

Coiled Tubing

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Coiled Tubing

1 Scope

This specification covers the manufacturing, inspection, and testing of all carbon and low alloy steel coiled tubing in Grades CT70, CT80, CT90, CT100 and CT110, in the designations and wall thicknesses given in Table A.5, that can be used as work strings, completion strings, and static installations in oil and gas wells. Coiled tubing may be ordered to this specification.

Coiled tubing is manufactured using the continuously milled process. This specification does not cover the joining of seamless or welded tubing segments in lengths less than 200 ft (61 m).

Tubing of a higher grade is not be substituted for tubing ordered as a lower grade without purchaser approval.

In the dimensional tables herein, coiled tubing is designated by outside diameter, expressed to the thousandth of an inch (0.1 mm), with OD sizes ranging from 0.750 in. (19.1 mm) through 3 1/2 in. (88.9 mm).

Both U.S. Customary units and SI units are shown in this document. Annex H covers specific information about conversion factors and rounding procedures.

The suitability of the coiled tubular products made to this specification for use in environments containing hydrogen sulfide (H₂S) is outside of the scope of this document. It is the responsibility of the purchaser (and/or the user) of coiled tubing to determine the level of resistance to sour service damage mechanisms such as sulfide stress cracking necessary for the end use of the tubing.

2 References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Requirements of other standards included by reference in this specification are essential to the safety and interchangeability of the equipment produced.

Other nationally or internationally recognized standards shall be submitted to and approved by API for inclusion in this specification prior to their use as equivalent standards.

API Technical Report 5C3, *Technical Report on Equations and Calculations for Casing, Tubing, and Line Pipe used as Casing or Tubing; and Performance Properties Tables for Casing and Tubing*

API Specification 5LCP, *Specification for Coiled Line Pipe*

API Recommended Practice 5SI, *Recommended Practice for Purchaser Representative Surveillance and/or Inspection at the Supplier*

API Standard 5T1, *Imperfection Technology*

API Standard 1104, *Welding of Pipelines and Related Facilities*

ASME Boiler and Pressure Vessel Code ¹, Section IX, *Welding and Brazing Qualifications*

¹ ASME International, 3 Park Avenue, New York, New York 10016-5990, www.asme.org.

ASNT SNT-TC-1A ², *Personnel Qualification and Certification in Nondestructive Testing*

ASTM A370 ³, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

ASTM A450, *Standard Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes*

ASTM A751, *Standard Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products*

ASTM E4, *Standard Practices for Force Verification of Testing Machine*

ASTM E8, *Standard Test Methods for Tension Testing of Metallic Materials*

ASTM E18, *Standard Test Methods for Rockwell Hardness of Metallic Materials*

ASTM E23, *Standard Test Methods for Notched Bar Impact Testing of Metallic Materials*

ASTM E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

ASTM E44, *Standard Definitions of Terms Relating to Heat Treatment of Metals*

ASTM E83, *Standard Practice for Verification and Classification of Extensometer Systems*

ASTM E94, *Standard Guide for Radiographic Examination*

ASTM E112, *Standard Test Methods for Determining Average Grain Size*

ASTM E140, *Standard Hardness Conversion Table for Metals*

ASTM E164, *Standard Practice for Contact Ultrasonic Testing of Weldments*

ASTM E165, *Standard Practice for Liquid Penetrant Examination*

ASTM E213, *Standard Practice for Ultrasonic Testing of Metal Pipe and Tubing*

ASTM E273, *Standard Practice for Ultrasonic Examination of the Weld Zone of Welded Pipe and Tubing*

ASTM E309, *Standard Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation*

ASTM E384, *Standard Test Method for Microindentation Hardness of Materials*

ASTM E570, *Standard Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products*

ASTM E709, *Standard Guide for Magnetic Particle Testing*

ASTM E747, *Standard Practice for Design, Manufacture, and Material Grouping Classification for Wire Image Quality Indicators (IQIs) Used for Radiology*

ASTM E797, *Standard Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo Contact method*

² American Society for Nondestructive Testing, 1711 Arlingate Lane, P.O. Box 28518, Columbus, Ohio 43228, www.asnt.org.

³ ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

ASTM E1025, *Standard Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators Used for Radiology*

ASTM E1444, *Standard Practice for Magnetic Particle Testing*

ISO 1027⁴, *Radiographic image quality indicators for nondestructive testing—Principles and identification*

3 Definitions

For the purposes of this specification, the following definitions apply.

3.1

as milled condition

Tubing that has completed all milling operations but has not been placed on a reel.

3.2

Bauschinger effect

A phenomenon that occurs in polycrystalline metals, including steel, that results in a decrease in the yield strength in one direction due to plastic deformation in another direction, such as caused by service loads, coiling, or straightening.

3.3

calibration

The comparison of an instrument with, or the adjustment to, a known reference(s) often traceable to a national metrology lab or institute.

3.4

coiled tubing

Continuously milled carbon or alloy steel tubular product manufactured to this specification.

3.5

completion string

Tubing string placed within a well to serve as an exhaust or delivery duct for produced or injected fluids.

3.6

continuously milled tubing

Coiled tubing manufactured in milled lengths greater than 200 ft (61 m).

3.7

defect

An imperfection of sufficient magnitude to warrant rejection of the product, or a section of the product, based on the criteria defined in this specification.

3.8

dent

A local change in surface contour caused by a mechanical impact, but not accompanied by the loss of metal.

3.9

electrodischarge machine

EDM

A machine that removes of a controlled amount of material by electric spark erosion.

⁴ International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, www.iso.org.

3.10**grain size**

The dimensions of the grains or crystals in polycrystalline metal exclusive of twinned regions and subgrains when present.

NOTE: Grain size is usually estimated or measured on the cross-section of an aggregate of grains. Average size of grains in the metal usually expressed as an average diameter or grains per unit area or volume.

3.11**flash**

A thin fin or web of metal formed at the joining edges of a weld when a small portion of metal is extruded during the high frequency induction seam-forming process. A flash extends above the plane of the OD surface or the plane of the ID surface.

3.12**flash-in**

The condition in which the internal flash from the seam welding process is left inside the tubing.

3.13**gouge**

Elongated grooves or cavities caused by mechanical removal of metal.

3.14**heat-affected zone****HAZ**

The zone directly adjacent to the weld fusion zone in a longitudinal seam weld, circumferential tube-to-tube weld and skelp-end weld. The mechanical properties in the HAZ are affected by the heat produced during the welding process.

3.15**high frequency induction welding****HFI**

A welding process used to form a longitudinal seam along the length of the milled tube. As the edges of the skelp are passed through a high-frequency induction coil, the edges of the skelp are heated through the resistance to flow of current.

3.16**imperfection**

A discontinuity in the product wall or on the product surface that can be detected by the nondestructive evaluation (NDE) methods.

3.17**inclusion**

Particles of nonmetallic impurities, usually oxides, sulfides, and silicates that are mechanically held within steel after solidification.

3.18**killed steel**

Steel deoxidized with certain deoxidizing elements, such as aluminum, silicon, etc. The term "killed" is used because such additions cause the steel to lie quietly in the molds during solidification.

3.19**lamination**

An internal metal separation creating layers generally parallel to the surface.

3.20**linear imperfection**

Linear irregularities, which include, but are not limited to, seams, laps, cracks, cuts, and scores.

3.21**manufacturer**

A firm, company, or corporation responsible for making and marking the product in accordance with this specification. The manufacturer is responsible for compliance with all of the applicable provisions of this specification.

3.22**master coil**

The original wide coil of steel that is supplied by the steel manufacturer and is subsequently slit into several narrower coils of skelp of the appropriate width for the manufacture of coiled tubing.

3.23**mill stop**

An interruption in the normal production of the seam welding of a string.

3.24**milled length**

A single length of coiled tubing created during continuous operation of a mill.

NOTE: A milled length can include tubing manufactured from a number of coils of skelp. The lengths of skelp can have a single specified wall thickness, or can have various specified wall thicknesses. A milled length does not include tube-to-tube welds.

3.25**normalize**

A heat treatment of steel whereby the steel is heated to a temperature above the upper critical temperature to achieve transformation to austenite then allowed to cool in air to a temperature substantially below the lower critical temperature.

