API Ballot ID 4798
SC5 TGOCTG

Work Item	2360 – Stress Relief of Cold-worked Ends
Ballot Type (Initial, Comment-only, Reballot)	Initial Ballot for Vote & Comment
Standard	API 5CT (10th Edition as basis)
Key	Current in black text Deletions in stricken red text Additions in blue text

Work Item Charge: The ends of PE pipe require cold work (swage and expand) in preparation for some special end finish connections. For Q&T product, this cold work requires stress relief to restore the material properties to the pre-cold worked condition. The stress relief process needs to be precise to relieve the stress and not exceed the original final tempering temperature. The FTT reported per SR15 may not be the actual pipe body temperature, but the set furnace temperature, not knowing this could cause inadvertent re-tempering of the material during SR. The intent of this WI is to: 1) evaluate the industry stress relief capability and determine the best relationship between the reported FTT and the SR temperature; and 2) propose any necessary revisions to the standard to make the SR requirements clear.

Ballot Rationale: This WI was initiated back in 2008 to address the stress relief of cold worked (swaged & expanded) pipe ends prior to machining certain SF connections. The intent is to create an industry standard to determine the appropriate stress relief temperature, how that temperature is measured, the allowable temperature tolerances, and how the process is verified.

NOTE See the ballot email notification for additional information.

3 Terms, Definitions, Symbols and Abbreviations

3.1.30 nascent strain area
Area of pipe body near pipe end that may be heated during thermal recovery but has no (or limited) plastic deformation during the end swaging or expansion process.

3.1.44 end swaging or expansion
An ambient-temperature operation that plastically deforms pipe ends to adjust dimensions, reducing or increasing OD and potentially changing wall thickness in the deformed area to allow threading of pin or box connections. The level of cold plastic strain is sufficient to change the mechanical properties of the original material.

NOTE Includes end sizing or rounding for either SF or API 5B connections.

3.1.46 Thermal recovery (stress relieving)
Heat treatment process on pipe ends previously swaged or expanded; intended to relieve stresses and recover mechanical properties

NOTE Common industrial terminology may refer to thermal recovery as stress relieving.

4.1 Reference for Annexes

For additional requirements or information concerning the manufacturing of casing and tubing, as referenced, see the following.

- requirements for validation of end swaging or expansion and thermal recovery processes of pipe ends, see Annex Z (normative)

5.2.2 The purchaser shall also state in the purchase agreement …

Table 2 – Purchaser Supplied Agreement Optional Requirements (Casing)

Requirement	Reference
SSC test in strained area during production for Annex Z	Z.3.3

5.2.3 The following may be agreed between purchaser and manufacturer …

Table 3 – Purchase Manufacture Agreement (Casing)

Requirement	Reference
Methods and acceptance criteria for determining mechanical properties on deformed ends	Z.3.2 Z.3.3

5.3.2 The purchaser shall also state in the purchase agreement …

Table 5 – Purchaser Supplied Agreement Optional Requirements (Tubing)

Requirement	Reference
SSC test in strained area during production for Annex Z	Z.3.3

5.3.3 The following may be agreed between purchaser and manufacturer …

Table 6 – Purchase Manufacture Agreement (Tubing)

Requirement	Reference
Methods and acceptance criteria for determining mechanical properties on swaged or expanded ends	Z.3.2 Z.3.3

(1)

6.5 Process requiring validation

Final operations performed during product manufacturing that affect attribute compliance as required in this standard (except chemical composition and dimensions) shall have their processes validated.

Those processes requiring validation are:

- for seamless, as-rolled product: final reheating practice and hot sizing or stretch-reducing. If applicable, upsetting, cold-working, end swaging or expansion and subsequent thermal recovery;
- for seamless, heat-treated product: heat treatment. If applicable, end swaging or expansion and subsequent thermal recovery;
- for electric-welded, as-rolled product: sizing and seam welding. If applicable, seam heat treatment and upsetting, end swaging or expansion and subsequent thermal recovery; and
- for electric-welded, heat-treated product: seam welding and full-body, full-length heat treatment. If applicable, end swaging or expansion and subsequent thermal recovery.

8.12.6 Special End-finish

Pipe with end-finish not specified in this standard may be furnished if so specified in the purchase agreement. This pipe shall have the body of the pipe manufactured in accordance with the requirements of this standard. When threaded by the pipe mill or processor, the pipe shall be marked as specified in 11.5.2.

