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Should: As used in a standard, "should" denotes a recommendation or that which is advised but not required in order to conform to the specification.

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Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

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Introduction

This Standard is based on API Spec 5L, 44th Edition.

In the preparation of this document, the technical committee maintained the concept of two basic levels of standard technical requirements for line pipe expressed as two product specification levels (PSL 1 and PSL 2). Level PSL 1 provides a standard quality level for line pipe. Level PSL 2 has additional mandatory requirements for chemical composition, notch toughness and strength properties and additional NDT. Requirements that apply to only PSL 1 or to only PSL 2 are so designated. Requirements that are not designated to a specific PSL designation apply to both PSL 1 and PSL 2 pipe.

The technical committee also recognized that the petroleum and natural gas industry often specifies additional requirements for particular applications. In order to accommodate such needs, optional additional requirements for special applications are available, as follows:

- PSL 2 pipe ordered with a qualified manufacturing procedure (Annex B), the requirements of which have been enhanced to include verification detail of critical processes in the production of feedstock material, line pipe manufacture and product testing and inspection;
- PSL 2 pipe ordered with resistance to ductile fracture propagation in gas pipelines (Annex G);
- PSL 2 pipe ordered for sour service (Annex H);
- pipe ordered as "Through the Flowline" (TFL) pipe (Annex I);
- PSL 2 pipe ordered for offshore service (Annex J);

The following new annex is added to this Standard.

- Equations for threaded and coupled pipe and background equations for guided bend and CVN test (Annex P).

The requirements of the annex apply only when specified on the purchase order.

When pipe is ordered for dual or multiple applications, the requirements of more than one annex for special applications can be invoked. In such instances, if a technical conflict arises due to applying the requirements of more than one annex for special applications, the most stringent requirement applicable to the intended service shall apply.

This Standard does not provide guidance on when it is necessary to specify the above supplementary requirements. Instead, it is the responsibility of the purchaser to specify, based upon the intended use and design requirements, which, if any, of the supplementary requirements apply for a particular purchase order.

Consideration has been given to traditional symbols (denoting mechanical or physical properties or their values, dimensions or test parameters) and the format of equations that have been widely used and which (in their traditional format) maintain strong links with other widely used standards and specifications, and with the original scientific work that led to their derivation. Accordingly, some symbols and equations, most specifically those in 9.2 and Table F.1 and Annex P have been retained in their traditional form to avoid causing confusion. Where changes have been made, care has been taken to ensure that the new symbol replacing the traditional one has been fully and clearly defined.

Specification for Line Pipe

1 Scope

This Standard specifies requirements for the manufacture of two product specification levels (PSL 1 and PSL 2) of seamless and welded steel pipes for use in pipeline transportation systems in the petroleum and natural gas industries.

This Standard is not applicable to cast pipe.

2 Conformity

2.1 Units of measurement

In this Standard, data are expressed in both SI units and USC units. For a specific order item, only one system of units shall be used, without combining data expressed in the other system. Data values expressed in SI and USC units shall not be combined on the same inspection document or in the same required pipe marking sequence.

Where product is tested and verified against requirements using one measurement system (USC or SI), and an inspection document is issued, with data reported in the alternate measurement system units, a statement shall appear on the inspection document indicating that the data presented was converted from the measurement system used for the original inspection.

The purchaser shall specify whether data, drawings, and maintenance dimensions of pipes shall be in the International System (SI) or US Customary (USC) system of measurements. Use of an SI data sheet indicates the SI measurements shall be used. Use of a USC data sheet indicates the USC system of measurements shall be used.

For data expressed in SI units, a comma is used as the decimal separator and a space is used as the thousands separator. For data expressed in USC units, a dot (on the line) is used as the decimal separator and a space is used as the thousands separator.

2.2 Rounding

Unless otherwise stated in this Standard, to determine conformance with the specified requirements, observed or calculated values shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the limiting value, in accordance with ISO 80000-1:2009/Cor 1:2011, Annex B, Rule A.

NOTE For the purposes of this provision, the rounding method of ASTM E29-04 ^[1] is equivalent to ISO 80000-1:2009/Cor 1:2011, Annex B, Rule A.

2.3 Compliance to this Standard

A documented quality system shall be applied to assist compliance with the requirements of this Standard.

NOTE Documentation of a quality system does not require certification by a third party certification body. Only the creation or adoption of a written quality system is necessary to meet the requirement of this standard. API defers to the expertise of responsible quality management personnel to create or adopt the system which best reflects the need of each company. There are many existing quality management systems to which personnel can refer to for

guidance in the development of an appropriate quality system, including ISO/TS 29001^[2] and API Spec Q1^[3], which contain provisions specific to the oil and gas industry, or ISO 9001^[4], which contains general requirements for quality management systems that are auditable. This list is not exhaustive and is provided for information only.

A contract can specify that the manufacturer shall be responsible for complying with all of the applicable requirements of this Standard. It shall be permissible for the purchaser to make any investigation necessary in order to be assured of compliance by the manufacturer and to reject any material that does not comply.

3 Normative 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.

ISO 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

ISO 404, *Steel and steel products — General technical delivery requirements*

ISO 2566-1, *Steel — Conversion of elongation values — Part 1: Carbon and low alloy steels*

ISO 4885, *Ferrous products — Heat treatments — Vocabulary*

ISO 5173, *Destructive tests on welds in metallic materials — Bend tests — Third Edition*

ISO 6506 (all parts), *Metallic materials — Brinell hardness test*

ISO 6507 (all parts), *Metallic materials — Vickers hardness test*

ISO 6508 (all parts), *Metallic materials — Rockwell hardness test*

ISO 6892-1, *Metallic materials — Tensile testing - Part 1: Method of test at ambient temperature*

ISO 6929, *Steel products — Definitions and classification*

ISO 7438, *Metallic materials — Bend test*

ISO 7539-2, *Corrosion of metals and alloys — Stress corrosion testing — Part 2: Preparation and use of bent-beam specimens*

ISO 8491, *Metallic materials — Tube (in full section) — Bend test*

ISO 8492, *Metallic materials — Tube — Flattening test*

ISO 8501-1, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

ISO 9712, *Non-destructive testing — Qualification and certification of personnel*

ISO/TR 9769, *Steel and iron — Review of available methods of analysis*

ISO/TR 10400 (API TR 5C3), *Petroleum and natural gas industries — Equations and calculations for the properties of casing, tubing, drill pipe and line pipe used as casing or tubing*

ISO 10474:1991, *Steel and steel products — Inspection documents*

- ISO 10893-2, *Non-destructive testing of steel tubes — Part 2: Automated eddy current testing of seamless and welded (except submerged arc welded) steel tubes for the detection of imperfections.*
- ISO 10893-3, *Non-destructive testing of steel tubes — Part 3: Automated full peripheral flux leakage testing of seamless and welded (except submerged arc welded) ferromagnetic steel tubes for the detection of longitudinal and/or transverse imperfections.*
- ISO 10893-4, *Non-destructive testing of steel tubes — Part 4: Liquid penetrant inspection of seams of welded steel tubes for the detection of surface imperfections*
- ISO 10893-5, *Non-destructive testing of steel tubes — Part 5: Magnetic particle inspection of seamless and welded steel tubes for the detection of surface imperfections*
- ISO 10893-6, *Non-destructive testing of steel tubes — Part 6: Radiographic testing of the weld seam of welded steel tubes for the detection of imperfections*
- ISO 10893-7, *Non-destructive testing of steel tubes — Part 7: Digital radiographic testing of the weld seam of welded steel tubes for the detection of imperfections*
- ISO 10893-8, *Non-destructive testing of steel tubes — Part 8: Automated ultrasonic testing of seamless and welded steel tubes for the detection of laminar imperfections.*
- ISO 10893-9, *Non-destructive testing of steel tubes — Part 9: Automated ultrasonic testing for the detection of laminar imperfections in strip/plate used for manufacture of welded steel tubes*
- ISO 10893-10, *Non-destructive testing of steel tubes — Part 10: Automated full peripheral ultrasonic testing of seamless and welded (except submerged arc welded) steel tubes for the detection of longitudinal flash and/or transverse imperfections.*
- ISO 10893-11, *Non-destructive testing of steel tubes — Part 11: Automated ultrasonic testing of the weld seam of welded steel tubes for the detection of longitudinal and/or transverse imperfections*
- ISO 10893-12, *Non-destructive testing of steel tubes — Part 12: Automated full peripheral ultrasonic thickness testing of seamless and welded (except submerged arc welded) steel tubes*
- ISO 11484, *Steel products – Employer's qualification system for non-destructive testing (NDT) personnel*
- ISO 11699-1:2008, *Non-destructive testing — Industrial radiographic films — Part 1: Classification of film systems for industrial radiography*
- ISO 12135, *Metallic materials — Unified method of test for the determination of quasistatic fracture toughness*
- ISO 13678, *Petroleum and natural gas industries — Evaluation and testing of thread compounds for use with casing, tubing and line pipe*
- ISO 14284, *Steel and iron — Sampling and preparation of samples for the determination of chemical composition*
- ISO 19232-1:2004, *Non-destructive testing — Image quality of radiographs — Part 1: Image quality indicators (wire type) — Determination of image quality value*
- ISO 80000-1:2009/Cor 1:2011, *Quantities and units — Part 1: General*

API Spec 5B¹⁾, *Specification for Threading, Gauging, and Thread Inspection of Casing, Tubing, and Line Pipe Threads (US Customary Units)*

API RP 5A3, *Recommended Practice on Thread Compounds for Casing, Tubing, and Line Pipe*

API RP 5L3, *Recommended Practice for Conducting Drop-Weight Tear Tests on Line Pipe*

API TR 5T1, *Standard on Imperfection Terminology*

ASNT SNT-TC-1A²⁾, *Recommended Practice No. SNT-TC-1A — Non-Destructive Testing*

ASTM A370³⁾, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

ASTM A435, *Standard Specification for Straight-Beam Ultrasonic Examination of Steel Plates*

ASTM A578, *Standard Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications*

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

ASTM A941, *Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys*

ASTM A956, *Standard Test Method for Leeb Hardness Testing of Steel Products*

ASTM A1038, *Standard Practice for Portable Hardness Testing by the Ultrasonic Contact Impedance Method*

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

ASTM E94, *Standard Guide for Radiographic Examination*

ASTM E110, *Standard Test Method for Indentation Hardness of Metallic Materials by Portable Hardness Testers*

ASTM E114, *Standard Practice for Ultrasonic Pulse-Echo Straight-Beam Examination by the Contact Method*

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

ASTM E165, *Standard Test Method for Liquid Penetrant Examination*

ASTM E213, *Standard Practice for Ultrasonic Examination 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 Knoop and Vickers Hardness of Materials*

1) American Petroleum Institute, 1220 L Street, N.W., Washington, DC 20005, USA.

2) American Society for Nondestructive Testing, 1711 Arlingate Lane, Columbus, OH 43228-0518, USA.

3) ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA.

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

ASTM E587, *Standard Practice for Ultrasonic Angle-Beam Contact Testing*

ASTM E709, *Standard Guide for Magnetic Particle Examination*

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

ASTM E1290, *Standard Test Method for Crack-Tip Opening Displacement (CTOD) Fracture Toughness Measurement*

ASTM E1806, *Standard Practice for Sampling Steel and Iron for Determination of Chemical Composition*

ASTM E1815-08, *Standard Test Method for Classification of Film Systems for Industrial Radiography*

ASTM E2033, *Standard Practice for Computed Radiology (Photostimulable Luminescence Method)*

ASTM E2698, *Standard Practice for Radiological Examination Using Digital Detector Arrays*

ASTM G39, *Standard Practice for Preparation and Use of Bent-Beam Stress-Corrosion Test Specimens*

BS 7448-14⁴⁾, *Fracture mechanics toughness tests - Method for determination of K_{Ic} , critical CTOD and critical J values of metallic materials*

EN 10168⁵⁾, *Steel products — Inspection documents — List of information and description*

EN 10204:2004, *Metallic products — Types of inspection documents*

NACE TM0177:2005⁶⁾, *Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H_2S Environments*

NACE TM0284:2003, *Standard Test Method — Evaluation of Pipeline and Pressure Vessel Steels for Resistance to Hydrogen-Induced Cracking*

4 Terms and definitions

For the purpose of this document, the terms and definitions

- in ISO 6929 or ASTM A941 for steel products,
- in ISO 4885 or ASTM A941 for heat treatment,
- in API TR 5T1 for imperfection terminology,
- in, ISO 404, ISO 10474 or ASTM A370, whichever is applicable, for the types of sampling procedures, inspection and inspection documents,

except as given in 4.1 to 4.67, shall apply.

4) BSI, British Standards Institute, 389 Chiswick High Road, London, W4 4AL, United Kingdom.

5) CEN, European Committee for Standardization, Management Centre, Avenue Marnix 17, B-1000, Brussels, Belgium.

6) NACE International, P.O. Box 201009, Houston, Texas 77216-1009, USA.

4.1**as agreed**

requirement to be as agreed upon by the manufacturer and the purchaser, and specified in the purchase order

NOTE Associated, for example, with items covered by 7.2 a).

4.2**as-rolled**

delivery condition without any special rolling and/or heat-treatment

4.3**coil/plate end weld**

weld that joins coil or plate ends together

4.4**cold expanded pipe**

pipe that, while at ambient mill temperature, has received a permanent increase in outside diameter or circumference throughout its length, by internal hydrostatic pressure in closed dies or by an internal expanding mechanical device

4.5**cold-sized pipe**

pipe that, after forming (including sizing on EW), while at ambient mill temperature, has received a permanent increase in outside diameter or circumference for all or part of its length, or permanent decrease in outside diameter or circumference for all or part of its length

4.6**cold finishing**

cold-working operation (normally cold drawing) with a permanent strain greater than 1,5 %

NOTE The amount of permanent strain generally differentiates it from cold expansion and cold sizing.

4.7**cold forming**

process in which a strip or plate is formed into a pipe without heating

4.8**continuous welding****CW**

process of forming a seam by heating the strip in a furnace and mechanically pressing the formed edges together, wherein successive coils of strip had been joined together to provide a continuous flow of strip for the welding mill

4.9**COW pipe****combination welded pipe**

tubular product having one or two longitudinal seams or one helical seam, produced by a combination of gas metal-arc and submerged-arc welding wherein the gas-metal arc weld bead is not completely removed by the submerged-arc welding passes

4.10**COWH pipe****combination helical welded pipe**

tubular product having one helical seam produced by a combination of gas metal-arc and submerged-arc welding wherein the gas-metal arc weld bead is not completely removed by the submerged-arc welding passes

4.11**COWL pipe****combination longitudinal welded pipe**

tubular product having one or two longitudinal seams produced by a combination of gas metal-arc and submerged-arc welding wherein the gas-metal arc weld bead is not completely removed by the submerged-arc welding passes

4.12**COW seam****combination welding seam**

longitudinal or helical seam produced by a combination of gas metal-arc and submerged-arc welding wherein the gas-metal arc weld bead is not completely removed by the submerged-arc welding passes

4.13**CW pipe****continuous welded pipe**

tubular product having one longitudinal seam produced by continuous welding

4.14**daughter coil**

portion of steel removed via slitting, cutting or shearing from the mother coil which is used to produce one or more pieces of pipe

4.15**daughter plate**

portion of steel removed via slitting, cutting or shearing from the mother plate which is used to produce one or more pieces of pipe

4.16**defect**

imperfection of a size and/or population density greater than the acceptance criteria specified in this Standard

4.17**EW pipe****electric welded pipe**

tubular product having one longitudinal seam produced by low- or high-frequency electric-welding

4.18**EW seam****electric welded seam**

longitudinal seam produced by electric welding

4.19**electric welding****EW**

process of forming a seam by electric-resistance welding, wherein the edges to be welded are mechanically pressed together and the heat for welding is generated by the resistance to flow of electric current applied by induction or conduction

4.20**flux core arc welding**

welding process that produces melting and coalescence of metals by heating them with an arc between a continuous filler metal electrode and the work-piece, wherein the arc and molten metal are shielded by a flux contained within the tubular electrode

NOTE In some cases, additional shielding is obtained from an externally supplied gas or gas mixture.

4.21**gas metal-arc welding****GMAW**

welding process that produces melting and coalescence of metals by heating them with an arc or arcs between a continuous consumable electrode and the work, wherein the arc and molten metal are shielded by an externally supplied gas or gas mixture

NOTE Contact pressure is not used and the filler metal is obtained from the electrode.

4.22**heat**

the metal produced by a single cycle of a batch melting process

4.23**HFW pipe****high-frequency welded pipe**

EW pipe produced with a welding current frequency equal to or greater than 70 kHz

4.24**if agreed**

requirement to be as prescribed, or more stringent than is prescribed, if agreed upon by the manufacturer and the purchaser and specified in the purchase order

NOTE Associated, for example, with items covered by 7.2 c).

4.25**imperfection**

discontinuity or irregularity in the product wall or on the product surface that is detectable by inspection methods outlined in this Standard

4.26**indication**

evidence obtained by non-destructive inspection

4.27**informative elements**

elements that:

- a) identify the document, introduce its content and explain its background, development, and its relationship with other documents, or
- b) provide additional information intended to assist with the understanding or use of the document

NOTE See ISO/IEC Directives Part 2.

4.28**inspection**

activities, such as measuring, examining, testing, weighing or gauging one or more characteristics of a product, and comparing the results of such activities with the specified requirements in order to determine conformity

NOTE Adapted from ISO 404.

4.29**instrument standardization**

adjustment of a non-destructive inspection instrument to an arbitrary reference value

4.30**jointer**

two or three lengths of pipe coupled or welded together by the manufacturer

4.31**ladle refining**

a post steelmaking secondary process, performed prior to casting to improve the steel quality, of which some examples may include degassing, desulfurization and various methods for the removal of non-metallic inclusions and for inclusion shape control

4.32**lamination**

internal metal separation that creates layers, generally parallel to the pipe surface

4.33**laser welding****LW**

process of forming a seam by using a laser-beam keyhole welding technique to produce melting and coalescence of the edges to be welded, with or without preheating of the edges, wherein shielding is obtained from an externally supplied gas or gas mixture

4.34**low frequency electric welded pipe****LFW pipe**

EW pipe produced with a welding current frequency less than 70 kHz

4.35**LW pipe****laser welded pipe**

tubular product having one longitudinal seam produced by laser welding

4.36**manufacturer**

firm, company or corporation responsible for making and marking the product in accordance with the requirements of this Standard

NOTE 1 The manufacturer is, as applicable, a pipe mill, processor, maker of couplings or threader.

NOTE 2 Adapted from ISO 11961 [5].

4.37**mother coil**

hot-rolled coil of steel processed from a single reheated slab which is used to produce one or more pieces of pipe

4.38**mother plate**

hot-rolled plate of steel processed from a single reheated slab which is used to produce one or more pieces of pipe

4.39**non-destructive inspection****non-destructive testing****NDT**

inspection of pipe to reveal imperfections, using radiographic, ultrasonic or other methods specified in this Standard that do not involve disturbance, stressing or breaking of the materials

4.40**normalizing formed**

pipe delivery condition resulting from the forming process in which the final deformation is carried out within a certain temperature range, leading to a material condition equivalent to that obtained after normalizing, such that the specified mechanical properties would still be met in the event of any subsequent normalizing

4.41**normalizing rolled**

pipe delivery condition resulting from the rolling process in which the final deformation is carried out within a certain temperature range, leading to a material condition equivalent to that obtained after normalizing, such that the specified mechanical properties would still be met in the event of any subsequent normalizing

4.42**normative elements**

elements that describe the scope of the document, and which set out provisions that are required to implement the standard

NOTE See ISO/IEC Directives Part 2.

4.43**pipe body**

<SMLS pipe> the entire pipe

4.44**pipe body**

<welded pipe> the entire pipe, excluding the weld(s) and HAZ

4.45**pipe grade**

designation of pipe strength level

NOTE Chemical composition and/or heat treatment condition of a pipe grade may differ.

4.46**pipe mill**

firm, company or corporation that operates pipe-making facilities

NOTE Adapted from ISO 11960 [6].

4.47**processor**

firm, company or corporation that operates facilities capable of heat treating pipe made by a pipe mill

NOTE Adapted from ISO 11960 [6].

4.48**product analysis**

chemical analysis of the pipe, plate or coil

4.49**purchaser**

party responsible for both the definition of requirements for a product order and for payment of that order

4.50**quenching and tempering**

heat treatment consisting of quench hardening followed by tempering

4.51**sample**

quantity of material taken from the product to be tested for the purpose of producing one or more test pieces

4.52**SAW pipe****submerged-arc welded pipe**

tubular product having one or two longitudinal seams, or one helical seam, produced by the submerged-arc welding process

4.53**SAWH pipe****submerged-arc helical welded pipe**

tubular product having one helical seam produced by the submerged-arc welding process

4.54**SAWL pipe****submerged-arc longitudinal welded pipe**

tubular product having one or two longitudinal seams produced by submerged-arc welding

4.55**SAW seam****submerged-arc welding seam**

longitudinal or helical seam produced by submerged-arc welding

4.56**seamless pipe****SMLS pipe**

pipe without a welded seam, produced by a hot-forming process, which can be followed by cold sizing or cold finishing to produce the desired shape, dimensions and properties

4.57**service condition**

condition of use that is specified by the purchaser in the purchase order

NOTE In this Standard, the terms "sour service" and "offshore service" are service conditions.

4.58**shielded metal arc welding****SMAW**

welding process that produces melting and coalescence of metals by heating them with an arc between a covered metal electrode and the work, wherein the arc and molten metal are shielded by decomposition of the electrode covering

NOTE Contact pressure is not used and the decomposition is obtained from the electrode.

4.59**submerged-arc welding****SAW**

welding process that produces melting and coalescence of metals by heating them with an arc or arcs between a bare metal consumable electrode or electrodes and the work-piece, wherein the arc and molten metal are shielded by a blanket of granular flux

NOTE Contact pressure is not used and part or all of the filler metal is obtained from the electrodes.

4.60**tack weld**

intermittent or continuous seam weld used to maintain the alignment of the abutting edges until the final seam weld is produced

4.61**test piece**

part of a sample with specified dimensions, machined or un-machined, brought to a required condition for submission to a given test

4.62**test unit**

prescribed quantity of pipe that is made to the same specified outside diameter and specified wall thickness, from coils/plates produced by the same hot rolling practice (as applicable to welded pipe), from the same pipe-manufacturing process from the same heat and under the same pipe-manufacturing conditions

4.63**thermomechanical forming**

hot-forming process for manufacture of pipe, in which the final deformation is carried out in a certain temperature range, leading to a material condition with certain properties that cannot be achieved or repeated by heat treatment alone, and such deformation is followed by cooling, possibly with increased cooling rates, with or without tempering, self-tempering included

CAUTION — Subsequent heating above 580 °C (1 075 °F) typically can lower the strength values.

4.64**thermomechanical rolled**

pipe delivery condition resulting from the hot-rolling process for coil or plate, in which the final deformation is carried out in a certain temperature range, leading to a material condition with certain properties that cannot be achieved or repeated by heat treatment alone, and such deformation is followed by cooling, possibly with increased cooling rates, with or without tempering, self-tempering included

CAUTION — Subsequent heating above 580 °C (1 075 °F) typically can lower the strength values.

4.65**undercut**

groove melted into the parent metal adjacent to the weld toe and left unfilled by the deposited weld metal

4.66**unless otherwise agreed**

requirement that applies, unless an alternative requirement is agreed upon between the manufacturer and the purchaser and specified in the purchase order

NOTE Associated, for example, with items covered by 7.2 b) and 7.2 c).

4.67**welded pipe**

CW, COWH, COWL, EW, HFW, LFW, LW, SAWH or SAWL pipe

5 Symbols and abbreviated terms

5.1 Symbols

a	length of coil/plate end weld
A_f	elongation after fracture, expressed in percent and rounded to the nearest percent
A_{gb}	breadth diameter of guided-bend test mandrel/roll, expressed in millimetres (inches)
A_I	internal cross-sectional area of pipe, expressed in square millimetres (square inches)
A_P	cross-sectional area of pipe wall, expressed in square millimetres (square inches)
A_R	cross-sectional area of end-sealing ram, expressed in square millimetres (square inches)
A_{xc}	applicable tensile test piece cross-sectional area, expressed in square millimetres (square inches)
b	specified width of bearing face, expressed in millimetres (inches)
B	distance of the die walls or distance of the supports in the guided bend test, expressed in millimetres (inches)
C	constant, which is dependent upon the system of units used
CE_{IIW}	carbon equivalent, based upon the International Institute of Welding equation
CE_{Pcm}	carbon equivalent, based upon the chemical portion of the Ito-Bessyo carbon equivalent equation
d	calculated inside diameter of pipe, expressed in millimetres (inches)
D_a	manufacturer-designated outside diameter after sizing, expressed in millimetres (inches)
D_b	manufacturer-designated outside diameter before sizing, expressed in millimetres (inches)
D	specified outside diameter of pipe, expressed in millimetres (inches)
Δ	is the tangential dimension from the OD to the intersection of the exposed OD Charpy shoulder and the end of the specimen, expressed in millimetres (inches)
δ	is the machined depth from the OD to the Charpy surface at mid-specimen length, expressed in millimetres (inches)
f	frequency, expressed in Hertz (cycles per second)
K_V	full-size Charpy V-notch absorbed energy, expressed in Joules (foot-pounds force)
L	length of pipe, expressed in metres (feet)
N_L	specified minimum length, coupling dimension, expressed in millimetres (inches)
P	hydrostatic test pressure, expressed in megapascals (pounds per square inch)
P_R	internal pressure on end-sealing ram, expressed in megapascals (pounds per square inch)
Q	specified diameter of recess coupling dimension, expressed in millimetres (inches)
r	radius, expressed in millimetres (inches)
r_a	radius of the mandrel for the guided-bend test, expressed in millimetres (inches)

r_b	radius of the die for the guided-bend test, expressed in millimetres (inches)
r_o	pipe outside radius, expressed in millimetres (inches)
R_m	tensile strength, expressed in megapascals (pounds per square inch)
$R_{p0,2}$	yield strength (0,2 % non-proportional extension), expressed in megapascals (pounds per square inch)
$R_{t0,5}$	yield strength (0,5 % total extension), expressed in megapascals (pounds per square inch)
s_r	sizing ratio
S	hoop stress for the hydrostatic test, expressed in megapascal (pounds per square inch)
t	specified wall thickness of pipe, expressed in millimetres (inches)
t_{min}	minimum permissible wall thickness of pipe, expressed in millimetres (inches)
U	specified minimum tensile strength, expressed in megapascals (pounds per square inch)
V_t	transverse ultrasonic velocity, expressed in metres per second (feet per second)
W	specified outside diameter coupling dimension, expressed in millimetres (inches)
ϵ	strain
λ	wavelength, expressed in metres (feet)
ρ_l	mass per unit length of plain-end pipe, expressed in kilograms per metre (pounds per foot)
σ_h	design hoop stress for the pipeline, expressed in megapascals (pounds per square inch)

5.2 Abbreviated terms

COW	combination welding process for pipe during manufacturing
COWH	combination helical welding process for pipe during manufacturing
COWL	combination longitudinal welding process for pipe during manufacturing
CTOD	crack tip opening displacement
CVN	Charpy V-notch
CW	continuous welding process for pipe during manufacturing
DWT	drop-weight tear
EDI	electronic data interchange
EW	electric resistance or electric induction welding process for pipe during manufacturing
GMAW	gas metal-arc welding process
HAZ	heat-affected zone
HBW	Brinell hardness with Tungsten ball
HFW	high-frequency electric welding process for pipe during manufacturing
HIC	hydrogen-induced cracking
HRC	Rockwell hardness, C scale

HV	Vickers hardness
IQI	image quality indicator
LFW	low-frequency electric welding process for pipe during manufacturing
LW	laser welding process for pipe during manufacturing
MT	magnetic particle testing
NDT	non-destructive testing
PSL	product specification level
PT	penetrant testing
SAW	submerged-arc welding process for pipe during manufacture
SAWH	submerged-arc helical welding process for pipe during manufacture
SAWL	submerged-arc longitudinal welding process for pipe during manufacture
SMAW	shielded metal-arc welding for pipe during manufacture
SSC	sulfide stress cracking
SWC	step-wise cracking
TFL	through the flowline
USC	United States customary
UT	ultrasonic testing

6 Pipe grade, steel grade and delivery condition

6.1 Pipe grade and steel grade

6.1.1 The pipe grade for PSL 1 pipe is identical to the steel grade (designated by a steel name) and shall be as given in Table 1. It consists of an alpha or alphanumeric designation that identifies the strength level of the pipe and is linked to the chemical composition of the steel.

