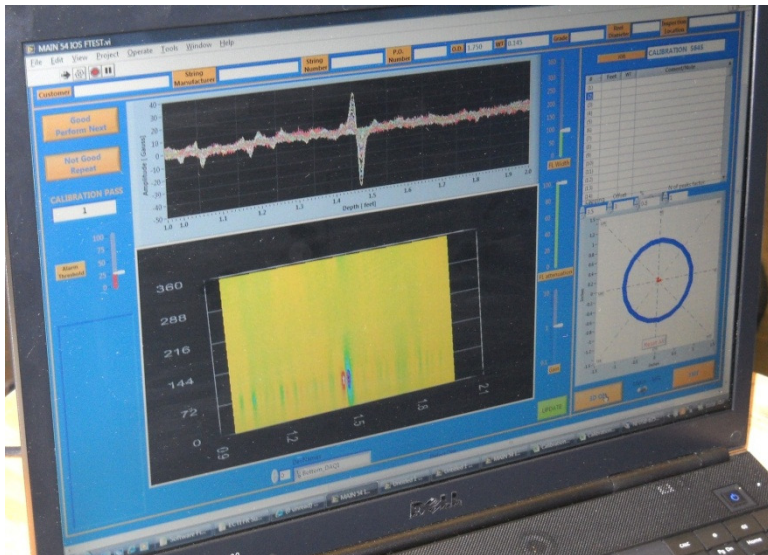
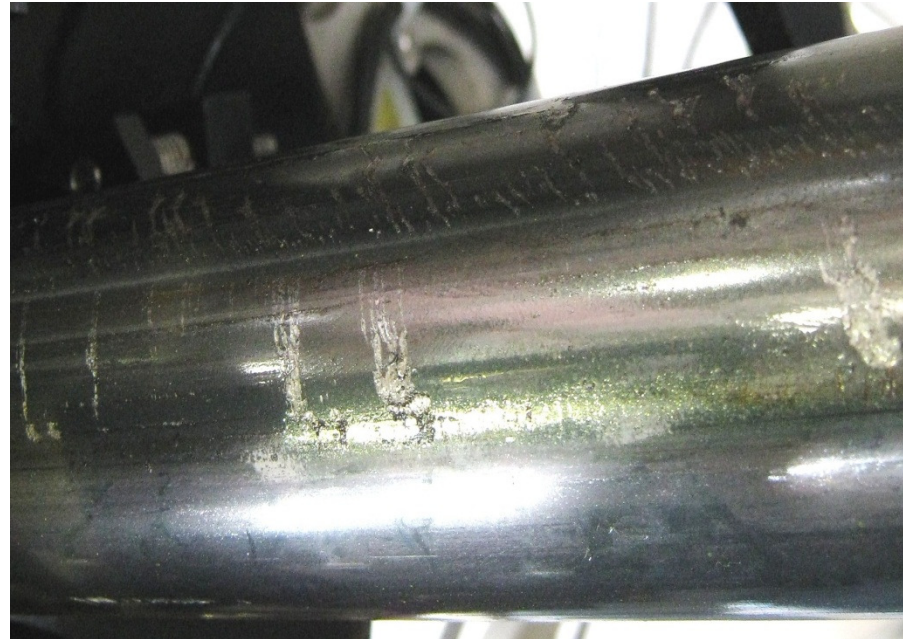
DOCUMENTATION

- 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.
 - Tensile and hardness test data.
 - All weld locations, measured from reference end.
 - Test pressure and duration 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.
 - Spool size and # of times spooled.
 - Certification of drying procedure.

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

TYPICAL FLAWS FOUND IN SR37

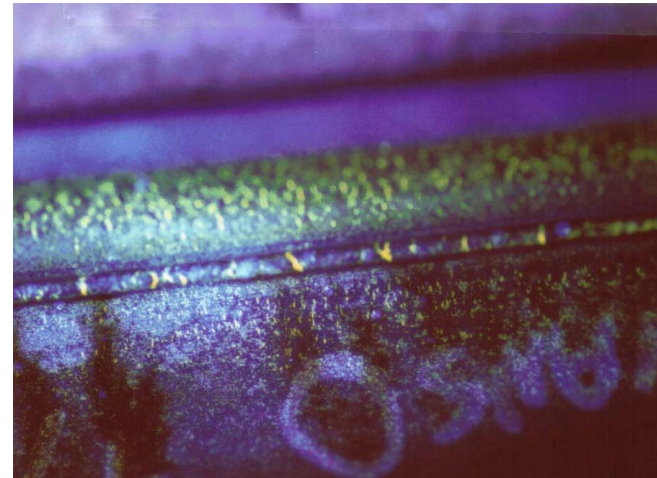
- OD chafing marks found in new tubing



MFL signal from one of the flaws

MAGNETIC PARTICLE & LIQUID PENETRANT

- 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 wall thickness after flaw as are repaired at mill.



API DOCUMENT CHANGES

- The need for coiled tubing standards was noted in 1992.
- API decided that it was too early to write a “Specification”, but approved the writing of a recommended practice.
- API RP 5C7 was the first “catch-all” (manufacturing, usage, corrosion, collapse) document published in 1996, & was reaffirmed by API RGCT twice.
- Now to be withdrawn as all text has been taken into 5ST, RP 16ST, RP 5C8.
- API RP 16ST published in 2009 to cover certain aspects of field use.

Recommended Practice for
Coiled Tubing Operations in
Oil and Gas Well Services

API RECOMMENDED PRACTICE 5C7
FIRST EDITION, DECEMBER 1996



SUMMARY

- You now have a national manufacturing STANDARD from which you can order CT.
- We document what exists today, and added some items.
- Grades outside of those listed are not API grades.
- Some restrictions occur for on lower grades.
- A re-inspection after the hydrotest has been added, and appears to be used for critical strings.
- The document will be reviewed by the RG for CT in 5 years.
- Publication of this document, along with RP 16ST and eventually RP 5C8 will allow RP 5C7 to be withdrawn.