When pipe ends are subject to swaging or expansion as part of the threading process, with or without subsequent thermal recovery, the product shall conform to the requirements of Annex Z.

Annex Z
(normative)

Requirements for validation of end swaging or expansion and thermal recovery processes of pipe ends

Z.1 General

The process validation requirements in this annex pertain to the operations needed for special end-finishes as specified in 8.12.6. Special end-finish typically refers to proprietary threaded connections. The pipe ends shall be manufactured to meet the design requirements of the proprietary thread and this annex.

The thermal recovery process shall be validated if any of the following circumstances are true:

a) the manufacturer's process or procedures mandate validation;

b) the maximum compressive or tensile strain in the deformed area prior to recovery exceeds that previously validated by the manufacturer for the same grade;

c) for Grades C90, T95, C110, P110 and Q125, unless a prior validation has been undertaken for the same grade, size, pipe end deformation process and special end-finish geometry.

The manufacturer shall demonstrate that the manufacturing route selected is validated for the particular combination of size, weight, grade, special end-finish geometry, and maximum strain in the deformed area.

The manufacturer may demonstrate that the process for a particular combination is covered by other validations already available based on metallurgical and deformation equivalences. The manufacturer shall provide objective evidence that cases validated are the worst case for process design. Justification for extrapolation to other products or connection design shall be provided.

The manufacturer shall document the validation process and parameters, the procedures, the evaluation data, and the technical analysis conducted to demonstrate compliance with the requirements of this annex. This information shall be available upon request to the purchaser.

Temperature sticks or paints shall not be used for temperature measurement.

For the purpose of tensile test frequency, thermal recovery setup temperature does not need to meet the requirements of 10.4.1 when performed only on pipe ends.

In the case that the full length is subject to thermal recovery after end swaging or expansion, the process shall be considered as a new heat treatment.

Z.2 Test Specimens

Tensile test specimens shall conform to the requirements of 10.4.5, or when applicable, ISO 6892-1 or ASTM A370. All tensile specimens shall be the largest applicable round bar. Specimens with diameter below 8.9 mm (0.350 in.) are acceptable for comparison to determine if thermal recovery is acceptable.

Sub-size round bars have been demonstrated to incorrectly represent full wall thickness mechanical properties. Sub-size round bars should not be used to gauge conformance to specifications.

Tensile test specimen geometry shall be selected so that the gauge section incorporates the strained area and particularly the maximum strain area. In the case of round bar specimens, all specimens shall be of the same diameter.

Hardness test specimens shall be prepared as specified in Figure D.10.

Impact test shall consist of a set of three test specimens with the largest possible test specimen listed in Table C.8 or Table E.8 and the hierarchy of test specimen size and orientation in accordance with Tables C.9 or Table E.9.

For Grades C90, T95 and C110, sour service tests shall be performed on either NACE TM0177-2016 Method A and/or Method D specimens. When applicable, test specimen sizes, method, and acceptance criteria are in accordance with 7.14 and 10.10. When agreed between purchaser and manufacturer, sub-size test specimens not listed in NACE TM0177-2016 may be used.

By agreement between purchaser and manufacturer, when the deformed area is too small to allow machining a minimum test specimen, that specific requirement will not be verified.

Z.3 Process Validation Requirements

Z.3.1 Sample location

Test specimens for process validation shall be taken from a test pipe from the following sections, defined in Figure Z.1:

a) for tensile, hardness, impact tests, and SSC test (as applicable), section as close as possible to the area of maximum strain;

b) when thermal recovery is applied, section for tensile test from the area of nascent strain that is affected by the heating process;

c) for tensile and impact tests, section from the adjacent area of the mother pipe that is unaffected by deformation or heating.

Z.3.2 Test requirements for Grades H40, J55, K55, N80, L80, R95, P110 and Q125

Tensile tests shall be performed following 10.4.7 and 10.4.8.

Yield strength shall be determined using the 0.2 % offset method or other method agreed between purchaser and manufacturer.

Yield strength from the deformed and nascent strain areas shall not differ by more than 10% or 10 ksi, whichever is larger, from the properties of the unaffected area and shall meet the minimum yield strength requirement for the grade as specified in Table C.5 or Table E.5.

A 0.2 % offset shall be the acceptance criteria for this annex. In the case that reported EUL results do not meet the requirements in Table C.5 or Table E.5, 0.2 % offset results shall govern.