3.26**ovality**

Defined herein as $2(D_{\max} - D_{\min}) / (D_{\max} + D_{\min})$ where $D_{\max}$ and $D_{\min}$ are the measured diameters at a specific location along the tubing, and may be expressed as a percentage.

3.27**processes requiring validation**

Certain operations performed during skelp joining and tube manufacturing that affect attribute compliance required in this document (except chemistry and dimensions) shall have their processes validated.

a) Welded without filler metal:

Manufacturing Condition	Processes requiring validation
Heat treated tubing	Friction-stir weld Heat treatment of friction stir skelp-end weld Seam weld and full body heat treatment Nondestructive evaluation

b) Welded with filler metal (skelp-end weld and tube-to-tube weld, and fitting welds):

Manufacturing Condition	Processes requiring validation
Heat treated tubing	Skelp-end weld Heat treatment of skelp-end weld Tube-to-tube weld Heat treatment of tube-to-tube weld Fitting weld Heat treatment of fitting weld Nondestructive evaluation

3.28

product analysis

A chemical analysis taken from master coils, skelp, or finished tubular product.

3.29

reference end

The end of the coiled tubing that is intended to be connected to the service reel. This end is used in reporting measured footage for the location of the skelp-end and tube-to-tube welds within the coiled tubing string.

3.30

service reel

A cylindrical-shaped core drum, typically fabricated from steel and bounded by parallel flanges mounted transverse to the core, for use in storing and transporting coiled tubular products.

NOTE: The service reel is usually equipped with a self-contained hydraulic drive system to control rotation of the reel, an onboard hydraulic levelwind apparatus, and onboard high-pressure piping which connects to the coiled tubing through a high pressure rotating swivel. The diameters of the cylindrical core and boundary flanges will vary relative to the tube diameter and length to be spooled onto the reel.

3.31

service string

The construction of a specific length of coiled tubing for use in concentric well intervention operations.

3.32

shipping reel

A wooden or metal capstan-like device for transporting coiled tubing.

NOTE: Also referred to as a transport reel.

3.33

skelp

Flat steel rolled to specified tolerances and slit to the appropriate width for the manufacture of coiled tubing.

3.34

soft metric conversion

A soft conversion is a direct mathematical conversion from a U.S. measurement to its metric equivalent.

3.35**spool**

The total length of “as-manufactured” coiled tubing that is placed either on the service reel or shipping reel for storage and/or transport.

NOTE: The tubing in a spool of tubing can contain one or more tube-to-tube welds. Can be used interchangeably with string or the capstan reel.

3.36**spooling radius ratio**

The ratio of the diameter of the shipping reel core to the diameter of the coiled tube.

NOTE: This ratio is used in determining the minimum recommended bending radius for spooling coiled tubular products onto the reel.

3.37**standardization**

The adjustment of nondestructive test instruments to a known reference value.

3.38**stress relief**

Heat treatment to a suitable temperature to reduce residual stresses, followed by cooling sufficiently slowly to minimize the development of new residual stresses.

3.39**string**

The finished product manufactured at a coiled tubing facility.

NOTE: Used interchangeably with spool.

3.40**strip**

A single length of skelp, cut from a master coil.

3.41**tapered string**

A complex string of coiled tubing manufactured with a constant outside diameter and variable wall thickness within the length of the spooled tube.

EXAMPLE A tapered string can be constructed as follows:

- a) a continuously milled string incorporating single or multiple wall thickness segments joined using skelp-end welds, and
- b) continuously milled coiled tubing segments of single wall thickness joined to other finished tube segments of increasing/decreasing wall thickness using the tube-to-tube welding process.

NOTE The tapering may occur within the original strip segments that are used to fabricate the string.

3.42**undercut**

Undercuts in tube-to-tube welds are defined as the reduction of thickness of the tubing wall adjacent to the weld where it is fused to the surface of the tubing.

NOTE Undercutting on the outside surface can best be identified and measured visually. Undercutting on the inside surface can be identified using radiographic or ultrasonic means.

3.43**wall thickness (specified)**

In untapered string segments, the specified wall thickness is given in tables in this Specification. In continuous tapered sections of strings, the specified thickness is the average of at least four measurements of the local wall thickness, taken by a suitably calibrated wall thickness measuring device.