NOTE The designations for Grade A and Grade B do not contain any reference to the specified minimum yield strength; however, the numerical portion of other designations correspond with the specified minimum yield strength in SI units or with the upward-rounded specified minimum yield strength, expressed in 1 000 psi for USC units. The suffix "P" indicates that the steel has a specified phosphorus range.

6.1.2 The pipe grade for PSL 2 pipe shall be as given in Table 1 and consists of an alpha or alphanumeric designation that identifies the strength level of the pipe. The steel name (designating a steel grade), linked to the chemical composition of the steel, additionally includes a suffix that consists of a single letter (R, N, Q or M) that identifies the delivery condition (see Table 3).

NOTE 1 The designation for Grade B does not contain any reference to the specified minimum yield strength; however, the numerical portion of other designations correspond with the specified minimum yield strength in SI units or USC units.

NOTE 2 For sour service, see H.4.1.1.

NOTE 3 For offshore service, see J.4.1.1.

6.1.3 Other steel grade designations (steel numbers) that are used in addition to the steel name in Europe are given for guidance in Table L.1.

6.2 Delivery condition

6.2.1 For each order item, the delivery condition for PSL 1 pipes shall be at the option of the manufacturer unless a specific delivery condition is specified in the purchase order. Delivery conditions for PSL 1 and PSL 2 pipes are given in Table 1 with additional information for PSL 2 pipes in Table 3.

6.2.2 For PSL 2 pipes, the delivery condition shall be in accordance with the purchase order as specified in the steel name.

Table 1 — Pipe grades, steel grades and acceptable delivery conditions

PSL	Delivery condition	Pipe grade/steel grade ^{a,b}
PSL 1	As-rolled, normalizing rolled, normalized or normalizing formed	L175 or A25
		L175P or A25P
		L210 or A
	As-rolled, normalizing rolled, thermomechanical rolled, thermomechanical formed, normalizing formed, normalized, normalized and tempered; or, if agreed, quenched and tempered for SMLS pipe only	L245 or B
	As-rolled, normalizing rolled, thermomechanical rolled, thermomechanical formed, normalizing formed, normalized, normalized and tempered or quenched and tempered	L290 or X42
		L320 or X46
		L360 or X52
		L390 or X56
		L415 or X60
		L450 or X65
L485 or X70		
PSL 2	As-rolled	L245R or BR
		L290R or X42R
	Normalizing rolled, normalizing formed, normalized or normalized and tempered	L245N or BN
		L290N or X42N
		L320N or X46N
		L360N or X52N
		L390N or X56N
		L415N or X60N
	Quenched and tempered	L245Q or BQ
		L290Q or X42Q
		L320Q or X46Q
		L360Q or X52Q
		L390Q or X56Q
		L415Q or X60Q
		L450Q or X65Q
L485Q or X70Q		
L555Q or X80Q		
L625Q or X90Q ^c		
L690Q or X100Q ^c		

Table 1 — Pipe grades, steel grades and acceptable delivery conditions (continued)

PSL	Delivery condition	Pipe grade/steel grade ^{a,b}
PSL 2	Thermomechanical rolled or thermomechanical formed	L245M or BM
		L290M or X42M
		L320M or X46M
		L360M or X52M
		L390M or X56M
		L415M or X60M
	Thermomechanical rolled	L450M or X65M
		L485M or X70M
		L555M or X80M
		L625M or X90M
		L690M or X100M
		L830M or X120M

^a For intermediate grades, the steel grade shall be in one of the following formats: (1) The letter L followed by the specified minimum yield strength in MPa and, for PSL 2 pipe, the letter describing the delivery condition (R, N, Q or M) consistent with the above formats. (2) The letter X followed by a two or three digit number equal to the specified minimum yield strength in 1000 psi rounded down to the nearest integer and, for PSL 2 pipe, the letter describing the delivery condition (R, N, Q or M) consistent with the above formats.

^b The suffix (R, N, Q or M) for PSL 2 grades belongs to the steel grade.

^c Seamless only.

7 Information to be supplied by the purchaser

7.1 General information

The purchase order shall include the following information:

- a) quantity (e.g. total mass or total length of pipe);
- b) PSL (1 or 2);
- c) type of pipe (see Table 2);
- d) reference to API 5L;
- e) steel grade (see 6.1, H.4.1.1, or J.4.1.1, whichever is applicable);
- f) outside diameter and wall thickness (see 9.11.1.2);
- g) length and type of length (random or approximate) (see 9.11.1.3, 9.11.3.3 and Table 12);
- h) confirmation of applicability of individual annexes.

7.2 Additional information

The purchase order shall indicate which of the following provisions apply for the specific order item:

- a) Items that are subject to mandatory agreement, if applicable:
 - 1) pipe designation for intermediate grades [see Table 1, footnote a)],
 - 2) chemical composition for intermediate grades (see 9.2.1 and 9.2.2),
 - 3) chemical composition for pipe with $t > 25,0$ mm (0.984 in) (see 9.2.3),
 - 4) carbon equivalent limits for PSL 2 pipe in Grade L415N or X60N (see Table 5),
 - 5) carbon equivalent limits for PSL 2 pipe in Grade L555Q or X80Q, L625Q or X90Q, and L690Q or X100Q (see Table 5),
 - 6) carbon equivalent limits for PSL 2 SMLS pipe with $t > 20,0$ mm (0.787 in) [see Table 5, footnote a)],
 - 7) diameter and out-of-roundness tolerances for pipe with $D > 1\,422$ mm (56.000 in) (see Table 10),
 - 8) diameter and out-of-roundness tolerances for the ends of SMLS pipe with $t > 25,0$ mm (0.984 in) [see Table 10, footnote b)],
 - 9) standard applicable to jointer welds (see A.1.2);
- b) Items that apply as prescribed, unless otherwise agreed:
 - 1) range of sizing ratio for cold-expanded pipe (see 8.9.2),
 - 2) equation for sizing ratio (see 8.9.3),
 - 3) chemical composition limits for PSL 1 pipe [see Table 4, footnotes c), e) and f)],
 - 4) chemical composition limits for PSL 2 pipe [see Table 5, footnotes c), e), f), g), h), i), k), and l)],
 - 5) yield/tensile ratio for grades L625Q or X90Q, L690 or X100 and L830 or X120 [see Table 7, footnotes g and h or Table J.2, footnotes h and i],
 - 6) estimation and reporting of Charpy shear area (see 9.8.2.3),
 - 7) tolerances for random length pipe [see 9.11.3.3 a)],
 - 8) type of thread compound (see 9.12.2.4),
 - 9) type of end face (see 9.12.5.1 or 9.12.5.2),
 - 10) International Standard applicable to Charpy testing (see 10.2.3.3, 10.2.4.3, D.2.3.4.2 and D.2.3.4.3),
 - 11) product analysis method (see 10.2.4.1),
 - 12) alternate method for diameter measurement for $D \geq 508$ mm (20.000 in) (see 10.2.8.1),
 - 13) jointer welding type (see A.1.1),
 - 14) offset of longitudinal pipe weld seams at jointer welds (see A.2.4),
 - 15) repairs in cold-expanded pipe (see C.4.2),

- 16) alternate IQI type (see E.4.3.1);
- c) Items that apply, if agreed:
- 1) delivery condition (see 6.2 and Table 1),
 - 2) supply of quenched and tempered PSL 1 Grade L245 or B SMLS pipe (see Table 1),
 - 3) supply of intermediate grades [see Table 2, footnote a)],
 - 4) supply of double-seam SAWL pipe [see Table 2, footnote c)],
 - 5) alternative to specified seam heat treatment for PSL 1 pipe (see 8.8.1),
 - 6) supply of SAWH pipe with coil/plate end welds at the pipe ends (see 8.10.3),
 - 7) supply of jointers (see 8.11),
 - 8) CVN impact test temperature lower than 0 °C (32 °F) (see 9.8.2.1, 9.8.2.2 and 9.8.3),
 - 9) CVN impact test of the pipe body of PSL 2 welded pipe with $D < 508$ mm (20.000 in) for shear fracture area (see 9.8.2.2 and Table 18),
 - 10) CVN impact test of the longitudinal seam weld of PSL 2 HFW pipe (see 9.8.3 and Table 18),
 - 11) DWT test of the pipe body of PSL 2 welded pipe with $D \geq 508$ mm (20.000 in) (see 9.9.1 and Table 18),
 - 12) DWT test temperature lower than 0 °C (32 °F) (see 9.9.1),
 - 13) fraction jointers comprising 2 or 3 pieces for 12 m (40 ft) nominal or 24 m (80 ft) nominal, respectively [see 9.11.3.3.c), d), and e)],
 - 14) power-tight make-up of couplings (see 9.12.2.3 and 10.2.6.1),
 - 15) special bevel configuration (see 9.12.5.3),
 - 16) removal of outside weld bead at pipe ends of SAW or COW pipe [see 9.13.2.2 e)],
 - 17) weldability data or tests for PSL 2 pipe (see 9.15),
 - 18) type of inspection document for PSL 1 pipe (see 10.1.2.1),
 - 19) manufacturing information for PSL 1 pipe (see 10.1.2.2),
 - 20) alternative type of inspection document for PSL 2 pipe (see 10.1.3.1),
 - 21) use of transverse test pieces for tensile tests of SMLS pipe, not cold-expanded [see Table 20, footnote c)],
 - 22) use of the ring expansion test for transverse yield strength determinations [see 10.2.3.2, Table 19 note c), and Table 20 note d)],
 - 23) use of an alternative to macrographic examination (see 10.2.5.2),
 - 24) hardness test during production of EW and LW pipe (see 10.2.5.3),
 - 25) specific condition to be used for hydrostatic tests for threaded and coupled pipe (see 10.2.6.1),
 - 26) alternate hydrotest pressure (see Table 26),
 - 27) use of minimum permissible wall thickness to determine hydrostatic test pressure (see 10.2.6.7),

- 28) specific method to be used for determining pipe diameter (see 10.2.8.1),
- 29) use of inside diameter measurements to determine diameter and out-of-roundness for expanded pipe with $D \geq 219,1$ mm (8.625 in) and for non-expanded pipe [see 10.2.8.3 and Table 10, footnote c)],
- 30) specific method to be used for determining other pipe dimensions (see 10.2.8.7),
- 31) paint-stencilled markings for couplings (see 11.1.2),
- 32) additional markings specified by the purchaser (see 11.1.4),
- 33) specific surface or location for pipe markings [see 11.2.2 b) and 11.2.6 b)],
- 34) die-stamping or vibro-etching of pipe (see 11.2.3),
- 35) alternative location for marking the pipe (see 11.2.4),
- 36) alternative format for pipe length marking locations (see 11.2.6 a),
- 37) colour identification for pipe (see 11.2.7),
- 38) multiple grade marking (see 11.4.1),
- 39) temporary external coating (see 12.1.2),
- 40) special coating (see 12.1.3),
- 41) lining (see 12.1.4),
- 42) manufacturing procedure qualification for PSL 2 pipe, in which case Annex B shall apply (see B.2),
- 43) radiographic inspection of SAW seam or coil/plate end weld (see Table E.1),
- 44) non-destructive inspection of PSL 1 SMLS pipe (see E.3.1.2),
- 45) NDT of EW seam welds after hydrotest [see E.3.1.3 b)],
- 46) ultrasonic inspection of welded pipe for laminar imperfections at pipe ends (see E.3.2.3),
- 47) ultrasonic inspection of SMLS pipe for laminar imperfections at pipe ends (see E.3.3.2),
- 48) radiographic inspection in accordance with Clause E.4,
- 49) use of both holes and notches in ultrasonic reference standard (see Table E.7),
- 50) alternative re-inspection technique for COW seams (see E.5.5.5),
- 51) ultrasonic inspection for laminar imperfections in the pipe body of EW, SAW or COW pipe (see E.8),
- 52) ultrasonic inspection for laminar imperfections along the coil/plate edges or the weld seam of EW, SAW or COW pipe (see E.9),
- 53) supply of welded couplings on pipe with $D \geq 355,6$ mm (14.000 in) (see F.1.4),
- 54) application of Annex G to PSL 2 pipe where purchaser shall specify the toughness test temperature, the minimum energy for each test and the minimum average energy value required for the order (see G.2),
- 55) PSL 2 pipe for sour service, in which case, Annex H shall apply (see H.2),

- 56) TFL pipe, in which case Annex I shall apply (see I.2),
 57) pipe for offshore service, in which case Annex J shall apply (see J.2),
 58) any other additional or more stringent requirements.

8 Manufacturing

8.1 Process of manufacture

Pipe furnished to this Standard shall be manufactured in accordance with the applicable requirements and limitations given in Tables 2 and 3.

Table 2 — Acceptable processes of manufacture and product specification levels

Type of pipe or pipe end	PSL 1 pipe grade ^a					PSL 2 pipe grade ^a		
	L175 or A25 ^b	L175P or A25P ^b	L210 or A	L245 or B	L290 or X42 to L485 or X70	L245 or B to L555 or X80	> L555 or X80 to L690 or X100	>L690 or X100 to L830 or X120
Type of pipe								
SMLS	X	X	X	X	X	X	X	—
CW	X	X	—	—	—	—	—	—
LFW	X	—	X	X	X	—	—	—
HFW	X	—	X	X	X	X	—	—
LW	—	—	—	—	X	—	—	—
SAWL ^c	—	—	X	X	X	X	X	X
SAWH ^d	—	—	X	X	X	X	X	X
COWL ^c	—	—	X	X	X	X	—	—
COWH ^d	—	—	X	X	X	X	—	—
Type of pipe end								
Belled end ^e	X	—	X	X	X	—	—	—
Plain end	X	—	X	X	X	X	X	X
Plain end for special coupling	X	—	X	X	—	—	—	—
Threaded end ^f	X	X	X	X	—	—	—	—
^a Intermediate grades are available if agreed, but limited to grades higher than Grade L290 or X42. ^b Grades L175, L175P, A25 and A25P are limited to pipe with $D \leq 141,3$ mm (5.563 in). ^c Double-seam pipe is available if agreed, but limited to pipe with $D \geq 914$ mm (36.000 in). ^d Helical-seam pipe is limited to pipe with $D \geq 114,3$ mm (4.500 in). ^e Belled-end pipe is limited to pipe with $D \leq 219,1$ mm (8.625 in) and $t \leq 3,6$ mm (0.141 in). ^f Threaded-end pipe is limited to SMLS and longitudinal seam welded pipes with $D \leq 508$ mm (20.000 in).								

Table 3 — Acceptable manufacturing routes for PSL 2 pipe

Type of pipe	Starting material	Pipe forming	Pipe heat treatment	Delivery condition
SMLS	Ingot, bloom or billet	As-rolled	—	R
		Normalizing forming	—	N
		Hot forming	Normalizing	N
			Quenching and tempering	Q
		Hot forming and cold finishing	Normalizing	N
Hot forming and cold finishing	Quenching and tempering	Q		
HFW	Normalizing-rolled coil	Cold forming	Heat treating ^a of weld area only	N
	Thermomechanical-rolled coil	Cold forming	Heat treating ^a of weld area only	M
			Heat treating ^a of weld area and stress relieving of entire pipe	M
	As-rolled or thermomechanical-rolled coil	Cold forming	Normalizing	N
			Quenching and tempering	Q
		Cold forming followed by hot reducing under controlled temperature resulting in a normalized condition	—	N
Cold forming followed by thermomechanical forming of pipe		—	M	
SAW or COW pipe	Normalized or normalizing-rolled coil or plate	Cold forming	—	N
	As-rolled, thermomechanical-rolled, normalizing-rolled or normalized	Cold forming	Normalizing	N
	Thermomechanical-rolled coil or plate	Cold forming	—	M
	Quenched and tempered plate	Cold forming	—	Q
	As-rolled, thermomechanical-rolled, normalizing-rolled or normalized coil or plate	Cold forming	Quenching and tempering	Q
	As-rolled, thermomechanical-rolled, normalizing-rolled or normalized coil or plate	Normalizing forming	—	N

^a See 8.8 for applicable heat treatments.

8.2 Processes requiring validation

Final operations performed during pipe 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 the following:

- for seamless, as-rolled pipe: final reheating practice and hot sizing or stretch-reducing; if applicable, upsetting, cold finishing;
- for seamless, heat-treated pipe: heat treatment;
- for electric-welded, as-rolled pipe: sizing and seam welding; if applicable, seam heat treatment and upsetting;
- for electric-welded, heat-treated pipe: seam welding and full-body heat treatment;
- for SAW and COW pipe, non expanded: pipe forming, seam welding, repair welding; if applicable, heat treatment;
- for SAW and COW pipe, expanded: pipe forming, seam welding, repair welding, expansion;

8.3 Starting material

8.3.1 The supplying steel and rolling mill(s) shall have a documented quality management system.

NOTE Documentation of a quality system does not require certification by a third party certification body. Only the creation or adoption of a written quality system is necessary to meet the requirement of this standard, API defers to the expertise of responsible quality management personnel to create or adopt the system which best reflects the need of each company. There are many existing quality management systems to which personnel can refer for guidance in the development of an appropriate quality system, including ISO/TS 29001 and API Spec Q1, which contain provisions specific to the oil and gas industry, or ISO 9001, which contains general requirements for quality management systems that are auditable. This list is not exhaustive and is provided for information only.

8.3.2 The ingots, blooms, billets, coils or plates used as starting material for the manufacture of pipe shall be made from steel made by the

- basic oxygen process,
- electric-furnace process, or
- open hearth process only in combination with a ladle refining process.

8.3.3 For PSL 2 pipe, the steel shall be killed and made according to fine grain practice.

8.3.4 The coil or plate used for the manufacture of PSL 2 pipe shall not contain any repair welds.

8.3.5 The width of the coil or plate used for the manufacture of helical seam pipe shall not be less than 0,8 times or more than 3,0 times the specified outside diameter of the pipe.

8.3.6 Any lubricant that contaminates the weld bevel or the surrounding areas shall be removed before making the longitudinal seam welds of SAWL or COWL pipes or the helical seam welds of SAWH or COWH pipes.

8.3.7 For welded pipe with delivery condition M, critical variables of the coil/plate rolling practice (e.g. reheating, rolling and cooling temperatures, times and tolerances) shall be defined and controlled to ensure the mechanical properties throughout the pipe are suitably uniform considering:

- coil/plate characteristics and variability;
- sensitivity of properties to rolling practice;
- appropriate coil/plate cropping distances;
- tensile property changes inherent in pipe forming.

The permissible ranges of critical variables for coil/plate rolling practice shall be documented.

8.3.8 For welded pipe with delivery condition M, the ability of the coil/plate rolling practice to achieve planned results consistent with 8.3.7 shall be verified as follows.

- Representative coil/plate and pipe manufacturing trials or historical data of coil/plate and/or pipe properties and processing conditions that demonstrate, within the ranges permitted by documented limits of the rolling practice, the consistent achievement of required pipe properties.
- For grades higher than L360M or X52M, the pipe manufacturer shall conduct or shall have previously conducted an on-site technical audit of the coil/plate mill and periodic on-site or remote confirmation that the coil/plate rolling practice continues to achieve the planned results. Coil/plate rolling practice validation criteria shall be verified as part of the audit.

8.3.9 Hot rolling practice process deviations from the manufacturer's documented limits shall be qualified through documented practices either in the hot rolled material by mechanical testing to defined limits and/or in the pipe form by designating that material as a new test unit.

8.4 Tack welds

8.4.1 Tack welds shall be made by

- a) semi-automatic submerged-arc welding,
- b) electric welding,
- c) gas metal-arc welding,
- d) flux-cored arc welding,
- e) shielded metal-arc welding using a low hydrogen electrode, or
- f) laser welding.

8.4.2 Tack welds shall be

- a) melted and coalesced into the final weld seam,
- b) removed by machining, or
- c) treated in accordance with Clause C.2.

8.5 Weld seams in COW pipe

For the production of weld seams in COW pipe, the first pass shall be continuous and made by gas-metal arc welding followed by submerged-arc welding, with at least one submerged-arc welding pass made on the inside of the pipe and at least one submerged-arc welding pass made on the outside of the pipe, wherein the gas-metal arc weld bead is not completely removed by the submerged-arc welding passes.

8.6 Weld seams in SAW pipe

For the production of weld seams in SAW pipe, at least one submerged-arc welding pass shall be made on the inside of the pipe and at least one submerged-arc welding pass shall be made on the outside of the pipe.

8.7 Weld seams in double-seam pipe

The seams of double-seam pipe shall be approximately 180° apart.

8.8 Treatment of weld seams in EW and LW pipes

8.8.1 PSL 1 EW pipe

For grades higher than Grade L290 or X42, the weld seam and the HAZ shall be heat treated so as to simulate a normalizing heat treatment, except that, if agreed, alternative heat treatments may be substituted. If such substitutions are made, the manufacturer shall demonstrate the effectiveness of the method selected using an agreed procedure. Such a procedure may include, but is not necessarily limited to, hardness testing, microstructural evaluation or mechanical testing.

For grades equal to or lower than Grade L290 or X42, the weld seam shall be heat treated so as to simulate a normalizing heat treatment, or the pipe shall be processed in such a manner that no untempered martensite remains.

8.8.2 LW pipe and PSL 2 HFW pipe

For all grades, the weld seam and the entire HAZ shall be heat treated so as to simulate a normalizing heat treatment.

8.9 Cold sizing and cold expansion

8.9.1 Except as allowed by 8.9.2, the sizing ratio for cold-sized pipe shall not be more than 0,015, unless

- a) the pipe is subsequently normalized or quenched and tempered, or
- b) the entire part of the pipe that is cold sized is subsequently stress relieved.

8.9.2 Unless otherwise agreed, the sizing ratio for cold-expanded pipe shall not be less than 0,003 or more than 0,015.

8.9.3 Unless otherwise agreed, the sizing ratio, s_r , shall be derived using Equation (1):

$$s_r = \frac{|D_a - D_b|}{D_b} \quad (1)$$

where

D_a is the manufacturer-designated outside diameter after sizing, expressed in millimetres (inches);

D_b is the manufacturer-designated outside diameter before sizing, expressed in millimetres (inches);

$|D_a - D_b|$ is the absolute value of the outside diameter difference, expressed in millimetres (inches).

8.10 Coil/plate end welds

8.10.1 Coil/plate end welds shall not be present in finished longitudinal seam pipe.

8.10.2 For finished helical seam pipe, junctions of coil/plate end welds and helical-seam welds shall be at least 300 mm (12.0 in) from the pipe ends.

8.10.3 If agreed, coil/plate end welds in helical-seam pipe may be present at the pipe ends, provided that there is a circumferential separation of at least 150 mm (6.0 in) between the coil/plate end weld and the helical seam at the applicable pipe ends.

8.10.4 Coil/plate end welds in finished helical seam pipe shall have been

- a) made by submerged-arc welding or a combination of submerged-arc welding and gas metal-arc welding,
- b) inspected to the same acceptance criteria as specified for the helical-seam weld.

8.11 Jointers

8.11.1 Jointers may be furnished if agreed.

8.11.2 Welded jointers shall be made in accordance with the requirements of Annex A.

8.11.3 No pipe used in making a jointer shall be less than 1,5 m (5.0 ft) long.

8.11.4 Portions of pipe used in the making of jointers shall have passed inspection, including hydrostatic testing. Alternatively the completed jointer may be hydrostatically tested.

8.12 Heat treatment

Heat treatments shall be performed in accordance with documented procedures.

8.13 Traceability

8.13.1 For PSL 1 pipe, the manufacturer shall establish and follow documented procedures for maintaining

- a) the heat identity until all related chemical tests are performed and conformance with the specified requirements is shown,

- b) the test-unit identity until all related mechanical tests are performed and conformance with the specified requirements is shown.

8.13.2 For PSL 2 pipe, the manufacturer shall establish and follow documented procedures for maintaining the heat identity and the test-unit identity for all such pipe. Such procedures shall provide means for tracing any length of pipe to the proper test unit and the related chemical and mechanical test results.

9 Acceptance criteria

9.1 General

9.1.1 The general technical delivery requirements shall be in accordance with ISO 404.

9.1.2 Pipe manufactured as Grade L415 or X60 or higher shall not be substituted for pipe ordered as Grade L360 or X52 or a lower grade, without the purchaser's approval.

9.2 Chemical composition

9.2.1 For PSL 1 pipe with $t \leq 25,0$ mm (0.984 in), the chemical composition for standard grades shall be as given in Table 4, and the chemical composition for intermediate grades shall be as agreed, but consistent with those given in Table 4.

NOTE Grade L175P or A25P is re-phosphorized and, therefore, has better threading properties than Grade L175 or A25; however, it can be somewhat more difficult to bend.

9.2.2 For PSL 2 pipe with $t \leq 25,0$ mm (0.984 in), the chemical composition for standard grades shall be as given in Table 5 and the chemical composition for intermediate grades shall be as agreed, but consistent with those given in Table 5.

9.2.3 For PSL 1 or PSL 2 pipe with $t > 25,0$ mm (0.984 in), the chemical composition shall be agreed, with the requirements of Tables 4 and 5 being amended as appropriate.

9.2.4 For PSL 2 pipe with a product analysis carbon mass fraction equal to or less than 0,12 %, the carbon equivalent, CE_{Pcm} , shall be determined using Equation (2):

$$CE_{Pcm} = C + \frac{Si}{30} + \frac{Mn}{20} + \frac{Cu}{20} + \frac{Ni}{60} + \frac{Cr}{20} + \frac{Mo}{15} + \frac{V}{10} + 5B \quad (2)$$

where the symbols for the chemical elements represent the mass fraction in percent (see Table 5).

If the heat analysis for boron is less than 0,000 5 %, then it is not necessary for the product analysis to include boron, and the boron content may be considered to be zero for the CE_{Pcm} calculation.

9.2.5 For PSL 2 pipe with a product analysis carbon mass fraction greater than 0,12 %, the carbon equivalent, CE_{IIW} , shall be determined using Equation (3):

$$CE_{IIW} = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Ni + Cu)}{15} \quad (3)$$

where the symbols for the chemical elements represent the mass fraction in percent (see Table 5).