Hardness tests shall be performed in accordance with 10.6.10 and 10.6.11 and shall meet the maximum hardness requirement specified in Table C.5 or Table E.5 for the grade.

Impact tests shall be performed in accordance with 10.7.5 and 10.7.6 and shall meet the requirements for the pipe nominal wall and grade in accordance with Table C.19 or Table E.19. The average energy of the deformed area shall be greater than 75 % of the average energy of the unaffected area.

No retests shall be allowed. If these requirements are not met, the thermal recovery process parameters shall be modified.

Z.3.3 Test requirements for Grades C90, T95 and C110

Tensile tests shall be performed following 10.4.7 and 10.4.8.

Yield strength shall be determined using the 0.2 % offset method or other method agreed between purchaser and manufacturer.

Yield strength from the deformed and nascent strain areas shall not differ by the largest of 5 % or 5 ksi, from the properties of the unaffected area and shall meet the minimum yield strength requirement for the grade as specified in Table C.5 or Table E.5.

A 0.2% offset shall be the acceptance criteria for this annex. In the case that reported EUL results do not meet the requirements in Table C.5 or Table E.5, 0.2 % offset results shall govern.

Hardness tests shall be performed in accordance with 10.6.10 and 10.6.11 and shall meet the maximum hardness and allowable hardness variation requirements specified in Table C.5 or Table E.5 for the grade.

Impact tests shall be performed in accordance with 10.7.5 and 10.7.6 and shall meet the requirements for the pipe nominal wall and grade in accordance with Table C.19 or Table E.19. The average energy of the deformed area shall be greater than 75% of the average energy of the unaffected area.

Sulfide stress-cracking tests shall meet the minimum requirement specified in 7.14.5. If NACE TM0177-2016 Method D sub-size or alternative specimens are used, acceptance criteria shall be agreed between purchaser and manufacturer.

No retests shall be allowed. If these requirements are not met, the thermal recovery process parameters shall be modified.

Z.2.4 Documentation

Manufacturer shall document all test results.

Report shall identify the maximum level of deformation applied, the location of the temperature measurement instruments used, the recovery temperature setup, and the total exposure time.

Z.3 Control during Production

Z.3.1 Sample location

Test specimens for process control during production shall be taken from the following sections, defined in Figure Z.1:

a) section as close as possible to the area of maximum strain for tensile, hardness, impact tests and SSC test as applicable;

b) section from the adjacent area not affected by deformation or heating for tensile.

Test specimens shall be taken from a pipe end of the first and last lot processed during a production run without changes to the set points for controlled variables and no interruption of more than 24 hours.

If a test fails to meet the requirements, then all lengths produced since the last complete successful testing shall be rejected.

Z.3.2 Test requirements for Grades H40, J55, K55, N80, L80, R95, P110 and Q125 during production

Tensile tests shall be performed following 10.4.7 and 10.4.8.

Yield strength shall be determined using the 0.2 % offset method or other method agreed between purchaser and manufacturer.

A 0.2 % offset shall be the acceptance criteria for this annex. In the case that reported EUL results do not meet the requirements in Table C.5 or Table E.5, 0.2 % offset results shall govern.

The difference of yield strength between the deformed and the unaffected pipe body shall be less than or equal to 7.5 ksi, If the difference is greater than 7.5 ksi and less than or equal to 10 ksi, additional tests on the same pipe end or additional pipe ends representative of equipment start-up may be performed to determine that the product and the process are acceptable. All additional tests shall show a difference between affected areas and pipe body lower than 10ksi.

Yield strength of deformed area shall also meet the requirement of minimum yield strength for the grade as specified in Table C5 or Table E.5.

If any test result does not meet the specification, acceptance of the product and the process shall follow a procedure previously agreed between purchaser and manufacturer.

Hardness test shall be performed in accordance with 10.6.10 and 10.6.11 and shall meet the requirement for maximum hardness specified in Table C.5 or Table E.5 for the grade.

Impact tests shall be performed in accordance with 10.7.5 and 10.7.6 and shall meet the requirements for the pipe nominal wall and grade in accordance with Table C.19 or Table E.19. The average energy of the deformed area shall be greater than 75 % of the average energy of the unaffected area.

Retests for maximum hardness and absorbed energy may be performed in the same pipe end or additional pipe ends representatives of equipment start-up, when applicable.

Z.3.3 Test requirements for Grades C90, T95 and C110 during production

Tensile tests shall be performed following 10.4.7 and 10.4.8.