4 Information to be Supplied by the Purchaser**4.1 Mandatory Purchaser Requirements**

In placing orders for coiled steel tubing to be manufactured in accordance with API 5ST, the purchaser shall specify the following as applicable on the purchase agreement (see Note 1).

Information	Reference
Specification	API Specification 5ST
Grade	Tables A.1, A.2
Method for yield strength	6.2.1.3
Preliminary String Length Profile	7.2
Length(s)	7.2
Diameter	7.3, 7.4, Table A.5
Wall thickness(es)	7.4
Tubular Ends	7.8
Product Analysis	8.2.2
Drying procedure	8.4.6
Alternate Drift Ball Material	8.5.2
NDE Reference Indicators	10.8.2, 10.8.2.2
Certificate of compliance	15.2
Tensile retest	12.2
Documentation	15.2.1
Additional NDE	Annex D
Coiled Tubing Shipping Reels	Annex G
Delivery date and shipping instructions	

4.2 Optional Purchaser Requirements and Requirements Subject to Agreement

The purchaser should also state on the purchase agreement requirements concerning the following optional requirements. Requirements subject to agreement are shown with an asterisk (*).

Information	Reference
Chemical composition *	6.1
Additional Hardness Tests *	6.2.2
Fracture toughness tests	6.2.6
Final string length profile *	7.2.2
Ovality measurement	7.3.2
Minimum remaining wall thickness *	7.4.2.2
Tube-to-tube welds *	7.6, Annex B and Annex C
Trim of Inside Flash *	7.7.4
End finish and connection *	7.8
Tensile Test Sample Width *	8.3.1
Alternate Hydrostatic pressure *	8.4.4
Demonstration of NDE standard	10.2
Additional skelp end weld inspection *	10.5.2, 10.7
Additional tube-to-tube weld inspection *	10.5.4, 10.7
Alternate Image Quality Indicators (IQIs)*	10.6.2
NDE Reference Indicators *	10.8.2, 10.8.2.2
Grain size determination	9.4
Markings in SI units	13.1
External coatings	14.1, 14.2
Internal coatings	14.2.3
Documentation to be Supplied	15.2.2
Supplementary requirements *	Annex D
Purchaser inspection	Annex E
Shipping reel dimensions *	Annex G

NOTE 1 Nothing in this specification is to be interpreted as indicating a preference by the committee for any material or process or as indicating equality between the various materials or processes. In the selection of materials and processes, the purchaser must be guided by his experience and by the service for which the tubing is intended.

5 Processes of Manufacture and Material

5.1 General

The various grades of steel used to manufacture coiled tubing furnished to this specification shall be made to a fine grain practice. A fine grain practice refers to the use of elements to deoxidize or “kill” the liquid steel, which results in a finer prior austenitic grain size upon solidification.

Coiled tubing furnished to this specification shall be manufactured by the high frequency induction (HFI) or laser weld processes as defined in 5.2.1 and 5.2.2 respectively. Cold drawn tubular products without appropriate heat treatment are not permitted.

The welds described in 5.2 (skelp-end weld, electric weld, laser weld, tube-to-tube weld) shall not be repair-welded.

5.2 Types of Welds

5.2.1 Electric Weld

An electric weld is a longitudinal seam weld produced by the HFI welding process defined in 5.3.1.1.

5.2.2 Laser Weld

A laser weld is a longitudinal seam weld produced by the laser welding process defined in 5.3.1.2.

5.2.3 Skelp End Weld

A skelp end weld is a butt weld that joins skelp ends together. Skelp end welds shall be made in accordance with a qualified welding procedure.

5.2.4 Tube-to-tube Weld

A tube-to-tube weld is a circumferential butt weld that joins two pieces of tubing together (see Annexes B and C).

5.3 Welding Processes

5.3.1 Without Filler Metal

5.3.1.1 HFI Welding

A process of forming a seam by electric induction welding wherein the edges to be welded are mechanically pressed together and the heat for welding is generated by resistance to flow of high frequency electric current. The welder frequency is 100 kHz or higher.

5.3.1.2 Laser Welding

A process of forming a seam by laser welding wherein the edges to be welded are mechanically pressed together and the heat for welding is generated by conversion of laser light energy to heat.