Table 4 — Chemical composition for PSL 1 pipe with $t \leq 25,0$ mm (0.984 in)

Steel grade (Steel name)	Mass fraction, based upon heat and product analyses ^{a, g}							
	C max. ^b	Mn max. ^b	P %		S max.	V max.	Nb max.	Ti max.
			min.	max.				
Seamless pipe								
L175 or A25	0,21	0,60	—	0,030	0,030	—	—	—
L175P or A25P	0,21	0,60	0,045	0,080	0,030	—	—	—
L210 or A	0,22	0,90	—	0,030	0,030	—	—	—
L245 or B	0,28	1,20	—	0,030	0,030	c,d	c,d	d
L290 or X42	0,28	1,30	—	0,030	0,030	d	d	d
L320 or X46	0,28	1,40	—	0,030	0,030	d	d	d
L360 or X52	0,28	1,40	—	0,030	0,030	d	d	d
L390 or X56	0,28	1,40	—	0,030	0,030	d	d	d
L415 or X60	0,28 ^e	1,40 ^e	—	0,030	0,030	f	f	f
L450 or X65	0,28 ^e	1,40 ^e	—	0,030	0,030	f	f	f
L485 or X70	0,28 ^e	1,40 ^e	—	0,030	0,030	f	f	f
Welded pipe								
L175 or A25	0,21	0,60	—	0,030	0,030	—	—	—
L175P or A25P	0,21	0,60	0,045	0,080	0,030	—	—	—
L210 or A	0,22	0,90	—	0,030	0,030	—	—	—
L245 or B	0,26	1,20	—	0,030	0,030	c,d	c,d	d
L290 or X42	0,26	1,30	—	0,030	0,030	d	d	d
L320 or X46	0,26	1,40	—	0,030	0,030	d	d	d
L360 or X52	0,26	1,40	—	0,030	0,030	d	d	d
L390 or X56	0,26	1,40	—	0,030	0,030	d	d	d
L415 or X60	0,26 ^e	1,40 ^e	—	0,030	0,030	f	f	f
L450 or X65	0,26 ^e	1,45 ^e	—	0,030	0,030	f	f	f
L485 or X70	0,26 ^e	1,65 ^e	—	0,030	0,030	f	f	f
<p>^a Cu \leq 0,50 %; Ni \leq 0,50 %; Cr \leq 0,50 % and Mo \leq 0,15 %</p> <p>^b For each reduction of 0,01 % below the specified maximum concentration for carbon, an increase of 0,05 % above the specified maximum concentration for Mn is permissible, up to a maximum of 1,65 % for grades \geq L245 or B, but \leq L360 or X52; up to a maximum of 1,75 % for grades $>$ L360 or X52, but $<$ L485 or X70; and up to a maximum of 2,00 % for grade L485 or X70.</p> <p>^c Unless otherwise agreed, Nb + V \leq 0,06 %.</p> <p>^d Nb + V + Ti \leq 0,15 %.</p> <p>^e Unless otherwise agreed.</p> <p>^f Unless otherwise agreed, Nb + V + Ti \leq 0,15 %.</p> <p>^g No deliberate addition of B is permitted and the residual B \leq 0,001 %.</p>								

Table 5 — Chemical composition for PSL 2 pipe with $t \leq 25,0$ mm (0.984 in)

Steel grade (Steel name)	Mass fraction, based upon heat and product analyses % maximum									Carbon equivalent ^a % maximum	
	C ^b	Si	Mn ^b	P	S	V	Nb	Ti	Other	CE _{IW}	CE _{Pcm}
Seamless and welded pipes											
L245R or BR	0,24	0,40	1,20	0,025	0,015	c	c	0,04	e,l	0,43	0,25
L290R or X42R	0,24	0,40	1,20	0,025	0,015	0,06	0,05	0,04	e,l	0,43	0,25
L245N or BN	0,24	0,40	1,20	0,025	0,015	c	c	0,04	e,l	0,43	0,25
L290N or X42N	0,24	0,40	1,20	0,025	0,015	0,06	0,05	0,04	e,l	0,43	0,25
L320N or X46N	0,24	0,40	1,40	0,025	0,015	0,07	0,05	0,04	d,e,l	0,43	0,25
L360N or X52N	0,24	0,45	1,40	0,025	0,015	0,10	0,05	0,04	d,e,l	0,43	0,25
L390N or X56N	0,24	0,45	1,40	0,025	0,015	0,10 ^f	0,05	0,04	d,e,l	0,43	0,25
L415N or X60N	0,24 ^f	0,45 ^f	1,40 ^f	0,025	0,015	0,10 ^f	0,05 ^f	0,04 ^f	g,h,l	as agreed	
L245Q or BQ	0,18	0,45	1,40	0,025	0,015	0,05	0,05	0,04	e,l	0,43	0,25
L290Q or X42Q	0,18	0,45	1,40	0,025	0,015	0,05	0,05	0,04	e,l	0,43	0,25
L320Q or X46Q	0,18	0,45	1,40	0,025	0,015	0,05	0,05	0,04	e,l	0,43	0,25
L360Q or X52Q	0,18	0,45	1,50	0,025	0,015	0,05	0,05	0,04	e,l	0,43	0,25
L390Q or X56Q	0,18	0,45	1,50	0,025	0,015	0,07	0,05	0,04	d,e,l	0,43	0,25
L415Q or X60Q	0,18 ^f	0,45 ^f	1,70 ^f	0,025	0,015	g	g	g	h,l	0,43	0,25
L450Q or X65Q	0,18 ^f	0,45 ^f	1,70 ^f	0,025	0,015	g	g	g	h,l	0,43	0,25
L485Q or X70Q	0,18 ^f	0,45 ^f	1,80 ^f	0,025	0,015	g	g	g	h,l	0,43	0,25
L555Q or X80Q	0,18 ^f	0,45 ^f	1,90 ^f	0,025	0,015	g	g	g	l,j	as agreed	
L625Q or X90Q	0,16 ^f	0,45 ^f	1,90	0,020	0,010	g	g	g	j,k	as agreed	
L690Q or X100Q	0,16 ^f	0,45 ^f	1,90	0,020	0,010	g	g	g	j,k	as agreed	
Welded pipe											
L245M or BM	0,22	0,45	1,20	0,025	0,015	0,05	0,05	0,04	e,l	0,43	0,25
L290M or X42M	0,22	0,45	1,30	0,025	0,015	0,05	0,05	0,04	e,l	0,43	0,25
L320M or X46M	0,22	0,45	1,30	0,025	0,015	0,05	0,05	0,04	e,l	0,43	0,25
L360M or X52M	0,22	0,45	1,40	0,025	0,015	d	d	d	e,l	0,43	0,25
L390M or X56M	0,22	0,45	1,40	0,025	0,015	d	d	d	e,l	0,43	0,25
L415M or X60M	0,12 ^f	0,45 ^f	1,60 ^f	0,025	0,015	g	g	g	h,l	0,43	0,25
L450M or X65M	0,12 ^f	0,45 ^f	1,60 ^f	0,025	0,015	g	g	g	h,l	0,43	0,25
L485M or X70M	0,12 ^f	0,45 ^f	1,70 ^f	0,025	0,015	g	g	g	h,l	0,43	0,25
L555M or X80M	0,12 ^f	0,45 ^f	1,85 ^f	0,025	0,015	g	g	g	l,l	0,43 ^f	0,25
L625M or X90M	0,10	0,55 ^f	2,10 ^f	0,020	0,010	g	g	g	i,l	—	0,25
L690M or X100M	0,10	0,55 ^f	2,10 ^f	0,020	0,010	g	g	g	i,j		0,25
L830M or X120M	0,10	0,55 ^f	2,10 ^f	0,020	0,010	g	g	g	i,j		0,25

Table 5 — Chemical composition for PSL 2 pipe with $t \leq 25,0$ mm (0.984 in) (continued)

a	Based upon product analysis. For seamless pipe with $t > 20,0$ mm (0.787 in), the CE limits shall be as agreed. The CE_{IV} limits apply if $C > 0,12$ % and the CE_{Pcm} limits apply if $C \leq 0,12$ %.
b	For each reduction of 0,01 % below the specified maximum for C, an increase of 0,05 % above the specified maximum for Mn is permissible, up to a maximum of 1,65 % for grades \geq L245 or B, but \leq L360 or X52; up to a maximum of 1,75 % for grades $>$ L360 or X52, but $<$ L485 or X70; up to a maximum of 2,00 % for grades \geq L485 or X70, but \leq L555 or X80; and up to a maximum of 2,20 % for grades $>$ L555 or X80.
c	Unless otherwise agreed, $Nb + V \leq 0,06$ %.
d	$Nb + V + Ti \leq 0,15$ %.
e	Unless otherwise agreed, $Cu \leq 0,50$ %; $Ni \leq 0,30$ %; $Cr \leq 0,30$ % and $Mo \leq 0,15$ %.
f	Unless otherwise agreed.
g	Unless otherwise agreed, $Nb + V + Ti \leq 0,15$ %.
h	Unless otherwise agreed, $Cu \leq 0,50$ %; $Ni \leq 0,50$ %; $Cr \leq 0,50$ % and $Mo \leq 0,50$ %.
i	Unless otherwise agreed, $Cu \leq 0,50$ %; $Ni \leq 1,00$ %; $Cr \leq 0,50$ % and $Mo \leq 0,50$ %.
j	$B \leq 0,004$ %.
k	Unless otherwise agreed, $Cu \leq 0,50$ %; $Ni \leq 1,00$ %; $Cr \leq 0,55$ % and $Mo \leq 0,80$ %.
l	For all PSL 2 pipe grades except those grades to which footnote j already applies, the following applies. Unless otherwise agreed no intentional addition of B is permitted and residual B $\leq 0,001$ %.

9.3 Tensile properties

9.3.1 For PSL 1 pipe, the tensile properties shall be as given in Table 6.

9.3.2 For PSL 2 pipe, the tensile properties shall be as given in Table 7.

Table 6 — Requirements for the results of tensile tests for PSL 1 pipe

Pipe grade	Pipe body of seamless and welded pipes			Weld seam of EW, LW, SAW and COW pipes
	Yield strength ^a $R_{10,5}$ MPa (psi) minimum	Tensile strength ^a R_m MPa (psi) Minimum	Elongation (on 50 mm or 2 in) A_f % minimum	Tensile strength ^b R_m MPa (psi) Minimum
L175 or A25	175 (25 400)	310 (45 000)	c	310 (45 000)
L175P or A25P	175 (25 400)	310 (45 000)	c	310 (45 000)
L210 or A	210 (30 500)	335 (48 600)	c	335 (48 600)
L245 or B	245 (35 500)	415 (60 200)	c	415 (60 200)
L290 or X42	290 (42 100)	415 (60 200)	c	415 (60 200)
L320 or X46	320 (46 400)	435 (63 100)	c	435 (63 100)
L360 or X52	360 (52 200)	460 (66 700)	c	460 (66 700)
L390 or X56	390 (56 600)	490 (71 100)	c	490 (71 100)
L415 or X60	415 (60 200)	520 (75 400)	c	520 (75 400)
L450 or X65	450 (65 300)	535 (77 600)	c	535 (77 600)
L485 or X70	485 (70 300)	570 (82 700)	c	570 (82 700)

^a For intermediate grades, the difference between the specified minimum tensile strength and the specified minimum yield strength for the pipe body shall be as given in the table for the next higher grade.

^b For intermediate grades, the specified minimum tensile strength for the weld seam shall be the same value as was determined for the pipe body using footnote a).

^c The specified minimum elongation, A_f , expressed in percent and rounded to the nearest percent, shall be as determined using the following equation:

$$A_f = C \frac{A_{xc}^{0,2}}{U^{0,9}}$$

where

C is 1 940 for calculations using SI units and 625 000 for calculations using USC units;

A_{xc} is the applicable tensile test piece cross-sectional area, expressed in square millimetres (square inches), as follows:

- for circular cross-section test pieces, 130 mm² (0.20 in²) for 12,7 mm (0.500 in) and 8,9 mm (0.350 in) diameter test pieces; and 65 mm² (0.10 in²) for 6,4 mm (0.250 in) diameter test pieces;
- for full-section test pieces, the lesser of a) 485 mm² (0.75 in²) and b) the cross-sectional area of the test piece, derived using the specified outside diameter and the specified wall thickness of the pipe, rounded to the nearest 10 mm² (0.01 in²);
- for strip test pieces, the lesser of a) 485 mm² (0.75 in²) and b) the cross-sectional area of the test piece, derived using the specified width of the test piece and the specified wall thickness of the pipe, rounded to the nearest 10 mm² (0.01 in²);

U is the specified minimum tensile strength, expressed in megapascals (pounds per square inch).

Table 7 — Requirements for the results of tensile tests for PSL 2 pipe

Pipe grade	Pipe body of seamless and welded pipes						Weld seam of HFW, SAW and COW pipes
	Yield strength ^a		Tensile strength ^a		Ratio ^{a, c}	Elongation (on 50 mm or 2 in)	Tensile strength ^d
	$R_{10,5}$ MPa (psi)		R_m MPa (psi)		$R_{10,5}/R_m$	A_f %	R_m MPa (psi)
	minimum	maximum	minimum	Maximum	maximum	minimum	minimum
L245R or BR L245N or BN L245Q or BQ L245M or BM	245 (35 500)	450 ^e (65 300) ^e	415 (60 200)	655 (95 000)	0,93	f	415 (60 200)
L290R or X42R L290N or X42N L290Q or X42Q L290M or X42M	290 (42 100)	495 (71 800)	415 (60 200)	655 (95 000)	0,93	f	415 (60 200)
L320N or X46N L320Q or X46Q L320M or X46M	320 (46 400)	525 (76 100)	435 (63 100)	655 (95 000)	0,93	f	435 (63 100)
L360N or X52N L360Q or X52Q L360M or X52M	360 (52 200)	530 (76 900)	460 (66 700)	760 (110 200)	0,93	f	460 (66 700)
L390N or X56N L390Q or X56Q L390M or X56M	390 (56 600)	545 (79 000)	490 (71 100)	760 (110 200)	0,93	f	490 (71 100)
L415N or X60N L415Q or X60Q L415M or X60M	415 (60 200)	565 (81 900)	520 (75 400)	760 (110 200)	0,93	f	520 (75 400)
L450Q or X65Q L450M or X65M	450 (65 300)	600 (87 000)	535 (77 600)	760 (110 200)	0,93	f	535 (77 600)
L485Q or X70Q L485M or X70M	485 (70 300)	635 (92 100)	570 (82 700)	760 (110 200)	0,93	f	570 (82 700)
L555Q or X80Q L555M or X80M	555 (80 500)	705 (102 300)	625 (90 600)	825 (119 700)	0,93	f	625 (90 600)
L625M or X90M	625 (90 600)	775 (112 400)	695 (100 800)	915 (132 700)	0,95	f	695 (100 800)
L625Q or X90Q	625 (90 600)	775 (112 400)	695 (100 800)	915 (132 700)	0,97 ^g	f	—
L690M or X100M	690 ^b (100 100) ^b	840 ^b (121 800) ^b	760 (110 200)	990 (143 600)	0,97 ^h	f	760 (110 200)
L690Q or X100Q	690 ^b (100 100) ^b	840 ^b (121 800) ^b	760 (110 200)	990 (143 600)	0,97 ^h	f	—
L830M or X120M	830 ^b (120 400) ^b	1 050 ^b (152 300) ^b	915 (132 700)	1 145 (166 100)	0,99 ^h	f	915 (132 700)

Table 7 — Requirements for the results of tensile tests for PSL 2 pipe (continued)

a	For intermediate grades, the difference between the specified maximum yield strength and the specified minimum yield strength shall be as given in the table for the next higher grade, and the difference between the specified minimum tensile strength and the specified minimum yield strength shall be as given in the table for the next higher grade. For intermediate grades up to Grade L320 or X46, the tensile strength shall be ≤ 655 MPa (95 000 psi). For intermediate grades greater than Grade L320 or X46 and lower than Grade L555 or X80, the tensile strength shall be ≤ 760 MPa (110 200 psi). For intermediate grades higher than Grade L555 or X80, the maximum permissible tensile strength shall be obtained by interpolation. For SI units, the calculated value shall be rounded to the nearest 5 MPa. For USC units, the calculated value shall be rounded to the nearest 100 psi.
b	For grades $> L625$ or X90, $R_{p0,2}$ applies.
c	This limit applies for pipe with $D > 323,9$ mm (12.750 in).
d	For intermediate grades, the specified minimum tensile strength for the weld seam shall be the same value as was determined for the pipe body using footnote a).
e	For pipe requiring longitudinal testing, the maximum yield strength shall be ≤ 495 MPa (71 800 psi).
f	The specified minimum elongation, A_f , shall be as determined using the following equation: $A_f = C \frac{A_{xc}^{0,2}}{U^{0,9}}$
	where
	C is 1 940 for calculations using SI units and 625 000 for calculations using USC units;
	A_{xc} is the applicable tensile test piece cross-sectional area, expressed in square millimetres (square inches), as follows:
	— for circular cross-section test pieces, 130 mm^2 (0.20 in^2) for 12,7 mm (0.500 in) and 8,9 mm (0.350 in) diameter test pieces; and 65 mm^2 (0.10 in^2) for 6,4 mm (0.250 in) diameter test pieces;
	— for full-section test pieces, the lesser of a) 485 mm^2 (0.75 in^2) and b) the cross-sectional area of the test piece, derived using the specified outside diameter and the specified wall thickness of the pipe, rounded to the nearest 10 mm^2 (0.01 in^2);
	— for strip test pieces, the lesser of a) 485 mm^2 (0.75 in^2) and b) the cross-sectional area of the test piece, derived using the specified width of the test piece and the specified wall thickness of the pipe, rounded to the nearest 10 mm^2 (0.01 in^2);
	U is the specified minimum tensile strength, expressed in megapascals (pounds per square inch).
g	Lower values of $R_{t0,5}/R_m$ may be specified by agreement.
h	For grades $> L625$ or X90, $R_{p0,2}/R_m$ applies. Lower values of $R_{p0,2}/R_m$ may be specified by agreement.

9.4 Hydrostatic test

9.4.1 Except as allowed by 9.4.2, the pipe shall withstand the hydrostatic test without leakage through the weld seam or the pipe body.

9.4.2 Joints need not be hydrostatically tested, provided that the portions of pipe used in making the joints were successfully hydrostatically tested prior to the joining operation.

9.5 Bend test

No cracks shall occur in any portion of the test piece and no opening of the weld shall occur.

NOTE For all bend tests, the weld extends to a distance of 6,4 mm (0.25 in) on each side of the fusion line.

9.6 Flattening test

Acceptance criteria for flattening tests shall be as follows:

a) EW pipe in grades $\geq L210$ or A and LW pipe with $D < 323,9$ mm (12.750 in):

- 1) For grades $\geq L415$ or X60 with $t \geq 12,7$ mm (0.500 in), there shall be no opening of the weld before the distance between the plates is less than 66 % of the original outside diameter. For all

other combinations of pipe grade and specified wall thickness, there shall be no opening of the weld before the distance between the plates is less than 50 % of the original outside diameter.

- 2) For pipe with a $D/t > 10$, there shall be no cracks or breaks other than in the weld before the distance between the plates is less than 33 % of the original outside diameter.
- 3) There shall be no evidence of lamination or burnt metal during the entire test before opposite walls of the pipe meet.

b) EW and CW pipes in Grade L175, L175P, A25 or A25P:

- 1) There shall be no opening of the weld before the distance between the plates is less than 75 % of the original outside diameter.
- 2) There shall be no cracks or breaks other than in the weld before the distance between the plates is less than 60 % of the original outside diameter.

NOTE 1 The weld extends to a distance, on each side of the weld line, of 6,4 mm (0.25 in) for $D < 60,3$ mm (2.375 in) and 13 mm (0.5 in) for $D \geq 60,3$ mm (2.375 in).

NOTE 2 For EW pipe that is processed through a hot-stretch mill and is flattened prior to such treatment, the original outside diameter is as designated by the manufacturer; for all other cases, the original outside diameter is the specified outside diameter.

NOTE 3 The term "opening of the weld" includes any cracks, breaks or tears that become visible during the flattening test but does not include slight incipient cracking at the test piece edges.

9.7 Guided-bend test

9.7.1 Except as allowed by 9.7.2, the test pieces shall not

- a) fracture completely,
- b) reveal any cracks or ruptures in the weld metal longer than 3,2 mm (0.125 in), regardless of depth, or
- c) reveal any cracks or ruptures in the parent metal, HAZ or fusion line longer than 3,2 mm (0.125 in) or deeper than 12,5 % of the specified wall thickness.

9.7.2 Cracks that occur at the edges of the test piece during testing shall not be cause for rejection, provided that they are not longer than 6,4 mm (0.250 in).

9.8 CVN impact test for PSL 2 pipe

9.8.1 General

9.8.1.1 If subsize test pieces are used, the required minimum average (set of three test pieces) absorbed energy values shall be the required values for full-size test pieces times the ratio of the specified width of the subsize test piece to the specified width of the full-size test piece, with such derived values rounded to the nearest joule (foot-pound force).

9.8.1.2 Individual test values for any test piece shall be ≥ 75 % of the required minimum average (of a set of three test pieces) absorbed energy values.

9.8.1.3 Tests conducted at temperatures lower than the specified test temperature shall be acceptable if the applicable requirements for energy absorption and shear fracture area are met at such lower temperatures.

9.8.2 Pipe body tests

9.8.2.1 The minimum average (of a set of three test pieces) absorbed energy for each pipe body test shall be as given in Table 8, based upon full-size test pieces and a test temperature of 0 °C (32 °F) or, if agreed, a lower test temperature.

NOTE The energy values specified in Table 8 provide sufficient fracture-initiation resistance for most pipeline designs.

9.8.2.2 For welded pipe with $D \leq 508$ mm (20.000 in), if agreed, the minimum average (set of three test pieces) shear fracture area for each test shall be at least 85 %, based upon a test temperature of 0 °C (32 °F) or, if agreed, a lower test temperature.

NOTE This percentage of shear fracture area ensures sufficiently ductile fracture at or above the test temperature.

9.8.2.3 If 9.8.2.2 does not apply for the order item, the shear fracture area on the CVN specimen shall be estimated and reported for information purposes for all grades and sizes of pipe that have been CVN tested, unless otherwise agreed.

Table 8 — CVN absorbed energy requirements for pipe body of PSL 2 pipe

Specified outside diameter D mm (in)	Full-size CVN absorbed energy, minimum						
	K_V J (ft-lbf)						
	Grade						
	\leq L415 or X60	> L415 or X60 to \leq L450 or X65	> L450 or X65 to \leq L485 or X70	> L485 or X70 to \leq L555 or X80	> L555 or X80 to \leq L625 or X90	> L625 or X90 to \leq L690 or X100	> L690 or X100 to \leq L830 or X120
≤ 508 (20.000)	27 (20)	27 (20)	27 (20)	40 (30)	40 (30)	40 (30)	40 (30)
> 508 (20.000) to 762 (30.000)	27 (20)	27 (20)	27 (20)	40 (30)	40 (30)	40 (30)	40 (30)
> 762 (30.000) to 914 (36.000)	40 (30)	40 (30)	40 (30)	40 (30)	40 (30)	54 (40)	54 (40)
> 914 (36.000) to 1 219 (48.000)	40 (30)	40 (30)	40 (30)	40 (30)	40 (30)	54 (40)	68 (50)
> 1 219 (48.000) to 1 422 (56.000)	40 (30)	54 (40)	54 (40)	54 (40)	54 (40)	68 (50)	81 (60)
> 1 422 (56.000) to 2 134 (84.000)	40 (30)	54 (40)	68 (50)	68 (50)	81 (60)	95 (70)	108 (80)

9.8.3 Pipe weld and HAZ tests

The minimum average (of a set of three test pieces) absorbed energy for each pipe weld and HAZ test, based upon full-size test pieces and a test temperature of 0 °C (32 °F), or if agreed a lower test temperature, shall be

- a) 27 J (20 ft·lbf) for pipe with $D < 1\,422$ mm (56.000 in) in grades \leq L555 or X80;
- b) 40 J (30 ft·lbf) for pipe with $D \geq 1\,422$ mm (56.000 in);
- c) 40 J (30 ft·lbf) for pipe in grades $>$ L555 or X80.

9.9 DWT test for PSL 2 welded pipe

9.9.1 For each test (of a set of two test pieces), the average shear fracture area shall be $\geq 85\%$, based upon a test temperature of 0 °C (32 °F) or, if agreed, a lower test temperature. For wall thickness $> 25,4$ mm (1.000 in), DWT test acceptance requirements shall be by agreement.

NOTE 1 Such shear-fracture area ensures a sufficiently ductile fracture at or above the test temperature.

NOTE 2 A combination of sufficient shear-fracture area and sufficient CVN absorbed energy is an essential pipe-body property to ensure the avoidance of brittle fracture propagation and the control of ductile fracture propagation in gas pipelines (see Annex G and Table 20).

9.9.2 Tests conducted at temperatures lower than the specified test temperature shall be acceptable if the applicable requirements for shear fracture area are met at such lower temperatures.

9.10 Surface conditions, imperfections and defects

9.10.1 General

9.10.1.1 All pipes shall be free from defects in the finished condition.

9.10.1.2 All pipes shall be free from cracks, sweats and leaks.

9.10.1.3 The acceptance criteria for imperfections found by non-destructive inspection shall be in accordance with Annex E.

9.10.2 Undercuts

Undercuts in SAW and COW pipes shall be investigated, classified, and treated as follows.

- a) Undercuts that have a depth $\leq 0,4$ mm (0.016 in) are acceptable, regardless of length, and shall be treated in accordance with Clause C.1.
- b) Undercuts that have a depth $> 0,4$ mm (0.016 in) but $\leq 0,8$ mm (0.031 in) are acceptable provided they are treated in accordance with Clause C.2 and provided that:
 - 1) their individual lengths are $\leq 0,5 t$,
 - 2) their individual depths are $\leq 0,1 t$, and
 - 3) there are no more than two such undercuts in any 300 mm (12.0 in) length of weld.

- c) Undercuts that exceed the limits specified in item b) shall be classified as defects and shall be treated in accordance with Clause C.3.

NOTE Undercuts can best be located visually.

9.10.3 Arc burns

- 9.10.3.1 Arc burns shall be classified as defects.

NOTE 1 Arc burns are localized points of surface melting caused by arcing between the electrode or ground and the pipe surface.

NOTE 2 Contact marks, which are intermittent marks adjacent to the weld line of EW pipe resulting from electrical contact between the electrodes supplying the welding current and the pipe surface, are treated in accordance with 9.10.7.

- 9.10.3.2 Arc burns shall be treated in accordance with Clause C.2, C.3 b) or C.3 c), except that they may be removed by grinding, chipping or machining, provided that the resultant cavity is thoroughly cleaned and checked for complete removal of damaged material by etching with a 10% solution of ammonium persulfate or a 5% solution of nital.

9.10.4 Laminations

Laminations or inclusions extending into the face or bevel of the pipe and having a visually determined length in the circumferential direction $> 6,4$ mm (0.250 in) shall be classified as defects. Pipes that contain such defects shall be rejected or cut back until no such lamination or inclusion is present at the pipe ends.

9.10.5 Geometric deviations

9.10.5.1 For other than dents, geometric deviations from the normal cylindrical contour of the pipe (e.g. flat spots and peaks) that occur as a result of the pipe forming process or manufacturing operations and that exceed 3,2 mm (0.125 in) in depth, measured as the gap between the extreme point of the deviation and the prolongation of the normal contour of the pipe, shall be considered defects and shall be treated in accordance with C.3 b) or C.3 c).

9.10.5.2 For dents, the length in any direction shall be $\leq 0,5 D$ and the depth, measured as the gap between the extreme point of the dent and the prolongation of the normal contour of the pipe, shall not exceed the following:

- a) 3,2 mm (0.125 in) for cold-formed dents with sharp-bottom gouges;
- b) 6,4 mm (0.250 in) for other dents.

Dents that exceed the specified limits shall be considered defects and shall be treated in accordance with C.3 b) or C.3 c).

9.10.6 Hard spots

Any hard spot larger than 50 mm (2.0 in) in any direction shall be classified as a defect if its hardness exceeds 35 HRC, 345 HV10 or 327 HBW, based upon individual indentations. Pipes that contain such defects shall be treated in accordance with C.3 b) or C.3 c).

9.10.7 Other surface imperfections

Other surface imperfections found by visual inspection shall be investigated, classified and treated as follows.

- a) Imperfections that have a depth $\leq 0,125 t$ and do not encroach on the minimum permissible wall thickness shall be classified as acceptable imperfections and shall be treated in accordance with Clause C.1.
- b) Imperfections that have a depth $> 0,125 t$ and do not encroach on the minimum permissible wall thickness shall be classified as defects, and shall be dressed-out by grinding in accordance with Clause C.2 or shall be treated in accordance with Clause C.3.
- c) Imperfections that encroach on the minimum permissible wall thickness shall be classified as defects and shall be treated in accordance with Clause C.3.

NOTE "Imperfections that encroach on the minimum permissible wall thickness" implies that the portion of the wall thickness that is beneath the surface imperfection is less than the minimum permissible wall thickness.

9.11 Dimensions, mass and tolerances

9.11.1 Dimensions

9.11.1.1 The pipe shall be delivered to the dimensions specified in the purchase order, subject to the applicable tolerances.

9.11.1.2 The specified outside diameter and specified wall thickness shall be within the applicable limits given in Table 9.