Yield strength shall be determined using the 0.2 % offset method or other method agreed between purchaser and manufacturer.

A 0.2 % offset shall be the acceptance criteria for this annex. In the case that reported EUL results do not meet the requirements in Table C.5 or Table E.5, 0.2 % offset results shall govern.

The difference of yield strength between the deformed and the unaffected pipe body shall be less than or equal to 5.0 ksi. If the difference is greater than 5.0 ksi and less than or equal to 10 ksi, additional tests on the same pipe end or additional pipe ends representative of equipment start-up may be performed to determine that the product and the process are acceptable. All additional tests shall show a difference between affected areas and pipe body lower than 10 ksi.

Yield strength of deformed area shall also meet the requirement of minimum yield strength for the grade as specified in Table C5 or Table E.5.

If any test result does not meet the specification, acceptance of the product and the process shall follow a procedure previously agreed between purchaser and manufacturer.

Hardness test shall be performed in accordance with 10.6.10 and 10.6.11 and shall meet the maximum hardness and allowable hardness variation requirements specified in Table C.5 or Table E.5 for the grade.

Impact tests shall be performed in accordance with 10.7.5 and 10.7.6 and shall meet the requirements for the pipe nominal wall and grade in accordance with Table C.19 or Table E.19. The average energy of the deformed area shall not be lower than 75 % of the average energy of the unaffected area.

Retests for maximum hardness and absorbed energy may be performed in the same pipe end or additional pipe ends representatives of equipment start-up, when applicable.

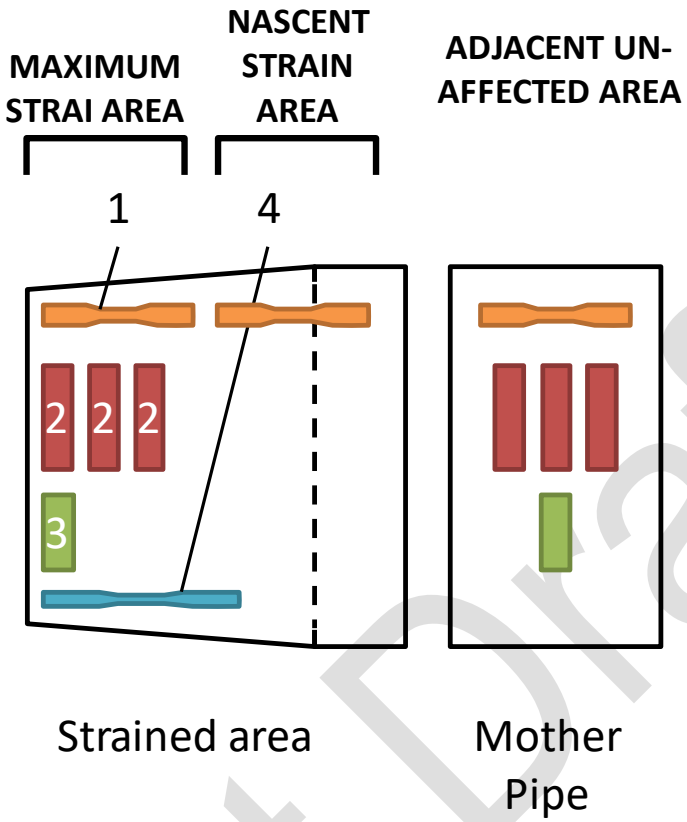
When specified in the purchase agreement, sulfide stress-cracking tests shall be performed. Tests shall meet the minimum requirement specified in 7.14.5. When NACE TM0177-2016 Method D sub-size or alternative specimens are used, acceptance criteria shall be agreed between purchaser and manufacturer.

Z.3.4 Thermal Recovery Process Control during Production

Temperature of pipe ends shall be controlled and recorded.

Manufacturer shall control the exit temperature consistent with the temperature and time parameters defined during validation of the process.

For temperature recording, the temperature shall be measured with a calibrated measuring device, e.g. optical pyrometer, hand held thermometer, contact pyrometer, thermocouple, or other device agreed between purchaser and manufacturer. Temperature sticks and paints shall not be used for recorded values but may be used for periodic temperature verification.



Key

1	tensile specimen
2	Impact test specimens
3	hardness test specimen
4	sulfide stress cracking specimen (method A or D)

Figure Z.1 – Example layout of test specimens for swaging and thermal recovery process validation