5.3.1.3 Friction Stir Welding

A solid state joining process utilizing a non-consumable rotating tool that generates heat through friction and deformation and simultaneously mechanically mixes the softened metals to form the metallurgical bond.

5.3.2 With Filler Metal

5.3.2.1 Gas Metal Arc Welding

A welding process that produces coalescence of metals by heating them with an arc or arcs between a continuous consumable electrode and the work. Shielding is obtained entirely from an externally supplied gas or gas mixture. Pressure is not used, and the filler metal is obtained from the electrode.

5.3.2.2 Plasma Arc Welding

A welding process that produces coalescence of metals by heating them with a constricted arc between an electrode and the work, or the electrode and a nozzle. Shielding is obtained from the hot ionized gas issuing from the torch, which may be supplemented by an auxiliary source of shielding gas. Shielding gas may be an inert gas or a mixture of gases. Pressure may or may not be used.

5.3.2.3 Gas Tungsten Arc Welding

A welding process that produces coalescence of the metals by heating them with an arc between a single tungsten electrode and the work. Shielding is obtained from a gas. Pressure is not used, and a filler metal may or may not be used.

5.4 Heat Treatment

The product shall be heat treated in accordance with a documented procedure. For all grades, the weld seam and the entire heat-affected zone shall be heat treated so as to simulate a normalizing heat treatment (see Note) followed by full body stress relief and/or temper, except that by agreement between the purchaser and the manufacturer, alternative heat treatments or combinations of heat treatment and chemical composition may be substituted. Where such substitutions are made, the manufacturer shall demonstrate the effectiveness of the method selected using a procedure that is agreed between the purchaser and the manufacturer. This procedure may include, but is not necessarily limited to, hardness testing, microstructural evaluation, and mechanical testing.

NOTE During the manufacture of electric-welded tubing, the product is in motion through the surrounding air. Normalizing is usually defined as "cooling in still air", hence the phrase "to simulate a normalizing heat treatment" is used here.

5.5 Traceability

The manufacturer shall establish and follow procedures for maintaining heat and master-coil identity until all required heat and master-coil tests are performed and conformance with specification requirements has been shown.

6 Material Requirements

6.1 Chemical Requirements

For coiled tubing manufactured to this specification, all skelp segments manufactured within a continuously-milled string shall be of the same grade with the same nominal specified chemistry and mechanical properties.

The composition of tubing furnished to this specification shall conform to the chemical requirements given in Table A.1, except that other chemical compositions may be furnished by agreement between the purchaser and the manufacturer.

Niobium (columbium), vanadium, titanium, or combinations thereof may be used at the discretion of the manufacturer. For all grades, by agreement between the purchaser and the manufacturer, elements other than niobium (columbium) vanadium, and titanium may be used; however, caution should be exercised in determining the quantity that may be present for any particular size and thickness of tubing, because the addition of such otherwise desirable elements may alter the weldability of the tubing.

As a minimum, each required analysis shall include the determination of the following:

- a) carbon, manganese, phosphorus, sulfur, and silicon;
- b) chromium, molybdenum, niobium (columbium), vanadium, nickel, copper, titanium, and boron or combinations thereof, if added during steelmaking;
- c) any other alloying element added during steelmaking for a reason other than for deoxidation purposes.

6.2 Mechanical Properties

6.2.1 Tensile Properties

6.2.1.1 General

All coiled tubing grades shall conform to the tensile requirements given in Table A.2. Tensile tests to determine conformance shall be conducted on samples taken prior to any spooling. Retests may be performed on as-milled or spooled product unless otherwise specified on the purchase agreement.

6.2.1.2 Elongation

The minimum elongation in a 2 in. (50.8 mm) sample shall be determined by the following Equation (1).

$$e = kA^{0.2}/U^{0.9} \quad (1)$$

where

e is the minimum elongation in 2 in. (50.8 mm) in %, reported to the nearest 0.5 %;

A is the cross-sectional area of the tensile test specimen in in.² (mm²);

U is the specified minimum ultimate tensile strength, psi (MPa);

k is a constant, 625,000 (1900).