9.11.1.3 The pipe shall be delivered in random lengths or approximate length, as specified in the purchase order.

Table 9 — Permissible specified outside diameter and specified wall thickness

Specified outside diameter <i>D</i> mm (in)	Specified wall thickness <i>t</i> mm (in)	
	Special light sizes ^a	Regular sizes
≥ 10,3 (0.405) to 13,7 (0.540)	—	≥ 1,7 (0.068) to 2,4 (0.094)
> 13,7 (0.540) to 17,1 (0.675)	—	≥ 2,2 (0.088) to 3,0 (0.118)
> 17,1 (0.675) to 21,3 (0.840)	—	≥ 2,3 (0.091) to 3,2 (0.125)
> 21,3 (0.840) to 26,7 (1.050)	—	≥ 2,1 (0.083) to 7,5 (0.294)
> 26,7 (1.050) to 33,4 (1.315)	—	≥ 2,1 (0.083) to 7,8 (0.308)
> 33,4 (1.315) to 48,3 (1.900)	—	≥ 2,1 (0.083) to 10,0 (0.394)
> 48,3 (1.900) to 60,3 (2.375)	—	≥ 2,1 (0.083) to 12,5 (0.492)
> 60,3 (2.375) to 73,0 (2.875)	≥ 2,1 (0.083) to 3,6 (0.141)	> 3,6 (0.141) to 14,2 (0.559)
> 73,0 (2.875) to 88,9 (3.500)	≥ 2,1 (0.083) to 3,6 (0.141)	> 3,6 (0.141) to 20,0 (0.787)
> 88,9 (3.500) to 101,6 (4.000)	≥ 2,1 (0.083) to 4,0 (0.156)	> 4,0 (0.156) to 22,0 (0.866)
> 101,6 (4.000) to 168,3 (6.625)	≥ 2,1 (0.083) to 4,0 (0.156)	> 4,0 (0.156) to 25,0 (0.984)
> 168,3 (6.625) to 219,1 (8.625)	≥ 2,1 (0.083) to 4,0 (0.156)	> 4,0 (0.156) to 40,0 (1.575)
> 219,1 (8.625) to 273,1 (10.750)	≥ 3,2 (0.125) to 4,0 (0.156)	> 4,0 (0.156) to 40,0 (1.575)
> 273,1 (10.750) to 323,9 (12.750)	≥ 3,6 (0.141) to 5,2 (0.203)	> 5,2 (0.203) to 45,0 (1.771)
> 323,9 (12.750) to 355,6 (14.000)	≥ 4,0 (0.156) to 5,6 (0.219)	> 5,6 (0.219) to 45,0 (1.771)
> 355,6 (14.000) to 457 (18.000)	≥ 4,5 (0.177) to 7,1 (0.281)	> 7,1 (0.281) to 45,0 (1.771)
> 457 (18.000) to 559 (22.000)	≥ 4,8 (0.188) to 7,1 (0.281)	> 7,1 (0.281) to 45,0 (1.771)
> 559 (22.000) to 711 (28.000)	≥ 5,6 (0.219) to 7,1 (0.281)	> 7,1 (0.281) to 45,0 (1.771)
> 711 (28.000) to 864 (34.000)	≥ 5,6 (0.219) to 7,1 (0.281)	> 7,1 (0.281) to 52,0 (2.050)
> 864 (34.000) to 965 (38.000)	—	≥ 5,6 (0.219) to 52,0 (2.050)
> 965 (38.000) to 1 422 (56.000)	—	≥ 6,4 (0.250) to 52,0 (2.050)
> 1 422 (56.000) to 1 829 (72.000)	—	≥ 9,5 (0.375) to 52,0 (2.050)
> 1 829 (72.000) to 2 134 (84.000)	—	≥ 10,3 (0.406) to 52,0 (2.050)

NOTE Standardized values for specified outside diameter and specified wall thickness of pipe are given in ISO 4200 [7] and ASME B36.10M [8].

^a Pipe having the combination of specified outside diameter and specified wall thickness is defined as special light size pipe. Other combinations given in this table are defined as regular size pipe. Pipe that has a combination of specified outside diameter and specified wall thickness that is intermediate to the tabulated values is considered to be special light size if the next lower tabulated value is for special light size pipe; other intermediate combinations are considered to be regular size pipe.

9.11.2 Mass per unit length

The mass per unit length, ρ_l , expressed in kilograms per metre (pounds per foot), shall be calculated using Equation (4):

$$\rho_l = t(D - t) \times C \quad (4)$$

where

D is the specified outside diameter, expressed in millimetres (inches);

t is the specified wall thickness, expressed in millimetres (inches);

C is 0,024 66 for calculations in SI units and 10.69 for calculations in USC units.

For threaded-and-coupled pipe, the weights determined as described above shall conform to the calculated weights or adjusted calculated weights within the tolerances specified in 9.14.

NOTE The nominal mass of a pipe is the product of its length and its mass per unit length.

9.11.3 Tolerances for diameter, wall thickness, length and straightness

9.11.3.1 Except as allowed by C.2.3, the diameter and out-of-roundness shall be within the tolerances given in Table 10 (see 10.2.8.2).

Table 10 — Tolerances for diameter and out-of-roundness

Specified outside diameter D mm (in)	Diameter tolerances ^d mm (in)				Out-of-roundness tolerances mm (in)	
	Pipe except the end ^a		Pipe end ^{a,b,c}		Pipe except the end ^a	Pipe end ^{a,b,c}
	SMLS pipe	Welded pipe	SMLS pipe	Welded pipe		
< 60,3 (2.375)	- 0,8 (0.031) to + 0,4 (0.016)		- 0,8 (0.031) to + 0,4 (0.016)		1,2 (0.048)	0,9 (0.036)
≥ 60,3 (2.375) to 168,3 (6.625)	± 0,007 5 D		- 0,4 (0.016) to + 1,6 (0.063)		0,020 D for $\frac{D}{t} \leq 75$; by agreement for $\frac{D}{t} > 75$	0,015 D for $\frac{D}{t} \leq 75$; by agreement for $\frac{D}{t} > 75$
> 168,3 (6.625) to 610 (24.000)	± 0,007 5 D	± 0,007 5 D , but maximum of ± 3,2 (0.125)	± 0,005 D , but maximum of ± 1,6 (0.063)		0,020 D	0,015 D
> 610 (24.000) to 1 422 (56.000)	± 0,01 D	± 0,005 D , but maximum of ± 4,0 (0.160)	± 2,0 (0.079)	± 1,6 (0.063)	0,015 D , but maximum of 15 (0.6) for $\frac{D}{t} \leq 75$; by agreement for $\frac{D}{t} > 75$	0,01 D , but maximum of 13 (0.5) for $\frac{D}{t} \leq 75$; by agreement for $\frac{D}{t} > 75$
> 1 422 (56.000)	as agreed					

^a The pipe end includes a length of 100 mm (4.0 in) at each of the pipe extremities.

^b For SMLS pipe, the tolerances apply for $t \leq 25,0$ mm (0.984 in), and the tolerances for thicker pipe shall be as agreed.

^c For expanded pipe with $D \geq 219,1$ mm (8.625 in) and for non-expanded pipe, the diameter tolerance and the out-of-roundness tolerance may be determined using the calculated inside diameter (the specified outside diameter minus two times the specified wall thickness) or measured inside diameter rather than the specified outside diameter (see 10.2.8.3).

^d For determining compliance to diameter tolerances, the pipe diameter is defined as the circumference of the pipe in any circumferential plane divided by π .

9.11.3.2 The tolerances for wall thickness shall be as given in Table 11.

Table 11 — Tolerances for wall thickness

Wall thickness t mm (in)	Tolerances ^a mm (in)
SMLS pipe ^b	
$\leq 4,0$ (0.157)	+ 0,6 (0.024) – 0,5 (0.020)
$> 4,0$ (0.157) to $< 25,0$ (0.984)	+ 0,150 t – 0,125 t
$\geq 25,0$ (0.984)	+ 3,7 (0.146) or + 0,1 t , whichever is the greater – 3,0 (0.120) or – 0,1 t , whichever is the greater
Welded pipe ^{c,d}	
$\leq 5,0$ (0.197)	$\pm 0,5$ (0.020)
$> 5,0$ (0.197) to $< 15,0$ (0.591)	$\pm 0,1 t$
$\geq 15,0$ (0.591)	$\pm 1,5$ (0.060)
<p>^a If the purchase order specifies a minus tolerance for wall thickness smaller than the applicable value given in this table, the plus tolerance for wall thickness shall be increased by an amount sufficient to maintain the applicable tolerance range.</p> <p>^b For pipe with $D \geq 355,6$ mm (14.000 in) and $t \geq 25,0$ mm (0.984 in), the wall-thickness tolerance locally may exceed the plus tolerance for wall thickness by an additional 0,05 t, provided that the plus tolerance for mass (see 9.14) is not exceeded.</p> <p>^c The plus tolerance for wall thickness does not apply to the weld area.</p> <p>^d See 9.13.2 for additional restrictions.</p>	

9.11.3.3 The tolerances for length shall be as follows.

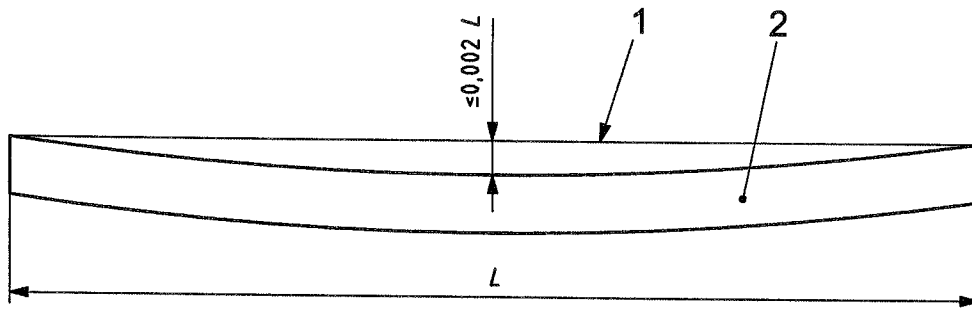
- a) Unless otherwise agreed, random lengths shall be delivered within the tolerances given in Table 12.
- b) Approximate lengths shall be delivered within a tolerance of ± 500 mm (20 in).
- c) If the supply of jointers is agreed, jointers comprising two pieces welded together to make a length shorter than 15,0 m (49.2 ft) may be furnished to a maximum of 5% of the order item, or as agreed.
- d) If the supply of jointers is agreed, jointers comprising two pieces welded together to make a length 15,0 m (49.2 ft) or longer may be furnished for the entire order item or any portion thereof.
- e) If the supply of jointers is agreed, jointers comprising three pieces welded together to make a length 15,0 m (49.2 ft) or longer may be furnished to a maximum of 5% of the order item, or as agreed.

Table 12 — Tolerances for random length pipe

Random length designation m (ft)	Minimum length m (ft)	Minimum average length for each order item m (ft)	Maximum length m (ft)
Threaded-and-coupled pipe			
6 (20)	4,88 (16.0)	5,33 (17.5)	6,86 (22.5)
9 (30)	4,11 (13.5)	8,00 (26.2)	10,29 (33.8)
12 (40)	6,71 (22.0)	10,67 (35.0)	13,72 (45.0)
Plain-end pipe			
6 (20)	2,74 (9.0)	5,33 (17.5)	6,86 (22.5)
9 (30)	4,11 (13.5)	8,00 (26.2)	10,29 (33.8)
12 (40)	4,27 (14.0)	10,67 (35.0)	13,72 (45.0)
15 (50)	5,33 (17.5)	13,35 (43.8)	16,76 (55.0)
18 (60)	6,40 (21.0)	16,00 (52.5)	19,81 (65.0)
24 (80)	8,53 (28.0)	21,34 (70.0)	25,91 (85.0)

9.11.3.4 The tolerances for straightness shall be as follows.

- a) The total deviation from a straight line, over the entire pipe length, shall be $\leq 0,2$ % of the pipe length, as shown in Figure 1.
- b) The local deviation from a straight line in the 1,0 m (3.0 ft) portion at each pipe end shall be $\leq 4,0$ mm (0.156 in), as shown in Figure 2.

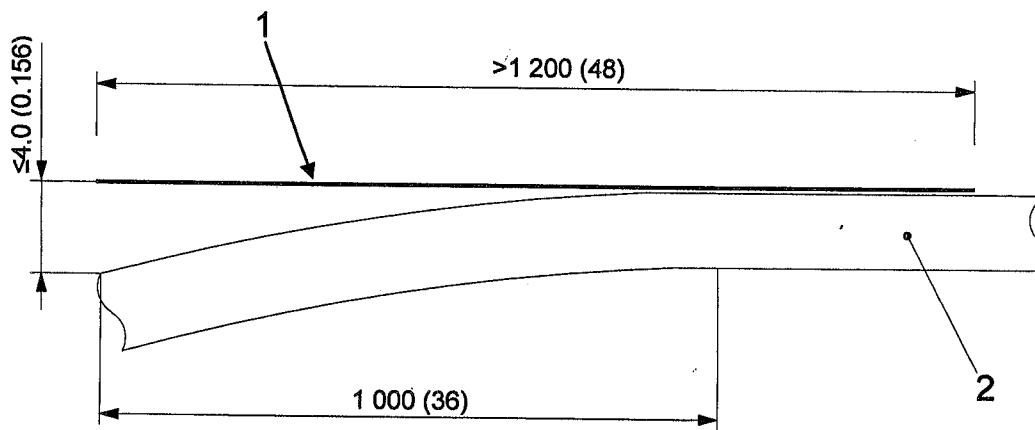


Key

- 1 taut string or wire
- 2 pipe

Figure 1 — Measuring full-length straightness

Dimensions in millimetres (inches)



Key

- 1 straight line
- 2 pipe

Figure 2 — Measuring end straightness

9.12 Finish of pipe ends

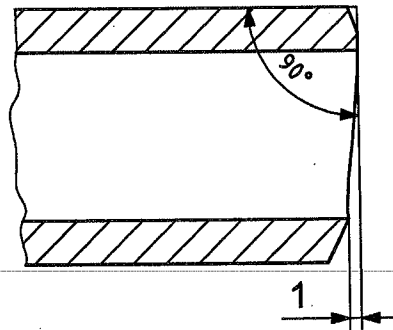
9.12.1 General

9.12.1.1 Grade L175P or A25P PSL 1 pipe shall be furnished with threaded ends; other grades of PSL 1 pipe shall be furnished with plain ends, unless another acceptable end finish (see Table 2) is specified in the purchase order.

9.12.1.2 PSL 2 pipe shall be furnished with plain ends.

9.12.1.3 Pipe ends shall be free from burrs.

9.12.1.4 The out-of-squareness, measured as shown in Figure 3, shall be $\leq 1,6$ mm (0.063 in).

**Key**

1 out-of-squareness

Figure 3 — Out-of-squareness**9.12.2 Threaded ends (PSL 1 only)**

9.12.2.1 Threaded ends shall conform to the threading, thread inspection and gauging requirements of API Spec 5B.

9.12.2.2 One end of each length of threaded pipe shall be provided with a coupling conforming to the requirements of Annex F and the other end shall be provided with thread protection conforming to the requirements of 12.2.

9.12.2.3 Couplings shall be screwed onto the pipe handling-tight or, if agreed, power-tight.

NOTE Handling-tight means sufficiently tight that the coupling cannot be removed without using a wrench. The purpose of making up couplings handling-tight is to facilitate removal of the couplings for cleaning and inspecting threads and applying fresh thread compound before laying the pipe. This procedure has been found necessary to prevent thread leakage, especially in gas pipelines, because manufacturer-applied couplings made up power-tight, although leak proof at the time of make-up, might not always remain so after transportation, handling and laying.

9.12.2.4 Before making up the joint, a thread compound that meets the performance objectives in ISO 13678 or API RP 5A3 shall be applied to cover the full surface of either the coupling or the pipe engaged threads. All exposed threads shall be coated with this thread compound or a storage compound of distinct colour. Unless otherwise agreed, the choice of thread compound is at the option of the manufacturer. Whichever compound is used, it shall be applied to a surface that is clean and reasonably free of moisture and cutting fluids.

9.12.3 Belled ends (PSL 1 only)

9.12.3.1 Belled-end pipe shall be furnished with one end belled in accordance with the configuration and dimensions specified in the purchase order.

9.12.3.2 Belled ends shall be visually inspected for conformance with 9.10.

9.12.4 Ends prepared for special couplings (PSL 1 only)

9.12.4.1 Where applicable, pipe shall be furnished with both ends prepared for use with special couplings, with the configuration and dimensions as specified in the purchase order.

9.12.4.2 The pipe shall be sufficiently free from indentations, projections and roll marks for a distance of at least 200 mm (8.0 in) from each pipe end in order to permit proper make-up of the couplings.

9.12.5 Plain ends

9.12.5.1 Unless otherwise agreed, the end faces of plain-end pipe with $t \leq 3,2$ mm (0.125 in) shall be square cut.

9.12.5.2 Unless otherwise agreed, the end faces of plain-end pipe with $t > 3,2$ mm (0.125 in) shall be bevelled for welding. Except as allowed by 9.12.5.3, the angle of the bevel, measured from a line drawn perpendicular to the axis of the pipe, shall be 30° with a tolerance of $+5^\circ$, and the width of the root face of the bevel shall be 1,6 mm (0.063 in), with a tolerance of $\pm 0,8$ mm (0.031 in).

9.12.5.3 If agreed, other bevel preparations may be furnished, for example on the basis of ISO 6761 [9].

9.12.5.4 Where internal machining or grinding is carried out in SMLS pipe, the angle of the internal taper, measured from the longitudinal axis, shall not exceed the applicable value given in Table 13.

9.12.5.5 For the removal of an internal burr on welded pipe $D > 114,3$ mm (4.500 in), the internal taper as measured from the longitudinal axis, shall be no greater than $7,0^\circ$.

Table 13 — Maximum angle of internal taper for SMLS pipe

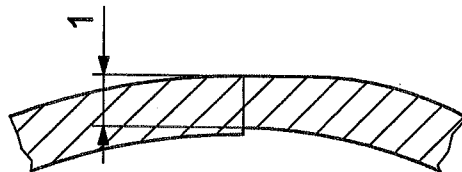
Specified wall thickness t mm (in)	Maximum angle of taper Degrees
< 10,5 (0.413)	7,0
10,5 (0.413) to < 14,0 (0.551)	9,5
14,0 (0.551) to < 17,0 (0.669)	11,0
$\geq 17,0$ (0.669)	14,0

9.13 Tolerances for the weld seam

9.13.1 Radial offset of strip/plate edges

For EW and LW pipes, the radial offset of the strip/plate edges [see Figure 4 a)] shall not cause the remaining wall thickness at the weld to be less than the minimum permissible wall thickness.

For SAW and COW pipes, the radial offset of the strip/plate edges [see Figure 4 b) or Figure 4 c), whichever is applicable] shall not exceed the applicable value given in Table 14.

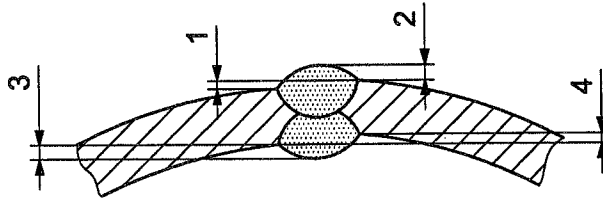


Key

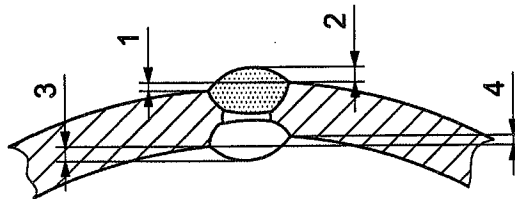
1 remaining wall thickness at the weld

a) Radial offset of strip/plate edges of EW and LW pipes

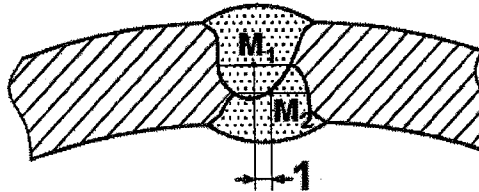
Figure 4 — Dimensional deviations of the weld seam

**Key**

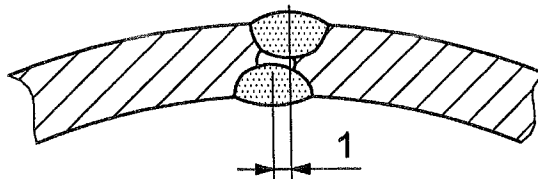
- 1 outside radial offset
- 2 height of outside weld bead
- 3 height of inside weld bead
- 4 inside radial offset

b) Radial offset of strip/plate edges and height of weld beads of SAW pipe**Key**

- 1 outside radial offset
- 2 height of outside weld bead
- 3 height of inside weld bead
- 4 inside radial offset

c) Radial offset of strip/plate edges and height of weld beads of COW pipe**Key**

- M_1, M_2 Midpoints of two parallel lines across the weld bead that are parallel to the tangent of the pipe surface and cross the intersections of the internal and external weld bead fusion lines;
- 1 misalignment distance, which is the distance between two lines through points M_1 and M_2 but perpendicular to the tangent of the pipe surface

d) Misalignment of weld beads of SAW pipe**Key**

- 1 misalignment

e) Misalignment of weld beads of COW pipe**Figure 4 — Dimensional deviations of the weld seam (continued)**

Table 14 — Maximum permissible radial offset for SAW and COW pipes

Specified wall thickness t mm (in)	Maximum permissible radial offset ^a mm (in)
≤ 15,0 (0.590)	1,5 (0.060)
> 15,0 (0.590) to 25,0 (0.984)	0,1 t
> 25,0 (0.984)	2,5 (0.098)

^a These limits apply also to strip/plate end welds.

9.13.2 Height of the flash or weld bead/reinforcement

9.13.2.1 For EW and LW pipes, the following shall apply.

- a) The outside flash shall be trimmed to an essentially flush condition.
- b) The inside flash shall not extend above the contour of the pipe by more than 1,5 mm (0.060 in).
- c) The wall thickness at the trim shall not be less than the minimum permissible wall thickness.
- d) The depth of groove resulting from trimming the internal flash shall not exceed the applicable value given in Table 15.

Table 15 — Maximum permissible depth of groove for EW and LW pipes

Specified wall thickness t mm (in)	Maximum permissible depth of groove ^a mm (in)
≤ 4,0 (0.156)	0,10 t
> 4,0 (0.156) to 8,0 (0.312)	0,40 (0.016)
> 8,0 (0.312)	0,05 t

^a The depth of groove is the difference between the wall thickness approximately 25 mm (1 in) from the weld line and the minimum wall thickness at the trim.

9.13.2.2 For SAW and COW pipes, the following shall apply.

- a) Except at undercuts, the crown surfaces of the as-deposited inside and outside weld beads shall not be below the adjacent pipe surface.
- b) Weld beads shall blend in smoothly with the adjacent pipe surface.
- c) For a distance of at least 100 mm (4.0 in) from each pipe end, the inside weld bead shall be removed by grinding such that it does not extend above the adjacent pipe surface by more than 0,5 mm (0.020 in). For the remainder of the pipe, the inside weld bead shall not extend above the adjacent pipe surface by more than the applicable value given in Table 16.
- d) The outside weld bead shall not extend above the adjacent pipe surface by more than the applicable value given in Table 16.
- e) If agreed, for a distance of at least 150 mm (6.0 in) from each pipe end, the outside weld bead shall be removed by grinding such that it does not extend above the adjacent pipe surface by more than 0,5 mm (0.020 in).

Table 16 — Maximum permissible weld bead height for SAW and COW pipes (except at pipe ends)

Specified wall thickness t mm (in)	Weld bead height ^a mm (in) maximum	
	Internal bead	External bead
≤ 13,0 (0.512)	3,5 (0.138)	3,5 (0.138)
> 13,0 (0.512)	3,5 (0.138)	4,5 (0.177)

^a At the option of the manufacturer, weld beads higher than permitted may be ground to acceptable heights.

9.13.3 Misalignment of the weld beads of SAW and COW pipes

Misalignment of the weld beads of SAW pipe [see Figure 4 d)] and COW pipe [see Figure 4 e)] shall not be cause for rejection if it is within the limits which follow and provided that complete penetration and complete fusion have been achieved, as indicated by non-destructive inspection. The maximum misalignment of the weld beads shall not exceed 3 mm (0.1 in) for pipe with specified wall thickness $t \leq 20$ mm (0.8 in) or 4 mm (0.16 in) for pipe with specified wall thickness $t > 20$ mm (0.8 in).

9.14 Tolerances for mass

9.14.1 Except as allowed by 9.14.2, the mass of each individual pipe shall not deviate from its nominal mass, as determined by multiplying its length by its mass per unit length (see 9.11.2), by more than the following:

- a) for special light size pipe (see Table 9): $\frac{+10,0\%}{-5,0\%}$;
- b) for pipe in Grade L175, L175P, A25 and A25P: $\frac{+10,0\%}{-5,0\%}$;
- c) for all other pipes: $\frac{+10,0\%}{-3,5\%}$.

9.14.2 If the purchase order specifies a minus tolerance for wall thickness smaller than the applicable value given in Table 11, the plus tolerance for mass shall be increased by a percentage equivalent to the applicable percentage reduction of the minus tolerance for wall thickness.

9.14.3 For each order item with a mass of 18 tonnes (20 ton) or more, the mass of the order item shall not deviate from its nominal mass, determined by multiplying the total length of pipe in the order item by its mass per unit length (see 9.11.2), by more than the following:

- a) for Grades L175, L175P, A25 and A25P: - 3,5 %;
- b) for all other grades: - 1,75 %.

9.15 Weldability of PSL 2 pipe

If agreed, the manufacturer shall supply weldability data for the type of steel concerned or perform weldability tests, for which the details for carrying out the tests and the acceptance criteria shall be as specified in the purchase order.

The requirements for the chemical composition of the steels and, in particular, the limiting values of CE_{Pcm} and CE_{IIW} (see Table 5, Table H.1, or Table J.1, whichever is applicable) have been selected to facilitate weldability; however, account should be taken of the fact that the behaviour of the steel during and after welding is dependent not only upon the steel composition, but also upon the welding consumables used and the conditions of preparing for, and carrying out, welding.

10 Inspection

10.1 Types of inspection and inspection documents

10.1.1 General

10.1.1.1 Compliance with the requirements of the purchase order shall be checked by specific inspection in accordance with ISO 10474.

NOTE 1 In ISO 10474, "specific inspection" is referred to as "specific inspection and testing".

NOTE 2 For the purpose of this provision, EN 10204 is equivalent to ISO 10474.

NOTE 3 The term "Inspection Documents" as used in section 10.1.2 and 10.1.3 is equivalent to, and interchangeable with, the term "Material Test Reports".

10.1.1.2 Inspection documents shall be in printed form or in electronic form as an EDI transmission that conforms to any EDI agreement between the purchaser and the manufacturer.

10.1.2 Inspection documents for PSL 1 pipe

10.1.2.1 If agreed, an Inspection Certificate 3.1.A, 3.1.B or 3.1.C in accordance with ISO 10474:1991 or an Inspection Certificate 3.1 or 3.2 in accordance with EN 10204:2004 shall be issued.

10.1.2.2 If supply of an inspection document is agreed, the following information, as applicable, shall be provided for each order item:

- a) specified outside diameter, specified wall thickness, PSL, type of pipe, pipe grade and the delivery condition,
- b) chemical composition (heat and product),
- c) tensile test results and the type, size, location and orientation of the test pieces,
- d) specified minimum hydrostatic test pressure and specified test duration,
- e) for welded pipe, the method of non-destructive weld inspection (radiological, ultrasonic or electromagnetic) used; and the type and size of reference indicator or image quality indicator used,
- f) for SMLS pipe, the method of non-destructive inspection (ultrasonic, electromagnetic or magnetic particle) used; and the type and size of the reference indicator used,
- g) for EW and LW pipes, the minimum temperature for heat treatment of the weld seam or "No heat treatment" if no heat treatment was performed,
- h) results of any supplementary testing specified in the purchase order,
- i) for pipe with welded jointer, coupled and/or through the flowline pipe certification that the product meets the requirements of Annexes A, F and/or I, as applicable, and
- j) name and location of facilities used for pipe manufacturing, plate/coil rolling and steelmaking.

10.1.3 Inspection documents for PSL 2 pipe

10.1.3.1 The manufacturer shall issue an Inspection Certificate 3.1.B in accordance with ISO 10474:1991 or an Inspection Certificate 3.1 in accordance with EN 10204:2004. Alternatively, if specified in the purchase order, an Inspection Certificate 3.1.A or 3.1.C in accordance with ISO 10474:1991 or an Inspection Certificate 3.2 in accordance with EN 10204:2004 shall be issued.

10.1.3.2 The following information, as applicable, shall be provided for each order item:

- a) specified outside diameter, specified wall thickness, pipe grade, PSL, type of pipe and the delivery condition,
- b) chemical composition (heat and product) and carbon equivalent (product analysis and acceptance criterion),
- c) tensile test results and the type, size, location and orientation of the test pieces,
- d) CVN impact test results; the size, orientation and location of the test pieces; the test temperature; and the acceptance criteria for the specific test piece sizes used,
- e) for welded pipe, DWT test results (individual and average test results for each test),
- f) specified minimum hydrostatic test pressure and specified test duration,
- g) for welded pipe, the method of non-destructive weld inspection (radiological, ultrasonic or electromagnetic) used; and the type and size of reference indicator or image quality indicator used,
- h) for SMLS pipe, the method of non-destructive inspection (ultrasonic, electromagnetic or magnetic particle) used; and the type and size of the reference indicator used,
- i) for HFW pipe, the minimum temperature for heat treatment of the weld seam,
- j) for pipe with welded jointer and/or through the flowline pipe, certification that the product meets the requirements of Annexes A and/or I, as applicable,
- k) name and location of facilities used for pipe manufacturing, plate/coil rolling and steelmaking, and
- l) results of any supplementary testing specified in the purchase order.

10.2 Specific inspection

10.2.1 Inspection frequency

10.2.1.1 For PSL 1 pipe, the inspection frequency shall be as given in Table 17.

10.2.1.2 For PSL 2 pipe, the inspection frequency shall be as given in Table 18.

Table 17 — Inspection frequency for PSL 1 pipe

No	Type of inspection	Type of pipe	Frequency of inspection ^e
1	Heat analysis	All pipe	One analysis per heat of steel
2	Product analysis	SMLS, CW, LFW, HFW, LW, SAW, or COW	Two analyses per heat of steel (taken from separate product items)
3	Tensile testing of the pipe body of welded pipe with $D \leq 48,3$ mm (1.900 in), in Grade L175 or A25	CW, LFW or HFW	Once per test unit ^e of not more than 25 tonnes (28 tons) of pipe
4	Tensile testing of the pipe body of welded pipe with $D \leq 48,3$ mm (1.900 in), in Grade L175P or A25P	CW	
5	Tensile testing of the pipe body of welded pipe with $D > 48,3$ mm (1.900 in), in Grade L175 or A25	CW, LFW or HFW	Once per test unit of not more than 50 tonnes (55 tons) of pipe
6	Tensile testing of the pipe body of welded pipe with $D > 48,3$ mm (1.900 in), in Grade L175P or A25P	CW	
7	Tensile testing of the pipe body of seamless pipe	SMLS	Once per test unit of pipe with the same cold-expansion ratio ^a
8	Tensile testing of the pipe body of welded pipe in grades higher than Grade L175 or A25	LFW, HFW, LW, SAW, or COW	
9	Tensile testing of the longitudinal or helical seam weld of welded pipe with $D \geq 219,1$ mm (8.625 in)	LFW, HFW, LW, SAW, or COW	Once per test unit of pipe with the same cold-expansion ratio ^{a,b,c}
10	Tensile testing of the coil/plate end weld of welded pipe with $D \geq 219,1$ mm (8.625 in)	SAWH or COWH	At least once per 50 coil/plate end welds from pipe with the same cold-expansion ratio ^{a,c,d}
11	Bend testing of the longitudinal seam weld of welded pipe with $D \leq 48,3$ mm (1.900 in), in Grade L175, L175P, A25 or A25P	CW, LFW, or HFW	Once per test unit of not more than 25 tonnes (28 tons) of pipe
12	Bend testing of the longitudinal seam weld of welded pipe with $48,3$ mm (1.900 in) $< D \leq 60,3$ mm (2.375 in), in Grade L175, L175P, A25 or A25P	CW, LFW, or HFW	Once per test unit of not more than 50 tonnes (55 tons) of pipe
13	Guided-bend testing of the longitudinal or helical-seam weld of welded pipe	SAW or COW	Once per test unit of not more than 50 lengths of pipe of the same grade
14	Guided-bend testing of the coil/plate end weld of welded pipe	SAWH or COWH	At least once per 50 coil/plate end welds from pipe with the same cold expansion ratio ^{a,c,d}
15	Guided-bend testing of the longitudinal seam weld of welded pipe with $D \geq 323,9$ mm (12.750 in)	LW	Once per test unit of not more than 50 lengths of pipe of the same grade
16	Flattening test of welded pipe	CW, LFW, HFW or LW	As shown in Figure 6
17	Hardness testing of hard spots in cold-formed welded pipe	LFW, HFW, LW, SAW, or COW	Any hard spot exceeding 50 mm (2.0 in) in any direction
18	Hydrostatic testing	SMLS, CW, LFW, HFW, LW, SAW, or COW	Each pipe

Table 17 — Inspection frequency for PSL 1 pipe (continued)

No	Type of inspection	Type of pipe	Frequency of inspection ^a
19	Macrographic testing of the longitudinal or helical-seam weld of welded pipe	SAW or COW	At least once per operating shift plus whenever any change of pipe size occurs during the operating shift; or, if 10.2.5.2 applies, at the beginning of the production of each combination of specified outside diameter and specified wall thickness
20	Metallographic testing of the longitudinal seam weld of welded pipe	LFW or HFW excluding full body normalized pipe	At least once per operating shift plus whenever changes of grade, specified outside diameter or specified wall thickness are made; plus whenever significant excursions from operating heat treatment conditions are encountered
21	Visual inspection	SMLS, CW, LFW, HFW, LW, SAW, or COW	Each pipe, except as allowed by 10.2.7.2
22	Pipe diameter and out-of-roundness	SMLS, CW, LFW, HFW, LW, SAW, or COW	At least once per 4 h per operating shift plus whenever any change of pipe size occurs during the operating shift
23	Wall thickness measurement	All pipes	Each pipe (see 10.2.8.5)
24	Other dimensional testing	SMLS, CW, LFW, HFW, LW, SAW, or COW	Random testing, with the details left to the discretion of the manufacturer
25	Weighing of pipe with $D < 141,3 \text{ mm (5.563 in)}$	SMLS, CW, LFW, HFW, LW, SAW, or COW	Each pipe or each convenient group of pipes, with the choice being at the discretion of the manufacturer
26	Weighing of pipe with $D \geq 141,3 \text{ mm (5.563 in)}$	SMLS, CW, LFW, HFW, LW, SAW, or COW	Each pipe
27	Length	SMLS, CW, LFW, HFW, LW, SAW, or COW	Each length of pipe shall be measured, except that pipe made in lengths that are uniform within 30 mm (0.1 ft) need not be individually measured, provided the accuracy of the length is verified at least once per 4 hours per operating shift.
28	Non-destructive inspection	SMLS, CW, LFW, HFW, LW, SAW, or COW	In accordance with Annex E

^a The cold-expansion ratio (if applicable) is designated by the manufacturer, and is derived using the designated before-expansion outside diameter or circumference and the after-expansion outside diameter or circumference. An increase or decrease in the cold-expansion ratio of more than 0,002 requires the creation of a new test unit.

^b For double-seam pipe, both longitudinal weld seams in the pipe selected to represent the test unit shall be tested.

^c Pipe produced by each welding machine shall be tested at least once per week.

^d Applies only to finished helical-seam pipe containing coil/plate end welds.

^e "Test unit" is as defined in 4.62.

Table 18 — Inspection frequency for PSL 2 pipe

No	Type of inspection	Type of pipe	Frequency of inspection ^o
1	Heat analysis	All pipe	One analysis per heat of steel
2	Product analysis	SMLS, HFW, SAW, or COW	Two analyses per heat of steel (taken from separate product items)
3	Tensile testing of the pipe body $D \leq 141,3$ mm (5.563 in)	SMLS, HFW, SAW, or COW	Once per test unit of not more than 400 pipes with the same cold-expansion ratio ^a
4	Tensile testing of the pipe body $D > 141,3$ mm (5.563 in) and $\leq 323,9$ mm (12.750 in)	SMLS, HFW, SAW, or COW	Once per test unit of not more than 200 pipes with the same cold-expansion ratio ^a
5	Tensile testing of the pipe body $D > 323,9$ mm (12.750 in)	SMLS, HFW, SAW, or COW	Once per test unit of not more than 100 pipes with the same cold-expansion ratio ^a
6	Tensile testing of the longitudinal or helical seam weld of welded pipe with $D \geq 219,1$ mm (8.625 in) and $\leq 323,9$ mm (12.750 in)	HFW, SAW, or COW	Once per test unit of not more than 200 pipes with the same cold-expansion ratio ^{a,b,c}
7	Tensile testing of the longitudinal or helical seam weld of welded pipe with $D > 323,9$ mm (12.750 in)	HFW, SAW, or COW	Once per test unit of not more than 100 pipes with the same cold-expansion ratio ^{a, b, c}
8	Tensile testing of the coil/plate end weld of welded pipe with $D \geq 219,1$ mm (8.625 in)	SAWH or COWH	At least once per 50 coil/plate end welds from pipe with the same cold-expansion ratio ^{a,b,d}
9	CVN impact testing of the pipe body of pipe with specified outside diameter and specified wall thickness as given in Table 22	SMLS, HFW, SAW, or COW	Once per test unit of pipe with the same cold-expansion ratio ^a
10	If agreed, CVN impact testing of the longitudinal seam weld of welded pipe with specified outside diameter and specified wall thickness as given in Table 22	HFW	Once per test unit of pipe with the same cold-expansion ratio ^{a,b}
11	CVN impact testing of the longitudinal or helical seam weld of welded pipe with specified outside diameter and specified wall thickness as given in Table 22	SAW or COW	Once per test unit of pipe with the same cold-expansion ratio ^{a,b,c}
12	CVN impact testing of the coil/plate end weld of welded pipe with specified outside diameter and specified wall thickness as given in Table 22	SAWH or COWH	At least once per 50 coil/plate end welds from pipe with the same cold-expansion ratio ^{a,b,d}
13	If agreed, DWT testing of the pipe body of welded pipe with $D \geq 508$ mm (20.000 in)	HFW, SAW, or COW	Once per test unit of pipe with the same cold-expansion ratio ^a
14	Guided-bend testing of the longitudinal or helical seam weld of welded pipe	SAW or COW	Once per test unit of not more than 50 lengths of pipe with the same cold-expansion ratio ^a
15	Guided-bend testing of the coil/plate end weld of welded pipe	SAWH or COWH	At least once per 50 coil/plate end welds from pipe with the same cold-expansion ratio ^{a,b,d}

Table 18 — Inspection frequency for PSL 2 pipe (continued)

No	Type of inspection	Type of pipe	Frequency of inspection ^a
16	Flattening test of welded pipe	HFW	As shown in Figure 6
17	Hardness testing of hard spots in cold-formed welded pipe	HFW, SAW, or COW	Any hard spot exceeding 50 mm (2.0 in) in any direction
18	Hydrostatic testing	SMLS, HFW, SAW, or COW	Each pipe
19	Macrographic testing of the longitudinal or helical seam weld of welded pipe	SAW or COW	At least once per operating shift plus whenever any change of pipe size occurs during the operating shift; or, if 10.2.5.3 or 10.2.5.4 applies, at the beginning of the production of each combination of specified outside diameter and specified wall thickness
20	Metallographic testing (or optional hardness test in lieu of metallography) of the longitudinal seam weld of welded pipe	HFW excluding full body normalized pipe	At least once per operating shift plus whenever changes of grade, specified outside diameter or specified wall thickness are made; plus whenever significant excursions from operating heat treatment conditions are encountered
21	Visual inspection	SMLS, HFW, SAW, or COW	Each pipe, except as allowed by 10.2.7.2
22	Pipe diameter and out-of-roundness	SMLS, HFW, SAW, or COW	At least once per 4 h per operating shift plus whenever any change of pipe size occurs during the operating shift
23	Wall thickness measurement	All pipes	Each pipe (see 10.2.8.5)
24	Other dimensional testing	SMLS, HFW, SAW, or COW	Random testing, with the details left to the discretion of the manufacturer
25	Weighing of pipe with $D < 141,3$ mm (5.563 in)	SMLS, HFW, SAW, or COW	Each pipe or each convenient group of pipes, with the choice being at the discretion of the manufacturer
26	Weighing of pipe with $D \geq 141,3$ mm (5.563 in)	SMLS, HFW, SAW, or COW	Each pipe
27	Length	SMLS, HFW, SAW, or COW	Each length of pipe shall be measured, except that pipe made in lengths that are uniform within 30 mm (0.1 ft) need not be individually measured, provided the accuracy of the length is verified at least once per 4 hours per operating shift.
28	Non-destructive inspection	SMLS, HFW, SAW, or COW	In accordance with Annex E

^a The cold-expansion ratio (if applicable) is designated by the manufacturer, and is derived using the designated before-expansion outside diameter or circumference and the after-expansion outside diameter or circumference. An increase or decrease in the cold-expansion ratio of more than 0,002 requires the creation of a new test unit.

^b Pipe produced by each welding machine shall be tested at least once per week.

^c For double-seam pipe, both longitudinal weld seams in the pipe selected to represent the test unit shall be tested.

^d Applies only to finished helical seam pipe containing coil/plate end welds.

^e "Test unit" is as defined in 4.62.

10.2.2 Samples and test pieces for product analysis

Samples shall be taken, and test pieces prepared, in accordance with ISO 14284 or ASTM E1806. Such samples shall be taken from the pipe, plate or coil.

10.2.3 Samples and test pieces for mechanical tests

10.2.3.1 General

For tensile tests, CVN impact tests, DWT tests, bend tests, guided-bend tests and flattening tests, the samples shall be taken, and the corresponding test pieces prepared, in accordance with the applicable reference standard.

Samples and test pieces for the various test types shall be taken from locations as shown in Figure 5 and Figure 6 and as given in Table 19 or Table 20, whichever is applicable, taking into account the supplementary details in 10.2.3.2 to 10.2.3.7 and in 10.2.4.

For any of the mechanical tests specified in Clause 9, any test piece that shows defective preparation or material imperfections unrelated to the intent of the particular mechanical test, whether observed before or after testing, may be discarded and replaced by another test piece from the same length of pipe.

10.2.3.2 Test pieces for the tensile test

Rectangular test pieces, representing the full wall thickness of the pipe, shall be taken in accordance with ISO 6892-1 or ASTM A370 and as shown in Figure 5. A standard sampling location along the coil or plate length shall be selected according to a documented practice.

For hot worked and heat treated seamless pipe, transverse test pieces shall have a round cross-section and shall be obtained from non-flattened samples.

For other pipe, transverse test pieces shall either have a rectangular or round cross-section. Rectangular cross-section test pieces shall be from flattened samples while round cross-section test shall be from non-flattened samples.

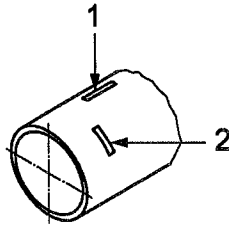
Flattening of test pieces shall be carried out according to documented procedures.

For transverse tensile tests using round cross-section test pieces, the diameter of such test pieces shall be as given in Table 21, except that the next larger diameter may be used at the option of the manufacturer. For longitudinal tensile tests of pipe with $t \geq 19,0$ mm (0.748 in), such test pieces shall be 12,7 mm (0.500 in) in diameter.

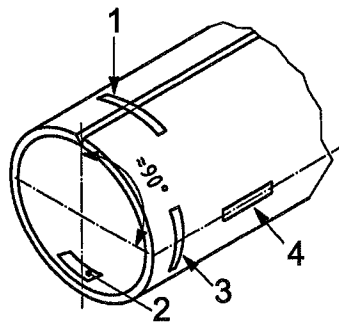
For testing pipe with $D < 219,1$ mm (8.625 in), full-section longitudinal test pieces may be used at the option of the manufacturer.

If agreed, ring expansion test pieces may be used for the determination of transverse yield strength.

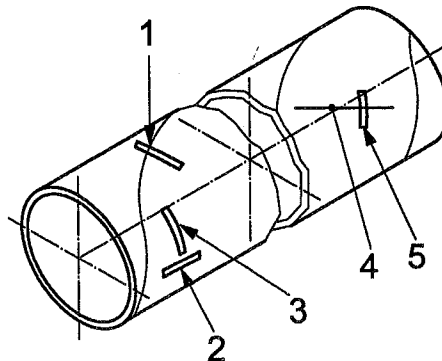
Weld beads may be ground flush and local imperfections may be removed.

**Key**

- 1 L — longitudinal sample
- 2 T — transverse sample

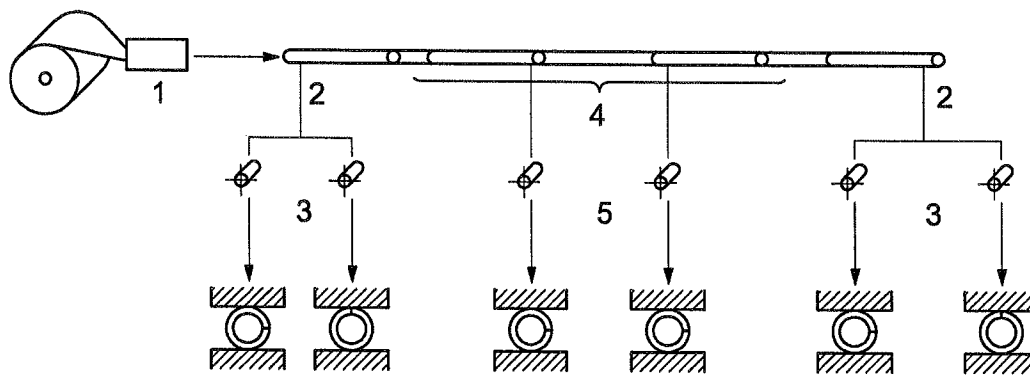
a) SMLS pipe**Key**

- 1 W — transverse weld sample, centred on the weld
- 2 T180 — transverse sample, centred $\approx 180^\circ$ from the longitudinal weld
- 3 T90 — transverse sample, centred $\approx 90^\circ$ from the longitudinal weld
- 4 L90 — longitudinal sample, centred $\approx 90^\circ$ from the longitudinal weld

b) CW, LFW, HFW, LW, SAWL and COWL pipes**Key**

- 1 W — transverse weld sample, centred on the helical seam weld
- 2 L — longitudinal sample, centred at least $a/4$ in the longitudinal direction from the helical seam weld
- 3 T — transverse sample, centred at least $a/4$ in the longitudinal direction from the helical seam weld
- 4 coil/plate end weld, where length a is the width of the coil/plate
- 5 WS — transverse weld sample, centred at least $a/4$ from the junctions of the helical seam weld and the coil/plate end weld

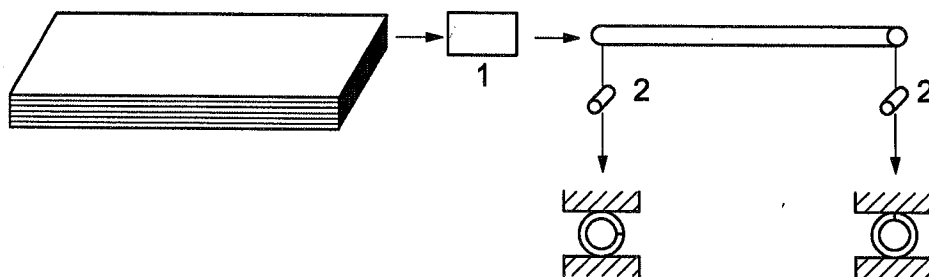
c) SAWH and COWH pipes**Figure 5 — Sample and test piece orientations and locations**



Key

- 1 welding
- 2 coil end
- 3 two test pieces from each coil end
- 4 weld stop
- 5 two test pieces, one from each side of the weld stop

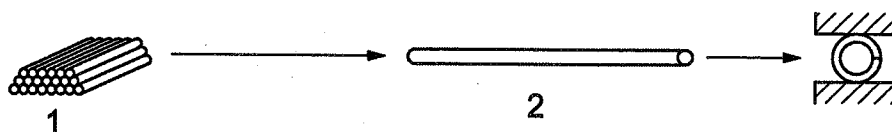
a) EW pipe in grades \geq L245 or B and LW with $D < 323,9$ mm (12.750 in) — Non-expanded, produced in multiple lengths



Key

- 1 welding
- 2 two test pieces, one from each pipe end

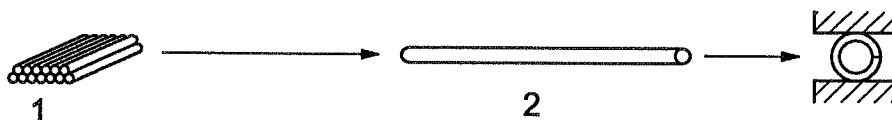
b) EW pipe in grades \geq L245 or B — Non-expanded, produced in single lengths



Key

- 1 test unit of \leq 50 tonnes (55 tons) of pipe
- 2 one test piece, from one pipe end

c) CW pipe or EW pipe in grades L175, L175P, A 25 or A 25P with $D \geq 73,0$ mm (2.875 in)



Key

- 1 test unit of \leq 100 lengths of pipe
- 2 one test piece, from one pipe end

d) EW pipe in grades \geq L245 or B and LW pipe with $D < 323,9$ mm (12.750 in) — Cold expanded

Figure 6 — Flattening tests

Table 19 — Number, orientation and location of test pieces per sample for mechanical tests for PSL 1 pipe

Type of pipe	Sample location	Type of test	Number, orientation and location of test pieces per sample ^a			
			Specified outside diameter			
			<i>D</i> mm (in)			
			< 219,1 (8.625)	219,1 (8.625) to < 323,9 (12.750)	323,9 (12.750) to < 508 (20.000)	≥ 508 (20.000)
SMLS, not cold-expanded [see Figure 5 a)]	Pipe body	Tensile	1L ^b	1L	1L	1L
SMLS, cold-expanded [see Figure 5 a)]	Pipe body	Tensile	1L ^b	1T ^c	1T ^c	1T ^c
CW [see Figure 5 b)]	Pipe body	Tensile	1L90 ^b	—	—	—
	Pipe body and weld	Bend	1 ^e	—	—	—
	Pipe body and weld	Flattening	as shown in Figure 6			
LW [see Figure 5 b)]	Pipe body	Tensile	1L90 ^b	1T180 ^c	1T180 ^c	1T180 ^c
	Seam weld	Tensile	—	1W	1W	1W
	Seam weld	Guided-bend	—	—	2W	2W
	Pipe body and weld	Flattening	as shown in Figure 6			
LFW or HFW [see Figure 5 b)]	Pipe body	Tensile	1L90 ^b	1T180 ^c	1T180 ^c	1T180 ^c
	Seam weld	Tensile	—	1W	1W	1W
	Pipe body and weld	Bend	1 ^e	—	—	—
	Pipe body and weld	Flattening	as shown in Figure 6			
SAWL or COWL [see Figure 5 b)]	Pipe body	Tensile	1L90 ^b	1T180 ^c	1T180 ^c	1T180 ^c
	Seam weld	Tensile	—	1W	1W	1W ^d
	Seam weld	Guided-bend	2W	2W	2W	2W ^d
SAWH or COWH [see Figure 5 c)]	Pipe body	Tensile	1L ^b	1T ^c	1T ^c	1T ^c
	Seam weld	Tensile	—	1W	1W	1W
	Seam weld	Guided-bend	2W	2W	2W	2W
	coil/plate end weld	Guided-bend	2WS	2WS	2WS	2WS

^a See Figure 5 for an explanation of the symbols used to designate orientation and location of samples and test pieces.

^b Full-section longitudinal test pieces may be used at the option of the manufacturer.

^c If agreed, annular test pieces may be used for the determination of transverse yield strength by the hydraulic ring expansion test in accordance with ASTM A370.

^d For double-seam pipe, both longitudinal weld seams in the pipe selected to represent the test unit shall be tested.

^e Testing limited to pipes of $D \leq 60,3$ mm (2.375 in),

Table 20 — Number, orientation and location of test pieces per sample for mechanical tests for PSL 2 pipe

Type of pipe	Sample location	Type of test	Number, orientation and location of test pieces per sample ^a			
			Specified outside diameter			
			<i>D</i> mm (in)			
			< 219,1 (8.625)	219,1 (8.625) to < 323,9 (12.750)	323,9 (12.750) to < 508 (20.000)	≥ 508 (20.000)
SMLS, not cold-expanded [see Figure 5 a)]	Pipe body	Tensile	1L ^b	1L ^{c,d}	1L ^{c,d}	1L ^{c,d}
		CVN	3T	3T	3T	3T
SMLS, cold-expanded [see Figure 5 a)]	Pipe body	Tensile	1L ^b	1T ^d	1T ^d	1T ^d
		CVN	3T	3T	3T	3T
HFW [see Figure 5 b)]	Pipe body	Tensile	1L90 ^b	1T180 ^d	1T180 ^d	1T180 ^d
		CVN	3T90	3T90	3T90	3T90
		DWT	—	—	—	2T90
	Seam weld	Tensile	—	1W	1W	1W
		CVN	3W	3W	3W	3W
	Pipe body and weld	Flattening	as shown in Figure 6			
SAWL or COWL [see Figure 5 b)]	Pipe body	Tensile	1L90 ^b	1T180 ^d	1T180 ^d	1T180 ^d
		CVN	3T90	3T90	3T90	3T90
		DWT	—	—	—	2T90
	Seam weld	Tensile	—	1W	1W	1W ^e
		CVN	3W and 3HAZ	3W and 3HAZ	3W and 3HAZ	3W ^e and 3HAZ ^e
		Guided-bend	2W ^f	2W ^f	2W ^f	2W ^{e,f}
SAWH or COWH [see Figure 5 c)]	Pipe body	Tensile	1L ^b	1T ^d	1T ^d	1T ^d
		CVN	3T	3T	3T	3T
		DWT	—	—	—	2T
	Seam weld	Tensile	—	1W	1W	1W
		CVN	3W and 3HAZ	3W and 3HAZ	3W and 3HAZ	3W and 3HAZ
		Guided-bend	2W ^f	2W ^f	2W ^f	2W ^f
	Coil/plate end weld	Tensile	—	1WS	1WS	1WS
		CVN	3WS and 3HAZ	3WS and 3HAZ	3WS and 3HAZ	3WS and 3HAZ
		Guided-bend	2WS ^f	2WS ^f	2WS ^f	2WS ^f

^a See Figure 5 for an explanation of the symbols used to designate orientation and location.

^b Full-section longitudinal test pieces may be used at the option of the manufacturer.

^c If agreed, transverse test pieces may be used.

^d If agreed, annular test pieces may be used for the determination of transverse yield strength by the hydraulic ring expansion test in accordance with ASTM A370.

^e For double-seam pipe, both longitudinal-weld seams in the pipe selected to represent the test unit shall be tested.

^f For pipe with $t > 19,0$ mm (0.748 in), the test pieces may be machined to provide a rectangular cross-section having a thickness of 18,0 mm (0.709 in).