See Table A.3 for minimum elongation values for various size tensile specimens and grades. These values are based upon specified outside diameters and specified wall thicknesses.

6.2.1.3 Yield Strength

The yield strength shall be determined by the 0.2 % offset method or the 0.5 % extension under load method by agreement between the purchaser and the manufacturer. Elongation shall be recorded and reported. The report shall show the nominal width of the test specimen when strip specimens are used, or state when full section specimens are used.

NOTE Spooling and unspooling of coiled tubing can result in a reduction of the yield strength of approximately 5 % to 10 % due to the Bauschinger Effect. For this reason, tubing grade is based on tests conducted before the first spooling step in the manufacturing process. Retests may be performed on as-milled or spooled product unless otherwise specified on the purchase agreement.

6.2.2 Hardness Test

For each tensile specimen required, a microhardness survey specimen (ring or block) shall be removed from the product at the location of the tensile samples. The hardness survey specimen shall be prepared and tested in accordance with the requirements of 8.7.3, and 8.9.5. The hardness values shall comply with the requirements given in Table A.2.

Surface macrohardness shall also be measured on the surfaces of skelp-end and tube-to-tube welds. The hardness values shall comply with the requirements given in Table A.2.

By agreement, and when specified on the purchase agreement, additional macro- or microhardness tests shall be taken at specified locations.

6.2.3 Grain Size

For all grades, the grain size shall be ASTM grain size 8 or finer.

6.2.4 Flattening Test

All coiled tubing products that are produced to this specification shall comply with the flattening requirements shown in Table A.4.

The acceptance criteria for flattening tests are as follows. No cracks or breaks exceeding 0.125 in. (3.2 mm) in any direction in the weld or the parent metal shall occur on the outside surface until the distance between the plates is less than the value calculated by the equations given in Table 4. Cracks that originate at the edge of the specimen and are less than 0.25 in. (6.4 mm) long shall not be cause for rejection. The minimum test frequency for milled lengths of coiled tubing shall be at least one flattening test from each end of each continuously milled length.

6.2.5 Flaring Test

All grades of coiled tubing shall be subjected to a flaring test as specified in 8.3.3. The acceptable criterion is no cracking in the weld seam region or base metal up to a minimum ID expansion of ID_f (defined in 8.3.3).

6.2.6 Fracture Toughness Test

Fracture toughness testing for Charpy V-Notch energy is required where requested on the purchase order, considering the limitations imposed by diameter and thickness of the tubing ordered. Full size transverse (to the tube direction) specimens should be used when possible based upon pipe geometry per ASTM A370. When full size transverse specimens are not possible, the largest sub size specimens shall be used ($3/4$, $1/2$). When transverse specimens are not possible, $1/2$ size longitudinal specimens shall be used. The test specimens shall be oriented circumferentially from a location 90° from the weld with the axis of the notch oriented through the pipe wall. All tests shall be conducted at 32°F (0°C). The minimum absorbed energy requirements for full size specimens shall be 20 ft-lb (27 J) average, 15 ft-lb (20 J) minimum individual for full size transverse specimens, 30 ft-lb (41 J) average, 20 ft-lb (27 J) minimum individual for full size longitudinal specimens. The minimum absorbed energy reduction factors for sub-size specimens are: 0.8 for $3/4$ size, and 0.55 for $1/2$ size. By agreement between the purchaser and manufacturer, alternate tests may be used if the above requirements can not be met due to pipe geometry.

6.2.7 Metallographic Examination

A metallographic examination of a weld cross section shall be performed on both ends of each milled length.

The specimen shall be ground, polished, and etched in such a way that the microstructure of the base metal and weld zone can be investigated. In the case of "flash-in" tubing, the profile of the weld root shall show that it is continuous, with smooth curves blending into the inside diameter of the tubing.

7 Dimensions, Masses per Unit Length, Lengths, Defects, and End Finishes

7.1 General

Coiled tubing shall be furnished in the sizes, wall thicknesses, and masses shown in Table A.5 as specified on the purchase agreement. (See Table A.6 for the SI unit equivalents of the U.S. customary values given in Table A.5).

7.2 Length of Strings and Sections of Strings

7.2.1 General

The minimum and maximum length of the tubing shall be specified on the purchase agreement.