Table 21 — Relationship between pipe dimensions and round bar test piece diameter for transverse tensile tests

Specified outside diameter <i>D</i> mm (in)	Specified wall thickness <i>t</i> mm (in)		
	Specified diameter of test piece within the gauge length mm (in)		
	12,7 (0.500)	8,9 (0.350)	6,4 (0.250) ^a
219,1 (8.625) to < 273,1 (10.750)	—	≥ 28,1 (1.106)	< 28,1 (1.106)
273,1 (10.750) to < 323,9 (12.750)	≥ 36,1 (1.421)	25,5 (1.004) to < 36,1 (1.421)	< 25,5 (1.004)
323,9 (12.750) to < 355,6 (14.000)	≥ 33,5 (1.319)	23,9 (0.941) to < 33,5 (1.319)	< 23,9 (0.941)
355,6 (14.000) to < 406,4 (16.000)	≥ 32,3 (1.272)	23,2 (0.913) to < 32,3 (1.272)	< 23,2 (0.913)
406,4 (16.000) to < 457 (18.000)	≥ 30,9 (1.217)	22,2 (0.874) to < 30,9 (1.217)	< 22,2 (0.874)
457 (18.000) to < 508 (20.000)	≥ 29,7 (1.169)	21,5 (0.846) to < 29,7 (1.169)	< 21,5 (0.846)
508 (20.000) to < 559 (22.000)	≥ 28,8 (1.134)	21,0 (0.827) to < 28,8 (1.134)	< 21,0 (0.827)
559 (22.000) to < 610 (24.000)	≥ 28,1 (1.106)	20,5 (0.807) to < 28,1 (1.106)	< 20,5 (0.807)
610 (24.000) to < 660 (26.000)	≥ 27,5 (1.083)	20,1 (0.791) to < 27,5 (1.083)	< 20,1 (0.791)
660 (26.000) to < 711 (28.000)	≥ 27,0 (1.063)	19,8 (0.780) to < 27,0 (1.063)	< 19,8 (0.780)
711 (28.000) to < 762 (30.000)	≥ 26,5 (1.043)	19,5 (0.768) to < 26,5 (1.043)	< 19,5 (0.768)
762 (30.000) to < 813 (32.000)	≥ 26,2 (1.031)	19,3 (0.760) to < 26,2 (1.031)	< 19,3 (0.760)
813 (32.000) to < 864 (34.000)	≥ 25,8 (1.016)	19,1 (0.753) to < 25,8 (1.016)	< 19,1 (0.753)
864 (34.000) to < 914 (36.000)	≥ 25,5 (1.004)	18,9 (0.744) to < 25,5 (1.004)	< 18,9 (0.744)
914 (36.000) to < 965 (38.000)	≥ 25,3 (0.996)	18,7 (0.736) to < 25,3 (0.996)	< 18,7 (0.736)
965 (38.000) to < 1 016 (40.000)	≥ 25,1 (0.988)	18,6 (0.732) to < 25,1 (0.988)	< 18,6 (0.732)
1 016 (40.000) to < 1 067 (42.000)	≥ 24,9 (0.980)	18,5 (0.728) to < 24,9 (0.980)	< 18,5 (0.728)
1 067 (42.000) to < 1 118 (44.000)	≥ 24,7 (0.972)	18,3 (0.720) to < 24,7 (0.972)	< 18,3 (0.720)
1 118 (44.000) to < 1 168 (46.000)	≥ 24,5 (0.965)	18,2 (0.717) to < 24,5 (0.965)	< 18,2 (0.717)
1 168 (46.000) to < 1 219 (48.000)	≥ 24,4 (0.961)	18,1 (0.713) to < 24,4 (0.961)	< 18,1 (0.713)
1 219 (48.000) to < 1 321 (52.000)	≥ 24,2 (0.953)	18,1 (0.713) to < 24,2 (0.953)	< 18,1 (0.713)
1 321 (52.000) to < 1 422 (56.000)	≥ 24,0 (0.945)	17,9 (0.705) to < 24,0 (0.945)	< 17,9 (0.705)
1 422 (56.000) to < 1 524 (60.000)	≥ 23,8 (0.937)	17,8 (0.701) to < 23,8 (0.937)	< 17,8 (0.701)
1 524 (60.000) to < 1 626 (64.000)	≥ 23,6 (0.929)	17,6 (0.693) to < 23,6 (0.929)	< 17,6 (0.693)
1 626 (64.000) to < 1 727 (68.000)	≥ 23,4 (0.921)	17,5 (0.689) to < 23,4 (0.921)	< 17,5 (0.689)
1 727 (68.000) to < 1 829 (72.000)	≥ 23,3 (0.917)	17,4 (0.685) to < 23,3 (0.917)	< 17,4 (0.685)
1 829 (72.000) to < 1 930 (76.000)	≥ 23,1 (0.909)	17,4 (0.685) to < 23,1 (0.909)	< 17,4 (0.685)
1 930 (76.000) to < 2 134 (84.000)	≥ 23,0 (0.906)	17,3 (0.681) to < 23,0 (0.906)	< 17,3 (0.681)
≥ 2 134 (84.000)	≥ 22,9 (0.902)	17,2 (0.677) to < 22,9 (0.902)	< 17,2 (0.677)

^a For pipe sizes too small to obtain 6,4 mm (0.250 in) diameter test pieces, round bar tensile-test pieces shall not be used.

10.2.3.3 Test pieces for the CVN impact test

The test pieces shall be prepared in accordance with ASTM A370 unless ISO 148-1 and the required striker radius (either 2 mm or 8 mm) are specified in the purchase order. The axis of the notch shall be perpendicular to the pipe surface.

For pipe weld and HAZ tests, each test piece shall be etched prior to notching in order to enable proper placement of the notch.

For test pieces taken in the weld of SAW and COW pipes, the axis of the notch shall be located on, or as close as practicable to, the centreline of the outside weld bead as shown in Figure 7. The specimen shall be taken as close as practicable to the OD surface of the pipe.

For test pieces taken in the HAZ of SAW and COW pipes, the axis of the notch shall be located as close as practicable to the fusion line of the outside weld bead as shown in Figure 7. The specimen shall be taken as close as practicable to the OD surface of the pipe.

For test pieces taken in the weld of HFW pipe, the axis of the notch shall be located on, or as close as practicable to, the weld line.

The size, orientation and source of the test pieces shall be as given in Table 22, except that the next smaller test piece size may be used if the absorbed energy is expected to exceed 80 % of the full-scale capacity of the impact testing machine.

NOTE It is not necessary to CVN impact-test combinations of specified outside diameter and specified wall thickness not covered by Table 22.

10.2.3.4 Test pieces for the DWT test

The test pieces shall be prepared in accordance with API RP 5L3.

10.2.3.5 Test pieces for the (full section) bend test

The test pieces shall be prepared in accordance with ISO 8491 or ASTM A 370.

10.2.3.6 Test pieces for the guided-bend test

The test pieces shall be prepared in accordance with ISO 7438 or ASTM A370 and Figure 8.

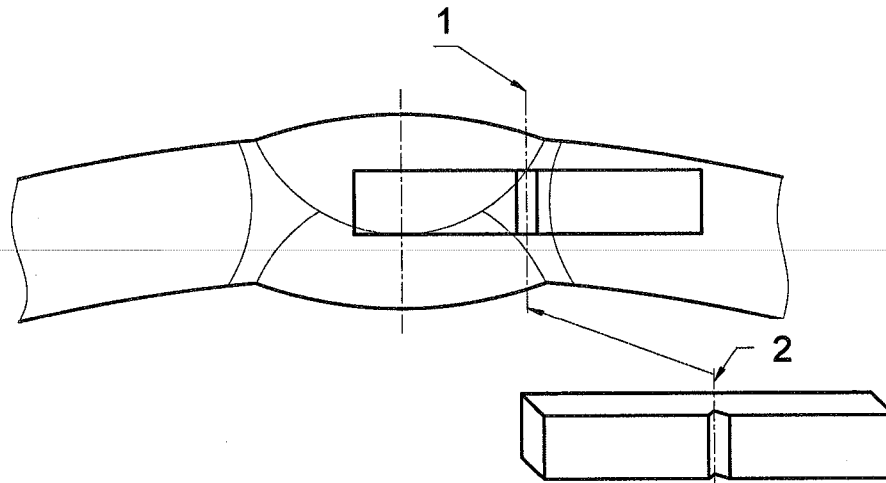
For pipe with $t > 19,0$ mm (0.748 in), the test pieces may be machined to provide a rectangular cross-section having a thickness of 18,0 mm (0.709 in). For pipe with $t \leq 19,0$ mm (0.748 in), the test pieces shall be full wall thickness curved-section test pieces.

For SAW and COW pipes, the weld reinforcement shall be removed from both faces.

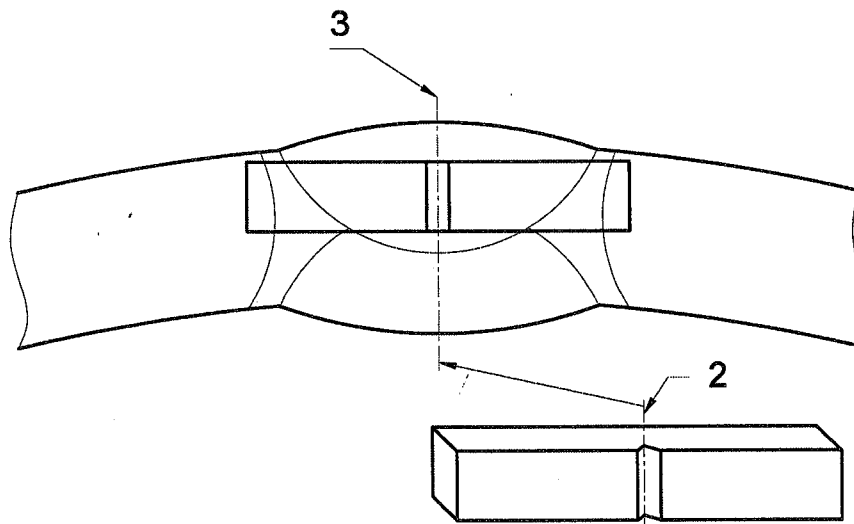
10.2.3.7 Test pieces for the flattening test

The test pieces shall be taken in accordance with ISO 8492 or ASTM A 370, except that the length of each test piece shall be ≥ 60 mm (2.5 in).

Minor surface imperfections may be removed by grinding.



a) HAZ specimen



b) Weld specimen

Key

- 1 material sampled by Charpy test piece notch in HAZ of seam weld — close to fusion line
- 2 centreline of Charpy test-piece notch
- 3 material sampled by Charpy test piece notch in weld seam — on or close to centerline of the outside weld bead

Figure 7 — Location of Charpy test specimens

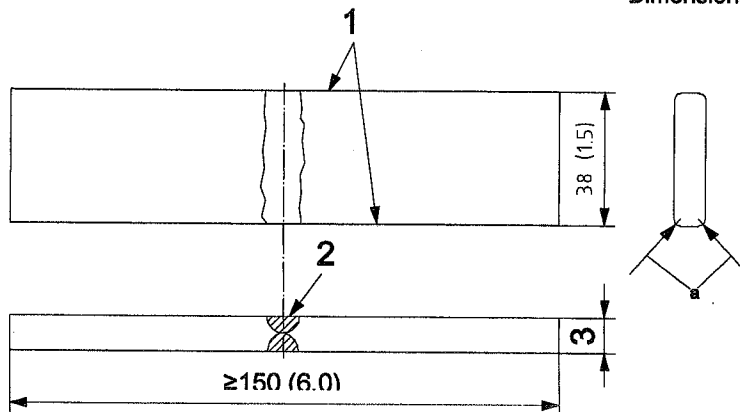
Table 22 — Relationship between pipe dimensions and required impact test piece for PSL 2 pipe

Specified outside diameter <i>D</i> mm (in)	Specified wall thickness <i>t</i> mm (in)			
	CVN test piece size, source and orientation			
	Full ^a	¾ ^a	⅔ ^a	½ ^a
114,3 (4.500) to < 141,3 (5.563)	≥ 12,6 (0.496)	11,7 (0.461) to < 12,6 (0.496)	10,9 (0.429) to < 11,7 (0.461)	10,1 (0.398) to < 10,9 (0.429)
141,3 (5.563) to < 168,3 (6.625)	≥ 11,9 (0.469)	10,2 (0.402) to < 11,9 (0.469)	9,4 (0.370) to < 10,2 (0.402)	8,6 (0.339) to < 9,4 (0.370)
168,3 (6.625) to < 219,1 (8.625)	≥ 11,7 (0.461)	9,3 (0.366) to < 11,7 (0.461)	8,6 (0.339) to < 9,3 (0.366)	7,6 (0.299) to < 8,6 (0.339)
219,1 (8.625) to < 273,1 (10.750)	≥ 11,4 (0.449)	8,9 (0.350) to < 11,4 (0.449)	8,1 (0.319) to < 8,9 (0.350)	6,5 (0.256) to < 8,1 (0.319)
273,1 (10.750) to < 323,9 (12.750)	≥ 11,3 (0.445)	8,7 (0.343) to < 11,3 (0.445)	7,9 (0.311) to < 8,7 (0.343)	6,2 (0.244) to < 7,9 (0.311)
323,9 (12.750) to < 355,6 (14.000)	≥ 11,1 (0.437)	8,6 (0.339) to < 11,1 (0.437)	7,8 (0.307) to < 8,6 (0.339)	6,1 (0.240) to < 7,8 (0.307)
355,6 (14.000) to < 406,4 (16.000)	≥ 11,1 (0.437)	8,6 (0.339) to < 11,1 (0.437)	7,8 (0.307) to < 8,6 (0.339)	6,1 (0.240) to < 7,8 (0.307)
≥ 406,4 (16.000)	≥ 11,0 (0.433)	8,5 (0.335) to < 11,0 (0.433)	7,7 (0.303) to < 8,5 (0.335)	6,0 (0.236) to < 7,7 (0.303)

NOTE The size limits for transverse specimens shown are based upon the use of non-flattened, tapered end, test specimens. See Clause P.8.

^a Test pieces, from non-flattened sample, transverse to pipe or weld axis, whichever is applicable.

Dimensions in millimetres (inches)



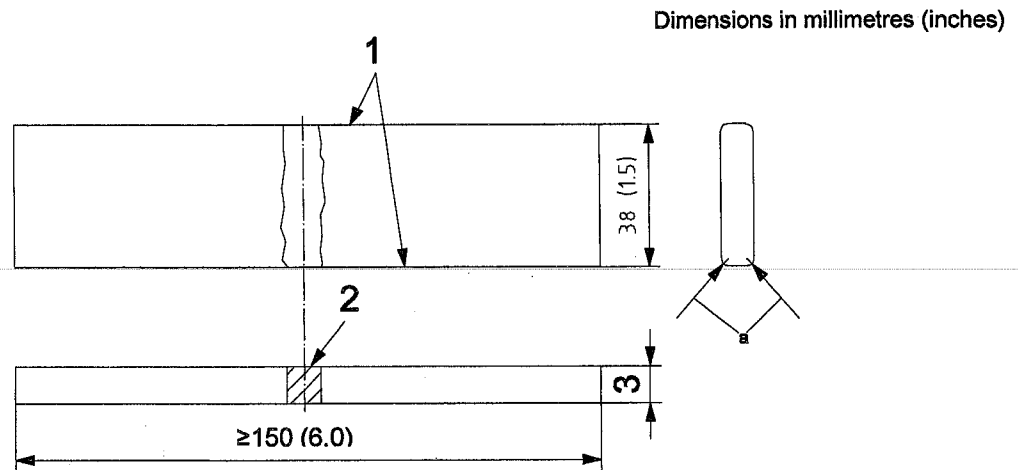
Key

- 1 long edges machined or oxygen cut, or both
- 2 weld
- 3 wall thickness

^a The radius, *r*, shall be less than or equal to 1,6 (0.063).

a) SAW and COW pipes

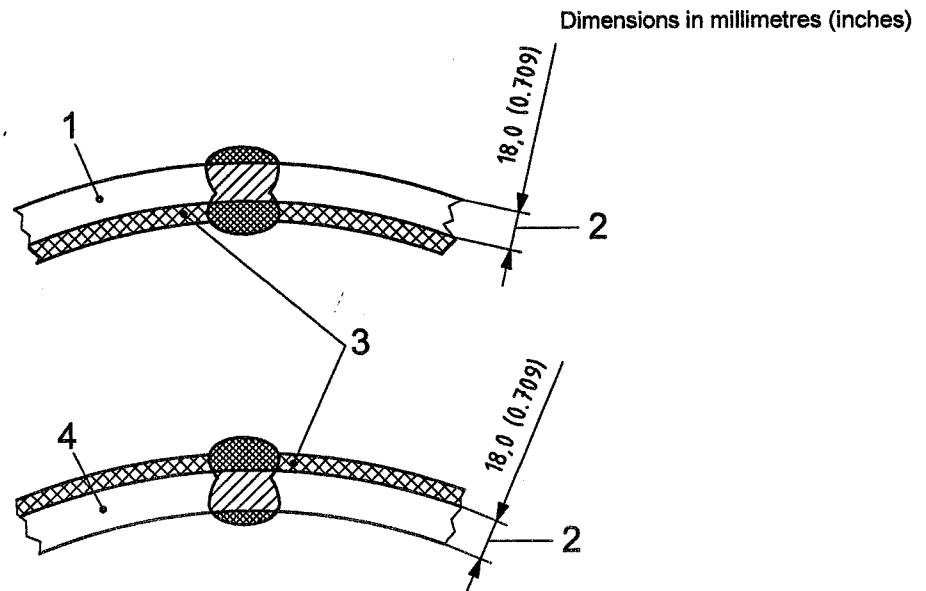
Figure 8 — Guided-bend test pieces

**Key**

- 1 long edges machined or oxygen cut, or both
- 2 weld
- 3 wall thickness

a The radius, r , shall be less than or equal to 1,6 (0.063).

b) LW pipe with $D \geq 323,9$ mm (12.750 in)

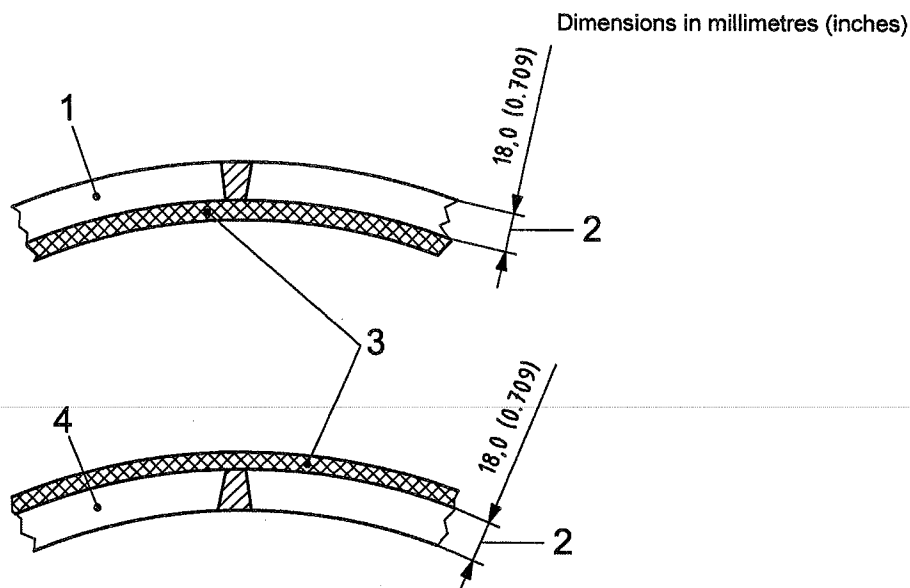
**Key**

- 1 face-bend test piece
- 2 reduced thickness
- 3 material removed before or after flattening
- 4 root-bend test piece

Jig dimensions for pipe with $t = 19,0$ mm (0.748 in) shall be used.

c) Reduced-thickness test pieces [optional for SAW and COW pipes with $t > 19,0$ mm (0.748 in)]

Figure 8 — Guided-bend test pieces (continued)

**Key**

- 1 face-bend test piece
- 2 reduced thickness
- 3 material removed before or after flattening
- 4 root-bend test piece

Jig dimensions for pipe with $t = 19,0$ mm (0.748 in) shall be used.

d) Reduced-thickness test pieces [optional for LW pipe with $t > 19,0$ mm (0.748 in)]

Figure 8 — Guided-bend test pieces (continued)

10.2.4 Test methods

10.2.4.1 Product analysis

Unless otherwise agreed upon when ordering, the choice of a suitable physical or chemical method of analysis to determine the product analysis is at the discretion of the manufacturer. In cases of dispute, the analysis shall be carried out by a laboratory approved by the two parties. In these cases, the reference method of analysis shall be agreed upon, where possible, with reference to ISO/TR 9769 or ASTM A751.

NOTE ISO/TR 9769 covers a list of available International Standards for chemical analysis, with information on the application and precision of the various methods.

10.2.4.2 Tensile test

The tensile test shall be carried out in accordance with ISO 6892-1 or ASTM A370.

For pipe body tests, the yield strength, the tensile strength, the yield ratio (as appropriate), and the percentage elongation after fracture shall be determined. For pipe weld tests, the tensile strength shall be determined.

The percentage elongation after fracture shall be reported with reference to a gauge length of 50 mm (2 in). For test pieces having a gauge length less than 50 mm (2 in), the measured elongation after fracture shall be converted to a percentage elongation in 50 mm (2 in) in accordance with ISO 2566-1 or ASTM A370.

10.2.4.3 CVN impact test

The Charpy test shall be carried out in accordance with ASTM A370 unless ISO 148-1 and the required striker radius (2 mm or 8 mm) are specified in the purchase order.

10.2.4.4 Drop-weight tear test

The drop-weight tear test shall be carried out in accordance with API RP 5L3.

10.2.4.5 Full section bend test

The bend test shall be carried out in accordance with ISO 8491 or ASTM A370.

For each test unit, one full-section test piece of appropriate length shall be bent cold through 90° around a mandrel having a diameter no larger than 12 *D*.

10.2.4.6 Guided-bend test

The guided-bend test shall be carried out in accordance with ISO 7438 or ASTM A370.

The mandrel dimension, A_{gb} , expressed in millimetres (inches), shall not be larger than that determined using Equation (5), with the result rounded to the nearest 1 mm (0.1 in):

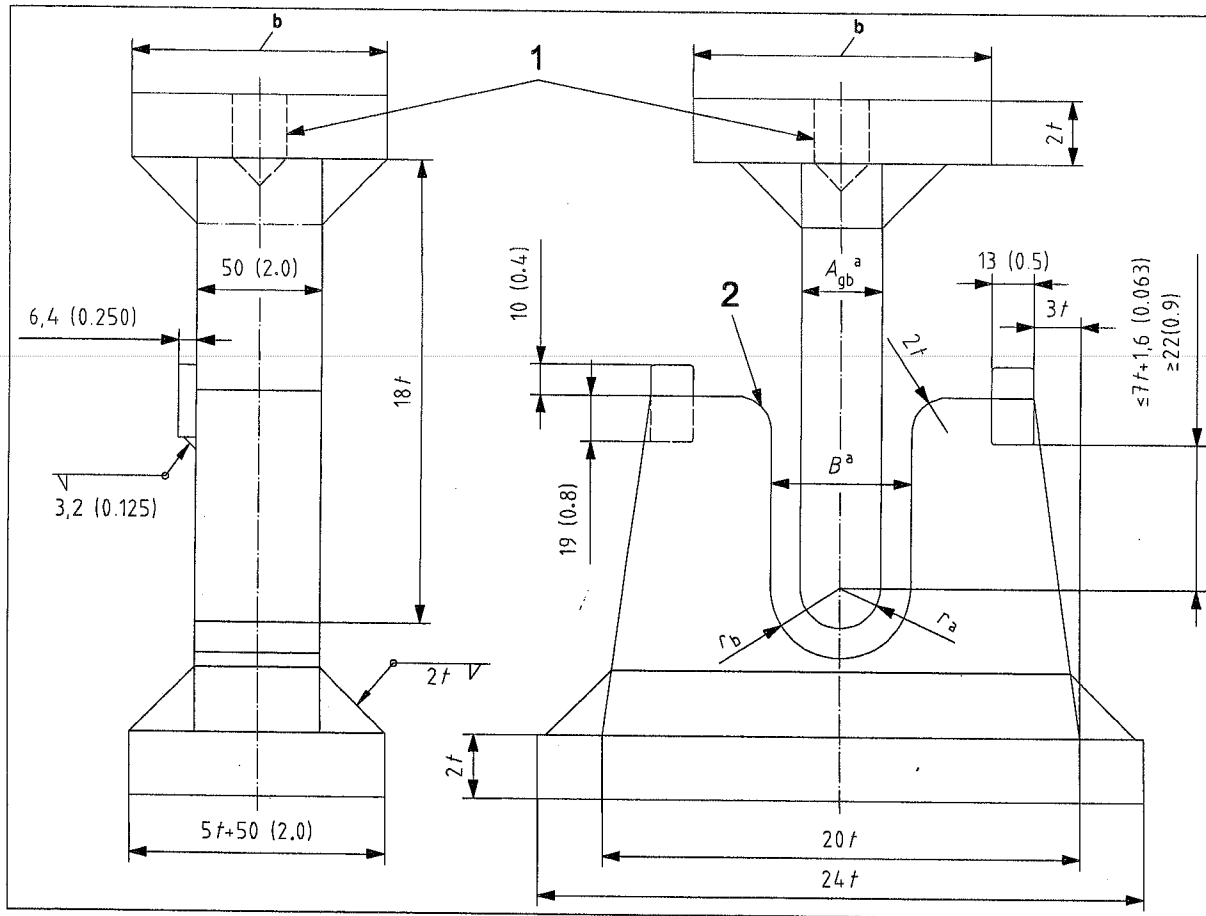
$$A_{gb} = \frac{1,15(D-2t)}{\left(\varepsilon \frac{D}{t} - 2\varepsilon - 1\right)} - t \quad (5)$$

where

- D* is the specified outside diameter, expressed in millimetres (inches);
- t* is the specified wall thickness when using full thickness pieces, expressed in millimetres (inches). It is 19 mm (0.748 in.) when using reduced-thickness test pieces;
- ε is the strain, as given in Table 23;
- 1,15 is the peaking factor.

Both test pieces shall be bent 180° in a jig as shown in Figure 9. One test piece shall have the root of the weld directly in contact with the mandrel; the other test piece shall have the face of the weld directly in contact with the mandrel.

Dimensions in millimetres (inches)



Key

- 1 tapped mounting hole
- 2 shoulders, hardened and greased, or hardened rollers

B $A_{gb} + 2t + 3,2 \text{ mm } (0.125 \text{ in})$

r_a radius of the mandrel for the guided-bend test

r_b radius of the die for the guided-bend test

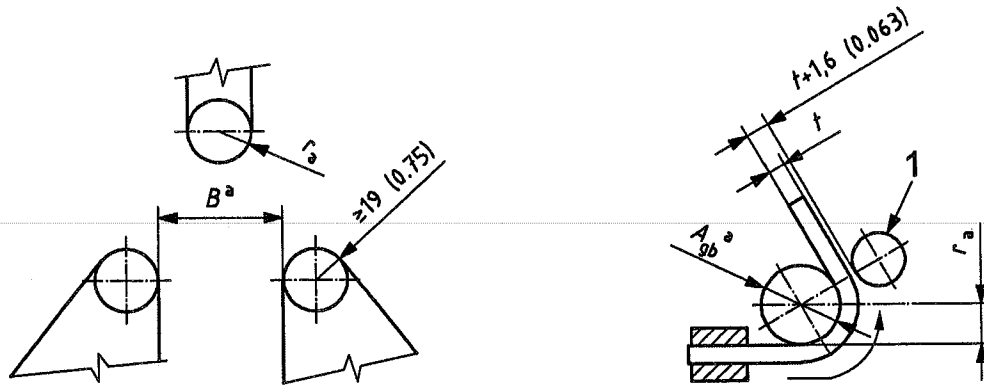
^a These symbols have been retained on the basis of their long-standing use by API in API 5L and API 5CT^[21].

^b As needed.

a) Plunger type

Figure 9 — Jigs for guided-bend test

Dimensions in millimetres (inches)

**Key**

1 roller

B $A_{gb} + 2t + 3,2 \text{ mm (0.125 in)}$ ^a These symbols have been retained on the basis of their long-standing use by API in API 5L and API 5CT^[21].**b) Adjustable type****c) Wrap-around type****Figure 9 — Jigs for guided-bend test (continued)****Table 23 — Strain values for guided-bend test**

Pipe grade	Strain value ^a ϵ
L210 or A	0,165 0
L245 or B	0,137 5
L290 or X42	0,137 5
L320 or X46	0,132 5
L360 or X52	0,125 0
L390 or X56	0,117 5
L415 or X60	0,112 5
L450 or X65	0,110 0
L485 or X70	0,102 5
L555 or X80	0,095 0
L625 or X90	0,085 0
L690 or X100	0,080 0
L830 or X120	0,067 5

^a For intermediate grades, the strain values shall be obtained by interpolation, based upon the specified minimum tensile strength, with the interpolated value rounded to the nearest multiple of 0,002 5.

10.2.4.7 Flattening test

The flattening test shall be carried out in accordance with ISO 8492 or ASTM A370.

As shown in Figure 6, one of the two test pieces taken from both end-of-coil locations shall be tested with the weld at the 6 o'clock position or 12 o'clock position, whereas the remaining two test pieces shall be tested at the 3 o'clock position or 9 o'clock position.

Test pieces taken from crop ends at weld stops shall be tested at the 3 o'clock position or 9 o'clock position only.

10.2.4.8 Hardness test

When suspected hard spots are detected by visual inspection, hardness tests shall be carried out in accordance with ISO 6506, ISO 6507, ISO 6508 or ASTM A370 using portable hardness test equipment and methods complying with ASTM A956, ASTM A1038 or ASTM E110 respectively depending on the method used.

10.2.5 Macrographic and metallographic tests

10.2.5.1 Except as allowed by 10.2.5.2, the alignment of internal and external seams of SAW and COW pipes [see Figure 4 d) and Figure 4 e)] shall be verified by macrographic testing.

10.2.5.2 Alternative methods, such as ultrasonic inspection, may be used if agreed, provided that the ability of such equipment to detect misalignment is demonstrated. If such an alternative method is used, a macrographic test shall be carried out at the beginning of the production of each combination of specified outside diameter and specified wall thickness.

10.2.5.3 For pipe that is required to be seam-heat-treated (see 8.8.1 or 8.8.2, whichever is applicable), it shall be verified by metallographic testing that the entire HAZ has been appropriately heat treated over the full wall thickness. For pipe that is not required to be seam-heat-treated (see 8.8.1), it shall be verified by metallographic testing that no untempered martensite remains.

In addition, a hardness test and maximum hardness may be agreed.

10.2.5.4 For SAW pipe seams made with tack welds, the melting and coalescence of the tack weld into the final weld seam shall be verified by macrographic testing [See 8.4.2 a)].

10.2.6 Hydrostatic test

10.2.6.1 Test pressures for all sizes of SMLS pipe, and for welded pipe with $D \leq 457$ mm (18.000 in), shall be held for not less than 5 seconds. Test pressures for welded pipe with $D > 457$ mm (18.000 in) shall be held for not less than 10 seconds. For threaded-and-coupled pipe, the test shall be applied with the couplings made up power-tight if agreed, except that pipe with $D > 323.9$ mm (12.375 in) may be tested in the plain-end condition. For threaded pipe furnished with couplings made up handling-tight, the hydrostatic test shall be made on the pipe in the plain-end, threads-only or coupled condition unless a specific condition is specified in the purchase order.

10.2.6.2 In order to ensure that every length of pipe is tested to the required test pressure, each tester, except those on which only continuous welded pipe is tested, shall be equipped with a recording gauge that can record the test pressure and the test duration for each length of pipe, or shall be equipped with some positive and automatic or interlocking device to prevent pipe from being classified as tested until the test requirements (pressure and duration) have been met. Such records or charts shall be available for examination at the manufacturer's facility by the purchaser's inspector, if applicable. The

test-pressure measuring device shall be calibrated by means of a dead-weight tester, or equivalent, no more than four months prior to each use. At the option of the manufacturer, test pressures that are higher than required may be used.

NOTE In all cases, the specified test pressure represents the gauge pressure value below which the pressure is not permitted to fall during the specified test duration.

10.2.6.3 Test pressures for light-wall threaded pipe shall be as given in Table 24.

10.2.6.4 Test pressures for heavy-wall threaded pipe shall be as given in Table 25.

Table 24 — Test pressures for light-wall threaded pipe

Specified outside diameter <i>D</i> mm (in)	Specified wall thickness <i>t</i> mm (in)	Test pressure MPa (psi) minimum			
		Grade			
		L175 or A25	L175P or A25P	L210 or A	L245 or B
10,3 (0.405)	1,7 (0.068)	4,8 (700)	4,8 (700)	4,8 (700)	4,8 (700)
13,7 (0.540)	2,2 (0.088)	4,8 (700)	4,8 (700)	4,8 (700)	4,8 (700)
17,1 (0.675)	2,3 (0.091)	4,8 (700)	4,8 (700)	4,8 (700)	4,8 (700)
21,3 (0.840)	2,8 (0.109)	4,8 (700)	4,8 (700)	4,8 (700)	4,8 (700)
26,7 (1.050)	2,9 (0.113)	4,8 (700)	4,8 (700)	4,8 (700)	4,8 (700)
33,4 (1.315)	3,4 (0.133)	4,8 (700)	4,8 (700)	4,8 (700)	4,8 (700)
42,2 (1.660)	3,6 (0.140)	6,9 (1 000)	6,9 (1 000)	6,9 (1 000)	6,9 (1 000)
48,3 (1.900)	3,7 (0.145)	6,9 (1 000)	6,9 (1 000)	6,9 (1 000)	6,9 (1 000)
60,3 (2.375)	3,9 (0.154)	6,9 (1 000)	6,9 (1 000)	6,9 (1 000)	6,9 (1 000)
73,0 (2.875)	5,2 (0.203)	6,9 (1 000)	6,9 (1 000)	6,9 (1 000)	6,9 (1 000)
88,9 (3.500)	5,5 (0.216)	6,9 (1 000)	6,9 (1 000)	6,9 (1 000)	6,9 (1 000)
101,6 (4.000)	5,7 (0.226)	8,3 (1 200)	8,3 (1 200)	8,3 (1 200)	9,0 (1 300)
114,3 (4.500)	6,0 (0.237)	8,3 (1 200)	8,3 (1 200)	8,3 (1 200)	9,0 (1 300)
141,3 (5.563)	6,6 (0.258)	8,3 (1 200)	8,3 (1 200)	8,3 (1 200)	9,0 (1 300)
168,3 (6.625)	7,1 (0.280)	a	a	8,3 (1 200)	9,0 (1 300)
219,1 (8.625)	7,0 (0.277)	a	a	7,9 (1 160)	9,2 (1 350)
219,1 (8.625)	8,2 (0.258)	a	a	9,3 (1 340)	10,8 (1 570)
273,1 (10.750)	7,1 (0.280)	a	a	6,5 (940)	7,5 (1 090)
273,1 (10.750)	7,8 (0.307)	a	a	7,1 (1 030)	8,3 (1 200)
273,1 (10.750)	9,3 (0.365)	a	a	8,5 (1 220)	9,8 (1 430)
323,9 (12.750)	8,4 (0.330)	a	a	6,4 (930)	7,5 (1 090)
323,9 (12.750)	9,5 (0.375)	a	a	7,3 (1 060)	8,5 (1 240)
355,6 (14.000)	9,5 (0.375)	a	a	6,6 (960)	7,7 (1 130)
406,4 (16.000)	9,5 (0.375)	a	a	5,8 (840)	6,8 (980)
457 (18.000)	9,5 (0.375)	a	a	5,2 (750)	6,0 (880)
508 (20.000)	9,5 (0.375)	a	a	4,6 (680)	5,4 (790)

^a Not applicable.

Table 25 — Test pressures for heavy-wall threaded pipe

Specified outside diameter <i>D</i> mm (in)	Specified wall thickness <i>t</i> mm (in)	Test pressure MPa (psi) minimum			
		Grade			
		L175 or A25	L175P or A25P	L210 or A	L245 or B
10,3 (0.405)	2,4 (0.095)	5,9 (850)	5,9 (850)	5,9 (850)	5,9 (850)
13,7 (0.540)	3,0 (0.119)	5,9 (850)	5,9 (850)	5,9 (850)	5,9 (850)
17,1 (0.675)	3,2 (0.126)	5,9 (850)	5,9 (850)	5,9 (850)	5,9 (850)
21,3 (0.840)	3,7 (0.147)	5,9 (850)	5,9 (850)	5,9 (850)	5,9 (850)
26,7 (1.050)	3,9 (0.154)	5,9 (850)	5,9 (850)	5,9 (850)	5,9 (850)
33,4 (1.315)	4,5 (0.179)	5,9 (850)	5,9 (850)	5,9 (850)	5,9 (850)
42,2 (1.660)	4,9 (0.191)	9,0 (1 300)	9,0 (1 300)	10,3 (1 500)	11,0 (1 600)
48,3 (1.900)	5,1 (0.200)	9,0 (1 300)	9,0 (1 300)	10,3 (1 500)	11,0 (1 600)
60,3 (2.375)	5,5 (0.218)	9,0 (1 300)	9,0 (1 300)	17,0 (2 470)	17,0 (2 470)
73,0 (2.875)	7,0 (0.276)	9,0 (1 300)	9,0 (1 300)	17,0 (2 470)	17,0 (2 470)
88,9 (3.500)	7,6 (0.300)	9,0 (1 300)	9,0 (1 300)	17,0 (2 470)	17,0 (2 470)
101,6 (4.000)	8,1 (0.318)	11,7 (1 700)	11,7 (1 700)	19,0 (2 760)	19,0 (2 760)
114,3 (4.500)	8,6 (0.337)	11,7 (1 700)	11,7 (1 700)	18,7 (2 700)	19,0 (2 760)
141,3 (5.563)	9,5 (0.375)	11,7 (1 700)	11,7 (1 700)	16,7 (2 430)	19,0 (2 760)
168,3 (6.625)	11,0 (0.432)	a	a	16,2 (2 350)	18,9 (2 740)
219,1 (8.625)	12,7 (0.500)	a	a	14,4 (2 090)	16,8 (2 430)
273,1 (10.750)	12,7 (0.500)	a	a	11,6 (1 670)	13,4 (1 950)
323,9 (12.375)	12,7 (0.500)	a	a	9,7 (1 410)	11,3 (1 650)

^a Not applicable.

10.2.6.5 Except as allowed by 10.2.6.6, 10.2.6.7 and the footnotes to Table 26, the hydrostatic test pressure, *P*, expressed in megapascals (pounds per square inch), for plain-end pipe shall be determined using Equation (6), with the results rounded to the nearest 0,1 MPa (10 psi):

$$P = \frac{2St}{D} \quad (6)$$

where

- S* is the hoop stress, expressed in megapascals (pounds per square inch), equal to a percentage of the specified minimum yield strength of the pipe, as given in Table 26;
- t* is the specified wall thickness, expressed in millimetres (inches);
- D* is the specified outside diameter, expressed in millimetres (inches).

Table 26 — Percentage of specified minimum yield strength for determination of S

Pipe grade	Specified outside diameter D mm (in)	Percentage of specified minimum yield strength for determination of S	
		Standard test pressure	Alternative test pressure
L175 or A25	≤ 141,3 (5.563)	60 ^a	75 ^a
L175P or A25P	≤ 141,3 (5.563)	60 ^a	75 ^a
L210 or A	Any	60 ^a	75 ^a
L245 or B	Any	60 ^a	75 ^a
L290 or X42 to L830 or X120	≤ 141,3 (5.563)	60 ^b	75 ^c
	> 141,3 (5.563) to 219,1 (8.625)	75 ^b	75 ^c
	> 219,1 (8.625) to < 508 (20.000)	85 ^b	85 ^c
	≥ 508 (20.000)	90 ^b	90 ^c

^a For $D \leq 88,9$ mm (3.500 in), it is not necessary that the test pressure exceed 17,0 MPa (2 470 psi); for $D > 88,9$ mm (3.500 in), it is not necessary that the test pressure exceed 19,0 MPa (2 760 psi).

^b It is not necessary that the test pressure exceed 20,5 MPa (2 970 psi).

^c For $D \leq 406,4$ mm (16.000 in), it is not necessary that the test pressure exceed 50,0 MPa (7 260 psi); for $D > 406,4$ mm (16.000 in), it is not necessary that the test pressure exceed 25,0 MPa (3 630 psi).

10.2.6.6 If pressure testing involves an end-sealing ram that produces a compressive longitudinal stress, the hydrostatic test pressure, P , expressed in megapascals (pounds per square inch), may be determined using Equation (7), with the result rounded to the nearest 0,1 MPa (10 psi), provided that the required test pressure produces a hoop stress in excess of 90 % of the specified minimum yield strength:

$$P = \frac{S - \left(\frac{P_R \times A_R}{A_p} \right)}{\frac{D}{2t} - \frac{A_i}{A_p}} \quad (7)$$

where

S is the hoop stress, expressed in megapascals (pounds per square inch), equal to a percentage of the specified minimum yield strength of the pipe (see Table 26);

P_R is the internal pressure on end-sealing ram, expressed in megapascals (pounds per square inch);

A_R is the cross-sectional area of end-sealing ram, expressed in square millimetres (square inches);

A_p is the cross-sectional area of pipe wall, expressed in square millimetres (square inches);

A_i is the internal cross-sectional area of pipe, expressed in square millimetres (square inches);

D is the specified outside diameter, expressed in millimetres (inches);

t is the specified wall thickness, expressed in millimetres (inches).

10.2.6.7 If agreed, the minimum permissible wall thickness, t_{\min} , may be used in place of the specified wall thickness, t , for the determination of the required test pressure (see 10.2.6.5 or 10.2.6.6, whichever is applicable), provided that a hoop stress of at least 95 % of the specified minimum yield strength of the pipe is used.

10.2.7 Visual inspection

10.2.7.1 Except as allowed by 10.2.7.2, each pipe shall be visually inspected to detect surface defects, with an illuminance of at least 300 lx (28 fc). Such inspection shall be over the entire external surface and shall cover as much of the internal surface as is practical.

NOTE Generally, the entire inside surface of large diameter SAW and COW pipes is visually inspected from inside the pipe.

10.2.7.2 Visual inspection may be replaced by other inspection methods that have a demonstrated capability of detecting surface defects.

10.2.7.3 Visual inspection shall be conducted by personnel who

- a) are trained to detect and evaluate surface imperfections;
- b) have visual acuity that meets the applicable requirements of ISO 11484 or ASNT SNT-TC-1A or equivalent.

10.2.7.4 The surface of cold-formed welded pipe shall be inspected to detect geometric deviations in the contour of the pipe. If this inspection fails to disclose mechanical damage as the cause of the irregular surface, but indicates that the irregular surface can be attributed to a hard spot, the dimensions of the area, and if necessary its hardness, shall be determined. The choice of the test method for hardness testing is at the option of the manufacturer. If the dimensions and hardness exceed the acceptance criteria given in 9.10.6, the hard spot shall be removed in accordance with procedures specified in 9.10.7 and Annex C.

10.2.8 Dimensional testing

10.2.8.1 The diameter of pipes shall be measured at least once per 4 hours per operating shift to verify conformance to the diameter tolerances (see Table 10). Unless a method is specified in the purchase order, diameter measurements shall be made with a circumferential tape, or appropriate uses of micrometer, ring gauge, snap gauge, caliper, ovality gauge, coordinate measuring machine, or optical measuring device. Unless otherwise agreed, for $D \geq 508$ mm (20.000 in.), measurements made by circumferential tape shall govern in case of dispute.

NOTE 1 Ring gauges used to measure pipe diameter are usually manufactured to specified dimensions for each pipe size from dimensionally stable material such as steel, aluminium or other approved material, and shall be of rigid construction but sufficiently light to permit manipulation by one inspector. The ring gauge design usually incorporates handles to allow the inspector to position the gauge accurately and safely within or over the pipe. The diameter of internal ring gauges is usually 3,2 mm (0.125 in) less than the nominal internal diameter of the pipe. External ring gauges usually have a bore diameter not exceeding the sum of the specified outside diameter of the pipe plus the allowable diameter tolerance. For inspection of submerged arc welded pipe, ring gauges can be slotted or notched to permit passage of the gauge over the weld reinforcement. It is necessary that the pipe permit the passage of the ring gauge within (internal) or over (external) each end of the pipe for a minimum distance of 100 mm (4.0 in).

NOTE 2 Coordinate measuring machines are mechanical systems designed to track a mobile measuring probe to determine the coordinates of points on a work surface.

10.2.8.2 The out-of-roundness of pipes shall be determined at least once per 4 hours per operating shift. Except as allowed by 10.2.8.3, the out-of-roundness shall be determined as the difference between

the largest outside diameter and the smallest outside diameter, as measured in the same cross-sectional plane.

NOTE Out-of-roundness measurements taken in stacks are invalid due to the elastic deformations caused by forces exerted by pipes adjacent to those being measured.

10.2.8.3 If agreed, for expanded pipe with $D \geq 219,1$ mm (8.625 in) and for non-expanded pipe, inside diameter measurements shall be used to determine conformance with the diameter tolerances. The out-of-roundness may be determined as the difference between the largest inside diameter and the smallest inside diameter, as measured in the same cross-sectional plane.

10.2.8.4 For SAW and COW pipe, the greatest deviation of flat spots or peaks from the normal contour of the pipe at the weld at a pipe end shall be measured with respect to a template that is oriented transverse to the pipe axis and has a length of $0,25 D$ or 200 mm (8.0 in), whichever is the lesser.

10.2.8.5 Each length of pipe shall be measured for conformance to the specified wall thickness requirements. The wall thickness at any location shall be within the tolerances specified in Table 11, except that the weld area shall not be limited by the plus tolerance. Wall thickness measurements shall be made with a mechanical calliper or with a properly calibrated non-destructive inspection device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical calliper shall govern. The mechanical calliper shall be fitted with contact pins. The end of the pin contacting the inside surface of the pipe shall be rounded to a maximum radius of 38,1 mm (1.50 in) for pipe of size 168,3 mm (6.625 in) or larger, and up to a radius of $D/4$ for pipe smaller than size 168,3 mm (6.625 in) with a minimum radius of 3,2 mm (0.125 in). The end of the pin contacting the outside surface of the pipe shall be either flat or rounded to a minimum radius of 31,2 mm (1.25 in).

10.2.8.6 For threaded-and-coupled pipe, the length shall be measured to the outer face of the coupling. The length of threaded-and-coupled pipe may be determined before the couplings are attached, provided the proper allowance is made for the length of the couplings.

10.2.8.7 For the verification of conformance with the dimensional and geometrical requirements specified in 9.11 to 9.13, suitable methods shall be used. Unless particular methods are specified in the purchase order, the methods used shall be at the discretion of the manufacturer.

10.2.9 Weighing

For pipe with $D \geq 141,3$ mm (5.563 in), the lengths of pipe shall be weighed individually, except that for welded jointers it shall be permissible to weigh the individual lengths comprising the jointer or the jointer itself. For pipe with $D < 141,3$ mm (5.563 in), the lengths of pipe shall be weighed either individually or in a convenient group of pipes selected by the manufacturer.

Threaded-and-coupled pipe shall be weighed either:

- a) with the couplings screwed on but without thread protectors, except for order items with a mass of 18 tonnes (20 tons) or more for which proper allowance shall be made for the weight of the thread protectors, or
- b) before the couplings are attached, provided that allowance is made for the weight of the couplings.

10.2.10 Non-destructive inspection

Non-destructive inspection shall be in accordance with Annex E.

10.2.11 Reprocessing

If any mechanical property test result for a test unit of pipe fails to conform to the applicable requirements, the manufacturer may elect to heat treat the test unit of pipe in accordance with the requirements of Table 3, consider it a new test unit, test it in accordance with all requirements of 10.2.12 and 10.2.4 that are applicable to the order item, and proceed in accordance with the applicable requirements of this Standard. After one reprocessing heat treatment, any additional reprocessing heat treatment shall be subject to agreement with the purchaser.

For non-heat treated pipe, any reprocessing heat treatment shall be subject to agreement with the purchaser. For heat treated pipe, any reprocessing with a different type of heat treatment (see Table 3) shall be subject to agreement with the purchaser.

10.2.12 Retesting

10.2.12.1 Recheck analyses

If the product analyses of both samples representing the heat fail to conform to the specified requirements, at the manufacturer's option either the heat shall be rejected or the remainder of the heat shall be tested individually for conformance to the specified requirements. If the product analysis of only one of the samples representing the heat fails to conform to the specified requirements, at the manufacturer's option, either the heat shall be rejected or two recheck analyses shall be made using two additional samples from the heat. If both recheck analyses conform to the specified requirements, the heat shall be accepted, except for the pipe, plate, or coil from which the initial sample that failed was taken. If one or both recheck analyses fail to conform to the specified requirements, at the manufacturer's option either the heat shall be rejected or the remainder of the heat shall be tested individually for conformance to the specified requirements.

For such individual testing, analyses for only the rejecting element or elements need be determined.

Samples for recheck analyses shall be taken in the same location as specified for product analyses samples.

10.2.12.2 Tensile retests

Tensile retest provisions are as follows.

- a) For all PSL 1 products, PSL 2 products with R, N, and Q delivery conditions, and PSL 2 products with M delivery conditions of grades less than L450 or X65, (see Tables 2 and 3).

If the tensile test specimen representing the test unit of pipe fails to conform to the specified requirements, the manufacturer may elect to retest two additional lengths from the same test unit. If both retested specimens conform to the specified requirements, all the lengths in the test unit shall be accepted, except the length from which the initial specimen was taken. If one or both of the retested specimens fail to conform to the specified requirements, the manufacturer may elect to individually test the remaining lengths in the test unit. Specimens for retest shall be taken in the same manner as the specimen that failed to meet the minimum requirements. If applicable, reprocessing shall be as defined in 10.2.11.

- b) For PSL 2 products with M delivery conditions of grades L450 or X65, or greater (see Table 3).

If the tensile specimen representing the test unit fails to conform to the specified requirements, the manufacturer may elect to retest two additional lengths from the same test unit. Specimens for retest shall be taken in the same manner as the original specimen that failed to meet the minimum requirements but should be from two different mother coils or plates, as applicable. If one or both of the retested specimens

fail to conform to the specified requirements, the manufacturer may elect to individually test the remaining lengths in the test unit. If both retest specimens conform to the specified requirements, the test unit shall be accepted except the lengths from the mother coil or plate from which the initial specimen was taken. These lengths shall have one of the following dispositions:

- 1) all pipes shall be rejected, or
- 2) each pipe in the test unit shall be tested with the pipe with satisfactory test results accepted, or
- 3) provided individual pipe traceability to mother coil/plate location, the manufacturer shall test additional lengths adjacent to (before, after and beside, as applicable) the initial failure within the mother coil or plate considering adjacent daughter coil(s) or plate(s) as applicable. Pipe testing shall continue until satisfactory results surround the non-conforming section of the mother coil/plate. The pipes from the non-conforming section of mother coil/plate shall be rejected and the remainder of the pipe from the test unit accepted.

If applicable, reprocessing shall be defined as in 10.2.11.

10.2.12.3 Flattening retests

Flattening retest provisions are as follows:

- a) Non-expanded electric welded pipe in grades higher than L175 or A25 and non-expanded laser welded pipe smaller than 323,9 mm (12.750 in) produced in single lengths:

The manufacturer may elect to retest any failed end until the requirements are met, providing the finished pipe is not less than 80% of its length after initial cropping.

- b) Non-expanded electric welded pipe in grades higher than L175 or A25 and non-expanded laser welded pipe smaller than 323,9 mm (12.750 in) produced in multiple lengths:

Where one or more of the flattening tests fail to conform to the specified requirements, the manufacturer may retest the pipe end after cropping the defective pipe end. Alternatively the manufacturer may reject the defective pipe(s) and retest the adjacent end of the next pipe. The retest shall consist of two specimens, one tested with the seam weld at 0° and one tested with the seam weld at 90°. If the retest fails to conform to the specified requirements, the manufacturer may either reject the pipes produced from the affected multiple length or retest each end of each remaining individual length produced from the coil with the weld alternatively at 0° and 90°. If the retest conforms to the specified requirements, the remaining portion of the multiple lengths shall be accepted.

- c) Cold-expanded electric welded pipe in grades higher than L175 or A25, all welded Grade L175 or A25 in sizes 60,3 mm (2.875 in) and larger; and cold-expanded laser welded pipe smaller than size 323,9 mm (12.750 in):

The manufacturer may elect to retest one end of each of two additional lengths of the same test unit. If both retests are acceptable, all lengths in the test unit shall be accepted, except the original failed length. If one or both retests fail, the manufacturer may elect to repeat the test on specimens cut from one end of each of the remaining individual lengths in the test unit.

If applicable, reprocessing shall be as defined in 10.2.11.

10.2.12.4 Bend retests

If the specimen fails to conform to the specified requirements, the manufacturer may elect to make retests on specimens cut from two additional lengths from the same test unit. If all retest specimens conform to the specified requirements, all the lengths in the test unit shall be accepted, except the length from which the initial specimen was taken. If one or more of the retest specimens fail to conform to the specified requirements, the manufacturer may elect to repeat the test on specimens cut from the individual lengths remaining in the test unit.

If applicable, reprocessing shall be as defined in 10.2.11.

10.2.12.5 Guided-bend retests

If one or both of the guided-bend specimens fail to conform to the specified requirements, the manufacturer may elect to repeat the tests on specimens cut from two additional lengths of pipe from the same test unit. If such specimens conform to the specified requirements, all lengths in the test unit shall be accepted, except the length initially selected for test. If any of the retested specimens fail to pass the specified requirements, the manufacturer may elect to test specimens cut from individual lengths remaining in the test unit. The manufacturer may also elect to retest any length that has failed to pass the test by cropping back and cutting two additional specimens from the same end. If the requirements of the original test are met by both of these additional tests, that length shall be acceptable. No further cropping and retesting is permitted. Specimens for retest shall be taken in the same manner as specified in Tables 19 and 20 and 10.2.3.6.

If applicable, reprocessing shall be as defined in 10.2.11.

10.2.12.6 Charpy retests

In the event that a set of Charpy test specimens fail to meet the acceptance criteria, the manufacturer may elect to replace the test unit of material involved or alternatively to test two more lengths from that test unit. If both of the new tests meet the acceptance criteria, then all pipe in that test unit, with the exception of the original selected length, shall be considered to meet the requirement. Failure of either of the two additional tests shall require testing of each length in the test unit for acceptance.

If applicable, reprocessing shall be as defined in 10.2.11.

10.2.12.7 Hardness retests

If the hardness test specimen representing a test unit of pipe fails to conform to the specified requirements, the manufacturer may elect to retest two additional lengths from the same test unit. If both retested specimens conform to the specified requirements, all the lengths in a test unit shall be accepted, except the length from which the initial specimen was taken. If one or both of the retested specimens fail to conform to the specified requirements, the manufacturer may elect to individually test the remaining lengths in the test unit. Specimens for retest shall be taken in the same manner as the specimen that failed to meet the minimum requirements (see H.7 or J.8, as applicable).

If applicable, reprocessing shall be as defined in 10.2.11.

10.2.12.8 DWT retests

In the event that a set of DWT test specimens fail to meet the acceptance criteria, the manufacturer may elect to replace the test unit of material involved or alternatively to test two more lengths from that test unit. If both of the new tests meet the acceptance criteria, then all pipe in that test unit, with the exception of the original selected length, shall be accepted. Failure of either of the two additional tests shall require

testing of each length in the test unit for acceptance. Specimens for retest shall be taken in the same manner as the specimen that failed to meet the minimum requirements (see 10.2.3).

If applicable, reprocessing shall be as defined in 10.2.11.

11 Marking

11.1 General

11.1.1 Pipe and pipe couplings manufactured in accordance with this Standard shall be marked by the manufacturer in the same sequence as they appear in 11.2.1 a) to j) as applicable.

NOTE While the required markings are generally applied in a single straight line, the markings are permitted to wrap around on to multiple lines provided the sequence of information is maintained as read from left to right and from top to bottom.

11.1.2 The required markings on couplings shall be die-stamped or, if agreed, paint-stencilled.

11.1.3 If the purchase order requires API Spec 5L pipe to be supplied, markings identifying Spec 5L pipe shall be required.

11.1.4 Additional markings, as desired by the manufacturer or as specified in the purchase order, may be applied but shall not interrupt the sequence of the required markings as they appear in 11.2.1 a) to j) as applicable. Such additional markings shall be located after the end of the required marking sequence or as a separate marking at some other location on the pipe.

11.2 Pipe markings

11.2.1 Pipe markings shall include the following information sequentially, as applicable:

- a) name or mark of the manufacturer of the pipe (X);
- b) "API Spec 5L" shall be marked when the product is in complete compliance with this standard, appropriate annexes and this section. Products in compliance with multiple compatible standards may be marked with the name of each standard;
- c) specified outside diameter;
- d) specified wall thickness;
- e) pipe steel grade (steel name) (see Table 1, Table H.1 or Table J.1, whichever is applicable) and if agreed, both corresponding SI and USC steel grades may be marked on the pipe with the corresponding steel grade marked immediately after the order item steel grade;
- f) product specification level designation followed by the letter G if Annex G is applicable (see G.5.1);
- g) type of pipe (see Table 2);
- h) mark of the customer's inspection representative (Y), if applicable;
- i) an identification number (Z), which permits the correlation of the product or delivery unit (e.g. bundled pipe) with the related inspection document, if applicable;

- j) if the specified hydrostatic test pressure is higher than the test pressure specified in Tables 24 or 25 as applicable, or exceeding the pressures stated in note a, b, or c of Table 26 if applicable, the word TESTED shall be marked at the end of the marking immediately followed by the specified test pressure in psi if ordered to USC units or MPa if ordered to SI units.

- EXAMPLE 1 (For SI units) X API Spec 5L 508 12,7 L360M PSL 2 SAWL Y Z
- EXAMPLE 2 (For USC units) X API Spec 5L 20 0.500 X52M PSL 2 SAWL Y Z
- EXAMPLE 3 If pipe also meets the requirements of compatible standard ABC.
(For SI units) X API Spec 5L/ABC 508 12,7 L360M PSL 2 SAWL Y Z
- EXAMPLE 4 If pipe also meets the requirements of compatible standard ABC.
(For USC units) X API Spec 5L/ABC 20 0.500 X52M PSL 2 SAWL Y Z
- EXAMPLE 5 If hydrotest pressure differs from the standard pressure.
(For SI units tested to 17,5 MPa) X API Spec 5L 508 12,7 L360M PSL 2 SAWL Y Z TESTED
17,5
- EXAMPLE 6 If hydrotest pressure differs from the standard pressure.
(For USC units tested to 2540 psi) X API Spec 5L 20 0.500 X52M PSL 2 SAWL Y Z TESTED
2540
- EXAMPLE 7 For USC units with both corresponding steel grades marked and application of Annex G indicated
X API Spec 5L 20 0.500 X52M L360M PSL2G SAWL Y Z
- EXAMPLE 8 For SI units with both corresponding steel grades marked and application of Annex G indicated
X API Spec 5L 508 12,7 L360M X52M PSL2G SAWL Y Z

NOTE For specified outside diameter markings in USC units, it is not necessary to include the ending zero digits to the right of the decimal sign.