The accuracy of length measuring devices shall be equal to or less than 1 %.

7.2.2 Coiled Tubing String Length Profile

The preliminary length profile of a tapered coiled tubing string shall be specified by the purchaser following established criteria for the proposed service, and attached to the purchase agreement form. The final coiled tubing string length profile shall be by agreement between the purchaser and the manufacturer.

7.3 Diameter

7.3.1 Outside Diameter

The outside diameter shall be within the tolerances shown in Table A.7 for product in the as-milled condition. Diameter measurements of coiled tubing shall be made with a caliper that measures actual diameter across a single plane, with the diameter of record representing the average of the maximum and minimum diameter readings. Diameter measurements shall be made on both ends of each spooled length of coiled tubing on segments that have not been subjected to plastic deformation from spooling.

7.3.2 Ovality

When agreed upon between the manufacturer and the purchaser the ovality of the tubing shall be measured within 150 ft (45.7 m) of the ends, as installed on the reel. Ovality is defined as $2(D_{\max} - D_{\min}) / (D_{\max} + D_{\min})$ where $D_{\max}$ and $D_{\min}$ are the measured diameters at a specific location along the tubing, and may be expressed as a percentage.

7.4 Wall Thickness

7.4.1 Wall Thickness Changes between Skelp Segments

The changes in specified wall thickness (Δt) between the adjoining skelp segments shall not exceed the values specified as follows:

- a) 0.008 in. (0.2 mm) where the specified wall thickness of the thicker of the adjoining segments is less than 0.110 in. (2.8 mm);
- b) 0.011 in. (0.3 mm) where the specified wall thickness of the thicker of the adjoining segments is between 0.110 in. (2.8 mm) and 0.150 in. (3.8 mm);
- c) 0.020 in. (0.5 mm) where the specified wall thickness of the thicker of the adjoining segments is between 0.151 in. (3.8 mm) and 0.204 in. (5.2 mm);
- d) 0.031 in. (0.8 mm) where the specified wall thickness of the thicker of the adjoining segments is 0.205 in. (5.2 mm).

7.4.2 Wall Thickness Measurement

7.4.2.1 General

Both ends of each milled length of tubing shall be measured for conformance to the wall thickness requirements. The wall thickness at any location shall be within the tolerances specified in Table A.8, except that the seam weld

area shall not be limited by the plus tolerance. Wall thickness measurements shall be made with a mechanical device or with a properly calibrated nondestructive inspection device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical device shall govern.

7.4.2.2 Minimum Remaining Wall Thickness

The remaining wall at locations of complete imperfection removal shall be agreed between the manufacturer and the purchaser, and stated in the purchase agreement.

7.5 Mass per Unit Length

The mass per unit length, w_{pe} , shall be calculated in accordance with the following Equation (2).

$$w_{pe} = k(D - t)t \quad (2)$$

where

w_{pe} is the mass per unit length, rounded to the nearest 0.01 lb/ft (0.01 kg/m);

D is the specified outside diameter, in. (mm);

t is the specified wall thickness, in. (mm);

k is the constant 10.69 (USC) or 0.024 661 5 (SI).

7.6 Tube-to-tube Welds

By written agreement, and when specified on the purchase agreement, two or more lengths of the same grade of tubing may be welded together by the manufacturer. See Annex B.

7.7 Workmanship and Defects

7.7.1 General

Imperfections of the types described in 7.7.2 to 7.7.12 that exceed the specified criteria shall be considered defects.

7.7.2 Dents

The tubing shall contain no dents.

7.7.3 Offset Skelp Edges

The radial offset of the skelp edges of the longitudinal weld shall not exceed 0.010 in. (0.3 mm) or $0.05t$, whichever is greater.

7.7.4 Height of Outside Seam Weld Flash

The outside seam weld flash shall be trimmed to be flush with the tube outer surface.

7.7.5 Height of Inside Seam Weld Flash Column

7.7.5.1 Flash Height

The inside seam weld of "flash-in" tubing shall not extend above the prolongation of the original inside surface of the tubing more than 0.090 in. (2.3 mm), or the specified wall thickness, t , whichever is less.