11.2.2 Except as allowed by 11.2.3 and 11.2.4, the required markings shall be applied durably and legibly, as follows:

- a) For pipe with $D \leq 48,3$ mm (1.900 in), the markings shall be in one or more of the following locations:
- 1) on a tag fixed to the bundle,
 - 2) on the straps or banding clips used to tie the bundle,
 - 3) on one end of each pipe,
 - 4) continuous along the length;
- b) For pipe with $D > 48,3$ mm (1.900 in), unless a specific surface is specified in the purchase order, the markings shall be
- 1) on the outside surface of the pipe, in the sequence listed in 11.2.1, starting at a point between 450 mm and 760 mm (1.5 ft and 2.5 ft) from one of the pipe ends, or
 - 2) on the inside surface of the pipe, starting at a point at least 150 mm (6.0 in) from one of the pipe ends;

11.2.3 If agreed, low-stress die-stamping or vibro-etching on the pipe surface may be used, subject to the following limitations.

- a) Such marks shall be on the pipe bevel face or within 150 mm (6.0 in) of one of the pipe ends.
- b) Such marks shall be at least 25 mm (1.0 in) from any weld.
- c) Cold die-stamping [at temperatures $< 100\text{ }^{\circ}\text{C}$ ($210\text{ }^{\circ}\text{F}$)] of plate, coil or pipe not subsequently heat treated shall be done only if rounded or blunt dies are used.
- d) Unless otherwise agreed and specified on the purchase order, cold die stamping shall not be used on all pipe with a specified wall thickness of 4,0 mm (0.156 in) or less and all pipe of grade higher than L175 or A25 not subsequently heat treated.

11.2.4 For pipe intended for subsequent coating, if agreed, marking may be done at the coater's facility rather than at the pipe mill. In such cases, traceability shall be ensured, e.g. by application of a unique number (by individual pipe or heat of steel).

11.2.5 If a temporary protective coating (see 12.1.2) is applied, the markings shall be legible after such coating.

11.2.6 In addition to the markings specified in 11.2.1, the pipe length shall be marked as follows, in metres to two decimal places (feet to tenths of a foot) or, if agreed, in a different format.

- a) For pipe with $D \leq 48,3\text{ mm}$ (1.900 in), the total length of pipe in the bundle shall be marked on a tag, strap or banding clip attached to the bundle.
- b) Unless a specific surface is specified on the purchase order for pipe with $D > 48,3\text{ mm}$ (1.900 in), the individual pipe length (as measured on the finished pipe) shall be marked
 - 1) at a convenient location on the outside surface of the pipe, or
 - 2) at a convenient location on the inside surface of the pipe.
- c) For pipe furnished with couplings, the length as measured to the outer face of the coupling shall be marked.

11.2.7 If agreed, the manufacturer shall apply a daub of paint, approximately 50 mm (2 in) in diameter, on the inside surface of each length of pipe. The paint colour shall be as given in Table 27 if the pipe grade is applicable; for all other grades, the paint colour shall be as specified in the purchase order.

Table 27 — Paint colour

Pipe grade	Paint colour
L320 or X46	Black
L360 or X52	Green
L390 or X56	Blue
L415 or X60	Red
L450 or X65	White
L485 or X70	Purple-violet
L555 or X80	Yellow

11.3 Coupling markings

All couplings in sizes 60,3 mm (2.375 in) and larger shall be identified with the manufacturer's name or mark together with API Spec 5L.

11.4 Marking of pipe to multiple grades

11.4.1 Marking of pipe to multiple grades is permitted only by agreement between the purchaser and the manufacturer within the following limits:

- a) Pipe may have multiple markings within the following grade ranges:
 - 1) \leq L290 (X42);
 - 2) $>$ L290 (X42) to $<$ L415 (X60);
- b) for L415 (X60) & above, multiple grade markings are not allowed;
- c) Pipe shall be marked to only one PSL level.

11.4.2 The manufacturer is responsible for ensuring that the pipe conforms to all requirements of each of the certified grades. This allows pipe to be used as any of the grades individually.

11.4.3 If pipe is marked to multiple grades, a single inspection document shall be issued referencing the grade combination as marked on the pipe. The inspection document may contain a specific statement that pipe conforms to each grade individually.

11.4.4 After delivery of the pipe, no re-marking or re-certification of the pipe to a different grade or different PSL level (PSL 1 to PSL 2) shall be permitted.

11.5 Thread identification and certification

11.5.1 At the manufacturer's option, threaded-end pipe may be identified by stamping or stenciling the pipe adjacent to the threaded ends, with the manufacturer's name or mark, API Spec 5B (to indicate the applicable threading specification), the specified outside diameter of the pipe and the letters "LP" (to indicate the type of thread). The thread marking may be applied to products that do or do not bear the API monogram.

EXAMPLE Size 168,3 mm (6.625 in) threaded-end pipe is marked as follows, using the value that is appropriate for the pipe outside diameter specified on the purchase order:

(for USC units) X API Spec 5B 6.625 LP

or

(for SI units) X API Spec 5B 168,3 LP

11.5.2 The use of the letters "API Spec 5B" as provided by 11.5.1 shall constitute a certification by the manufacturer that the threads so marked comply with the requirements in API Spec 5B but should not be construed by the purchaser as a representation that the product so marked is, in its entirety, in accordance with any API Specification. Manufacturers who use the letters "API Spec 5B" for thread identification are required to have access to properly certified API master pipe gauges per API Spec 5B.

11.6 Pipe processor markings

Pipe heat treated by a processor other than the original pipe manufacturer shall be marked as stipulated in the applicable sub-clauses of Clause 11. The processor shall remove any marking that does not indicate the new condition of the product as a result of heat treating (such as prior grade identity and original pipe manufacturer's name or logo).

If a processor is subcontracted by the pipe manufacturer and performs operations that unavoidably remove or obliterate the marking, the subcontractor may reapply the marking provided the reapplication is controlled by the pipe manufacturer.

12 Coatings and thread protectors

12.1 Coatings and linings

12.1.1 Except as allowed by 12.1.2 to 12.1.4, pipe shall be delivered bare (not coated).

12.1.2 If agreed, pipe shall be delivered with a temporary external coating to provide protection from rusting in storage and transit. Such coating shall be hard to the touch and smooth, without excessive sags.

12.1.3 If agreed, pipe shall be delivered with a special coating.

12.1.4 If agreed, pipe shall be delivered with a lining.

12.2 Thread protectors

12.2.1 For threaded pipe with $D < 60,3$ mm (2.375 in), the thread protectors shall be suitable fabric wrappings or shall be suitable metal, fibre or plastic protectors.

12.2.2 For threaded pipe with $D \geq 60,3$ mm (2.375 in), the thread protectors shall be of such design, material and mechanical strength as to protect the thread and pipe end from damage under normal handling and transportation conditions.

12.2.3 Thread protectors shall cover the full length of the thread on the pipe, and shall exclude water and dirt from the thread during transportation and the period of normal storage, which is considered to be approximately one year.

12.2.4 The thread forms in thread protectors shall be such that they do not damage the pipe threads.

12.2.5 Protector material shall contain no compounds that are capable of causing corrosion or promoting adherence of the protectors to the threads, and shall be suitable for service at temperatures of -45 °C to $+65$ °C (-50 °F to $+150$ °F).

13 Retention of records

Records of the following inspections, if applicable, shall be retained by the manufacturer and shall be made available to the purchaser, upon request, for a period of three years after the date of purchase from the manufacturer:

- a) heat and product analyses;
- b) tensile tests;

- c) guided-bend tests;
- d) CVN tests;
- e) DWT tests;
- f) hydrostatic-tester recorder charts or electronic methods of record storage;
- g) radiographic images for pipe inspection;
- h) non-destructive inspection by other methods where applicable;
- i) qualifications of non-destructive inspection personnel;
- j) radiographic images for jointer welds;
- k) repair welding procedure tests;
- l) records of any other test as specified in the annexes or the purchase order, including all welding-procedure specifications (WPS) and welding-procedure qualification test records (WPQT/PQR) (see Annex A and Annex D).

14 Pipe loading

If the manufacturer is responsible for the shipment of pipe, the manufacturer shall prepare and follow loading diagrams that detail how the pipe is to be arranged, protected and secured on trucks, railcars, barges or ocean-going vessels, whichever is applicable. The loading shall be designed to prevent end damage, abrasion, peening and fatigue cracking. The loading shall comply with any rules, codes, standards or recommended practices which are applicable.

NOTE For additional information refer to API RP 5L1^[18] and API RP 5LW^[19].

Annex A (normative)

Specification for welded jointers

A.1 Method

A.1.1 Welding of any type that uses deposited filler metal and is generally considered to be sound practice shall be permitted unless the purchaser specifies a particular method.

A.1.2 Welding procedures, welders and welding machine operators (hereafter called operators) shall be qualified in accordance with a standard approved by the purchaser.

A.1.3 Copies of the welding procedure specification and procedure qualification record shall be provided to the purchaser upon request.

A.2 Workmanship

A.2.1 The ends of the pipe to be welded together shall be prepared in accordance with the qualified welding procedure specification.

A.2.2 The completed jointers shall be straight within the limits of 9.11.3.4. Completed jointers shall not be straightened by bending at the jointer welds.

A.2.3 Each weld shall have a substantially uniform cross-section around the entire circumference of the pipe. At no point shall its as-deposited crowned surface be below the outside surface of the parent metal, nor shall it rise above the parent metal by more than the limits specified in Table 16 if submerged-arc welded or by more than 1,6 mm (0.063 in) if welded by another process.

A.2.4 Unless otherwise agreed, there shall be 50 mm to 200 mm (2.0 in to 8.0 in) of circumferential separation between longitudinal-seam welds at jointer welds.

A.2.5 There shall be at least 50 mm (2.0 in) of circumferential separation between helical-seam welds and coil/plate end welds at jointer welds.

A.3 Marking

Each jointer shall be legibly marked to identify the welder or operator.

A.4 Non-destructive inspection

The full length (100 %) of jointer welds shall be non-destructively inspected in accordance with Annex E or Annex K, whichever is applicable, using radiographic or ultrasonic methods or a combination thereof.

Annex B (normative)

Manufacturing procedure qualification for PSL 2 pipe

B.1 Introduction

B.1.1 This annex specifies additional provisions that apply if manufacturing procedure qualification is ordered for PSL 2 pipe [see 7.2 c) 42)] or if Annex H, and/or if Annex J applies.

B.1.2 In special cases (e.g. first supply or new steel grade) the purchaser may, when ordering large quantities, ask for data demonstrating that the requirements specified in this Standard can be met using the proposed manufacturing route.

B.1.3 Verification of the manufacturing procedure shall be by the provision of acceptable data from previous production or by qualification in accordance with Clause B.3, B.4, B.5, or any portion or combination thereof.

B.2 Additional information to be supplied by the purchaser

The purchase order shall indicate which of the following provisions apply for the specific order item:

- a) qualification in accordance with Clause B.3, B.4, B.5 or any portion or any combination thereof (see B.1.3);
- b) frequency and amount of testing (see B.5.2).

B.3 Characteristics of the manufacturing procedure specification

Before production commences or at the manufacturer's risk from the initial production run, the manufacturer shall supply the purchaser with summary information or identification of the control documents, as applicable, on the main characteristics of the manufacturing procedure. This information shall include at least the following:

- a) Steelmaking and casting — for all pipe:
 - 1) name/location of manufacturing facility;
 - 2) equipment and process description including steelmaking method, heat size, deoxidation practice, inclusion shape control practices (where applicable) and casting method;
 - 3) chemical composition ranges including all elements intentionally added and those listed in Table 5;
 - 4) steelmaking and casting process control;
 - 5) hydrogen control practices for slabs used to make plate/coil greater than 20 mm (0.78 in) thick;
 - 6) product identification and traceability practices;

- 7) product rework/retest/release controls for non-conformances to manufacturer's documented practices including grade intermixes/transitions and process/chemistry deviations;
 - 8) centerline segregation controls and acceptance criteria, as applicable.
- b) Pipe manufacturing — for all pipe:
- 1) name/location of manufacturing facility;
 - 2) equipment and process description;
 - 3) hydrostatic testing practices including calibration/verification of equipment;
 - 4) non-destructive inspection methods and practices including instrument standardization practices;
 - 5) chemical/mechanical property test and retest sample location(s) and specimen specification;
 - 6) dimensional control methods including methods to straighten pipe or correct dimensions;
 - 7) for full body normalized and quenched and tempered pipe, the aim and control tolerances for the austenitizing and tempering times and temperatures and a description of the temperature monitoring and control methods;
 - 8) pipe marking process and details;
 - 9) product traceability practices from plate/coil/billet receipt to pipe release;
 - 10) product rework/retest/release controls for non-conformances from manufacturer's documented practices; and
 - 11) pipe storage, handling, loading and shipping practices.
- c) Hot rolling — for welded pipe:
- 1) name/location of manufacturing facility;
 - 2) equipment and process description, including heat-treatment method (N or Q) if applicable;
 - 3) applicable rolling practice control temperature tolerances (reheating, rolling and cooling);
 - 4) applicable time tolerances (reheating, rolling, and cooling);
 - 5) applicable non-destructive inspection methods and practices for the coil/plate including instrument standardization practices;
 - 6) dimensional and mechanical property control limits;
 - 7) end cropping practices;
 - 8) product traceability practices from slab receipt to plate/coil delivery;
 - 9) product rework/retest/release controls for non-conformances to manufacturer's documented practices (including process, chemical/ mechanical, and dimensional deviations), and
 - 10) storage, handling, loading and shipping practices.
- d) Secondary processing (if applicable) — for welded pipe:
- 1) name/location of manufacturing facility;

- 2) equipment and process description;
 - 3) product identification and traceability practices from plate/coil receipt to plate/coil delivery;
 - 4) product rework/recoil/retest/release controls for non-conformances from manufacturer's documented practices (including process, chemical/ mechanical, and dimensional deviations), and
 - 5) storage, handling, loading and shipping practices.
- e) Pipe manufacture – for welded pipe:
- 1) pipe-forming procedures, including preparation of edges, control of alignment and shape;
 - 2) pipe heat-treatment procedure, where applicable, including in-line heat treatment of the weld seam;
 - 3) welding procedure specification with previous qualification records for this procedure, if available. This shall include sufficient information of the following kind:
 - i) for HFW seam welding:
 - confirmation of adequate weld seam heat treatment through metallography;
 - description and controls of welding process;
 - ii) for SAW and COW seam, repair, coil/plate end, and jointer welding, as applicable:
 - wire/flux consumable manufacturer(s), classification and wire diameter(s);
 - welding parameters and ranges including current, voltage, travel speed, heat input;
 - 4) for SAW and COW pipes:
 - i) seam welding bevel dimensional tolerances;
 - ii) method of tack welding and spacing of tack welds (if applicable);
 - iii) procedures for wire and flux storage and handling including moisture control and practices for recycling flux, as applicable;
 - iv) weld defect removal methods.
- f) Pipe manufacture - for SMLS pipe:
- 1) pipe-forming process for as-rolled pipe:
 - i) applicable rolling practice control temperature tolerances (reheating, rolling and cooling);
 - ii) applicable time tolerances (reheating, rolling and cooling);
 - 2) pipe heat-treatment practice.

B.4 Characteristics of the Inspection and Test Plan

Before production commences, the manufacturer shall supply the purchaser with summary information or identification of the control documents, as applicable, on the main characteristics of the inspection and test plan. This plan shall include at least the following:

- a) Inspection activity;
- b) Organization or individuals responsible for performing the inspection activity (including manufacturer, subcontractor, purchaser or third party representative);
- c) Inspection/test and calibration practices, as applicable;
- d) Frequency of inspection;
- e) Acceptance criteria;
- f) Actions to non-conformances;
- g) Result recording, as applicable;
- h) Identification of processes requiring validation;
- i) Witness and hold points.

B.5 Manufacturing procedure qualification tests

B.5.1 For the qualification of the manufacturing procedure, the mandatory tests specified in Table 18, Table H.3, and/or Table J.7, whichever are applicable, shall be carried out prior to or at the beginning of the production.

B.5.2 The frequency and amount of qualification testing shall be as specified in the purchase order, while requalification testing shall be approved by the purchaser. The manufacturer may offer prequalification data from previous production if noted in the purchase order.

B.5.3 For welded pipe, at a minimum the following welding procedure qualification information shall be provided:

- a) for HFW pipes:
 - welding process control parameters;
 - weld mechanical test results per Table 18, H.3 and J.7 (as appropriate);
 - confirmation of adequate heat treatment through metallography, and
 - weld region hardness test results where required per clause H.7.2.4 and H.7.3.3, or J.8.2.3 and J.8.3.2.
- b) for SAW and COW pipes:
 - bevel dimensions;

- wire/flux consumable manufacturer(s), classification and wire diameter(s);
- welding parameters including current, voltage, travel speed, heat input, and number of arcs;
- weld mechanical test results per Table 18, H.3 and J.7 (as appropriate);
- weld region hardness test results where required per clause H.7.2.4 and H.7.3.3, or J.8.2.3 and J.8.3.2, and
- weld metal chemical analysis of each deposited bead.

B.5.4 The purchaser may ask for characteristic data on other properties (e.g. weldability) of the product.

NOTE Purchaser requests for weldability data on particular steel grades can require specific weldability testing to be conducted. In such instances, it is the responsibility of the purchaser to supply the manufacturer with details of the welding processes and parameters for which weldability data are required. It is important to consider weldability testing of newly developed steel grades such as L690 or X100 and L830 or X120 where data are otherwise unavailable.

B.5.5 This qualification shall consider an assessment of coil/plate tensile property variability and coil/plate to pipe strength changes.

B.5.6 Prior to release of pipe, the purchaser shall be notified of all plate/coil/pipe that does not meet the initial defined rolling practices control parameters, but have been requalified (see 8.3.9).

Annex C **(normative)**

Treatment of surface imperfections and defects

C.1 Treatment of surface imperfections

Surface imperfections not classified as defects may remain in the pipe without repair or may be cosmetically dressed-out by grinding.

C.2 Treatment of dressable surface defects

C.2.1 All dressable surface defects shall be dressed-out by grinding.

C.2.2 Grinding shall be carried out in such a way that the dressed area blends in smoothly with the contour of the pipe.

C.2.3 Complete removal of defects shall be verified by local visual inspection, aided, where necessary, by suitable non-destructive inspection methods. To be acceptable, the wall thickness in the ground area shall be in accordance with 9.11.3.2; however, the minus tolerances for diameter and out-of-roundness (see 9.11.3.1) shall not apply in the ground area.

C.3 Treatment of non-dressable surface defects

Pipes that contain non-dressable surface defects shall be given one or more of the following dispositions.

- a) Weld defects in SAW and COW pipes shall be repaired by welding in accordance with Clause C.4.
- b) The sections of pipe containing the surface defects shall be cut off, within the limits on length.
- c) The entire pipe length shall be rejected.

C.4 Repair of defects by welding

C.4.1 For PSL 1 pipe only, repair of the pipe body by welding is permitted. For PSL 2 pipe, repair of the pipe body by welding is not permitted.

C.4.2 Except as allowed by C.4.1, repair by welding shall be confined to the weld of SAW and COW pipes. The defect shall be completely removed and the resulting cavity shall be thoroughly cleaned. For PSL 2 pipe, the rim of the resulting cavity shall not extend into the parent metal by more than 3,2 mm (0.125 in), as measured along the pipe surface perpendicular to the weld (see Figure C.1). Unless otherwise agreed, repairs to welds in cold-expanded PSL 2 pipe shall have been performed prior to cold expansion. Seam welds made without filler metal shall not be repaired by welding.

C.4.3 The total length of repaired zones on each pipe weld shall be $\leq 5\%$ of the total weld length for SAW and COW weld seams. For coil/plate end welds, the total length of the repaired zone shall not exceed 100 mm (4.0 in) and shall not be within 100 mm (4.0 in) of the junction between the end weld and the helical seam weld.

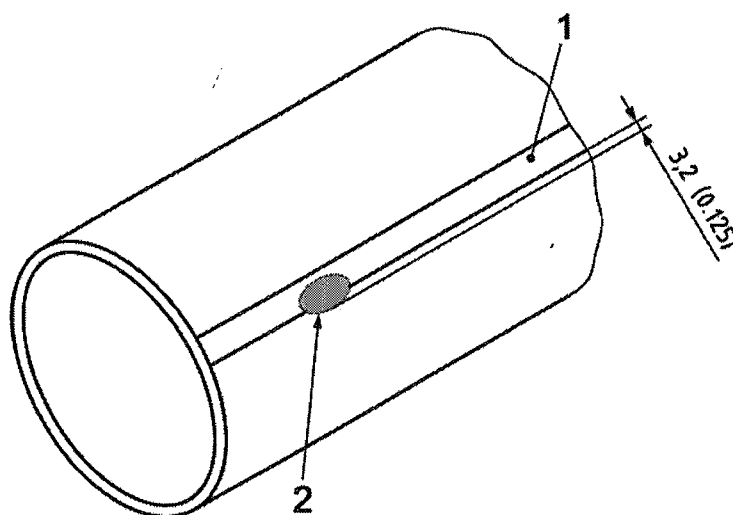
C.4.4 Weld defects separated by less than 100 mm (4.0 in) shall be repaired as a continuous single weld repair. Each single repair shall be carried out with a minimum of two layers/passes over a length of at least 50 mm (2.0 in).

C.4.5 Weld repairs shall be performed using a welding procedure that is qualified in accordance with Annex D.

C.4.6 After weld repair, the total area of the repair shall be ultrasonically or radiographically inspected in accordance with Annex E and, if applicable, Annex K. Before expansion or hydrotest, the type of UT may be at the option of the pipe manufacturer but, after expansion or hydrotest, inspection shall be by manual UT. It would also be acceptable to carry out combined automatic and manual UT after expansion or hydrotest.

C.4.7 For SMLS pipe (PSL 1 only), prior to weld repair, MT or PT inspection shall be performed to ensure complete removal of defect.

C.4.8 Pipe that has been repair welded shall be hydrostatically tested after repair welding in accordance with 10.2.6.



Key

- 1 weld reinforcement
- 2 rim of resultant cavity

Figure C.1 — Resultant cavity of weld repair (PSL 2 only)

Annex D **(normative)**

Repair welding procedure

D.1 General

D.1.1 Repair welds shall be made

- a) with the pipe axis being in the horizontal plane;
- b) in accordance with a qualified welding procedure;
- c) by a welding machine operator (hereafter called operator) or repair welder who is qualified in accordance with Clause D.3.

D.1.2 Repair welds shall be made by one or more of the following methods:

- a) automatic submerged arc;
- b) automatic or semi-automatic gas metal arc;
- c) manual shielded metal arc using low-hydrogen electrodes.

D.1.3 All welding materials shall be properly handled and stored in accordance with the manufacturer's recommendations, so as to preclude moisture or other contamination.

D.1.4 Test welds shall be made on strip, plate or pipe.

D.1.5 The manufacturer shall maintain a record of the welding procedure and the procedure qualification-test results. Copies of the welding-procedure specification and the welding-procedure qualification record shall be provided to the purchaser upon request.

D.2 Repair welding procedure qualification

D.2.1 General

D.2.1.1 Welding procedures shall be qualified by preparing and testing welds in accordance with this annex, except as allowed by D.2.1.2.

D.2.1.2 At the option of the manufacturer, the welding procedure qualification mechanical tests specified in ISO 15614-1^[24], API Spec 5L, 43rd Edition^[17] or ASME Section IX^[26] may be substituted for those specified in D.2.3.

D.2.1.3 For the purpose of this annex, the term automatic welding includes machine welding, mechanized welding and automatic welding.

D.2.2 Essential variables

An existing procedure shall not be applicable and a new procedure shall be qualified if any of the following essential variables is changed beyond the stated limits:

- a) welding process:
 - 1) a change in the welding process, such as submerged-arc to gas metal arc,
 - 2) a change in the method, such as manual to semi-automatic;
- b) pipe material:
 - 1) a change in pipe grade category; if different alloying systems are used within one pipe grade category, each alloying composition shall be separately qualified, wherein pipe grade categories are as follows:
 - i) pipe grade \leq L290 or X42,
 - ii) pipe grade $>$ L290 or X42, and pipe grade $<$ L450 or X65,
 - iii) each pipe grade \geq Grade L450 or X65,
 - 2) within each pipe grade category, a thicker material than the material qualified,
 - 3) within the pipe grade category and thickness range, a carbon equivalent (CE_{IIW} if the carbon mass fraction is greater than 0,12 % and CE_{Pcm} if the carbon mass fraction is less than or equal to 0,12 %), based upon product analysis for the material to be repaired, that is more than 0,03 % greater than the carbon equivalent of the material qualified,
 - 4) change in delivery condition (see Table 3);
- c) welding materials:
 - 1) change in the filler metal classification,
 - 2) when impact tests are required, a change in the consumable brand name,
 - 3) change in the electrode diameter,
 - 4) change in the composition, X , of the shielding gas of more than $(X \pm 5)$ %,
 - 5) change in the flow rate, q , of the shielding gas of more than $(q \pm 10)$ %,
 - 6) change in submerged-arc welding flux from one designation to another;
- d) welding parameters:
 - 1) change in the type of current (such as from alternating current to direct current),
 - 2) change in polarity,
 - 3) for automatic and semi-automatic welding, the ranges of welding current, voltage, speed and heat input may be established to cover ranges of wall thickness. Within the range, appropriately

selected points shall be tested to qualify the entire range. Thereafter, a new qualification is required if there is a deviation from the qualified range greater than one or more of the following:

- i. 10 % in amperage,
 - ii. 7 % in voltage,
 - iii. 10 % in travel speed for automatic welding,
 - iv. 10 % in heat input;
- 4) any increase in groove depth, a , over that qualified. The depth of groove shall be set by the manufacturer, unless otherwise agreed;
- e) weld bead: for manual and semi-automatic welding, a change in bead width greater than 50 %;
- f) preheat and post-weld heat treatment:
- 1) repair welding at a pipe temperature lower than the pipe temperature of the qualification test,
 - 2) the addition or deletion of post-weld heat treatment.

D.2.3 Mechanical testing

D.2.3.1 Number of test pieces

Two test pieces for each type of test (see D.2.3.2 and D.2.3.3) shall be prepared and tested for each welding procedure qualification test. For impact testing, three test pieces for each location shall be prepared and tested (see D.2.3.4).

D.2.3.2 Transverse tensile test

D.2.3.2.1 The reduced width of transverse tensile test pieces shall be approximately 38 mm (1.5 in) and the repair weld shall be at the mid-length of the test piece, as shown in Figure 8 a). The weld reinforcement shall be removed from both faces and the longitudinal edges shall be machine cut.

NOTE Although Figure 8 a) shows a guided bend test specimen, it is referred to for guidance of where the repair weld is to be located for a tensile specimen.

D.2.3.2.2 The tensile strength shall be at least equal to the minimum specified for the applicable pipe grade.

D.2.3.3 Transverse guided-bend test

D.2.3.3.1 The transverse guided-bend test pieces shall be as shown in Figure D.1, with the weld having been made in a groove.

D.2.3.3.2 Each test piece shall be bent 180° in a jig (see Figure 9 and Table D.1), with the exposed surface of the weld in tension.

D.2.3.3.3 Except as allowed by D.2.3.3.4, the bend test shall be considered acceptable if no crack or other defect exceeding 3,2 mm (0.125 in) in any direction is present in the weld metal or base metal after bending.

D.2.3.3.4 Cracks that occur at the edges of the test piece during testing shall not be cause for rejection, provided that they are not longer than 6,4 mm (0.250 in).

D.2.3.4 Charpy (CVN) impact test

D.2.3.4.1 Charpy impact test pieces shall be taken from weld-repaired areas of repair welding procedure qualification tests (see D.2.1.1).

D.2.3.4.2 Charpy test pieces shall be prepared in accordance with the requirements of 10.2.3.3 of this Standard.

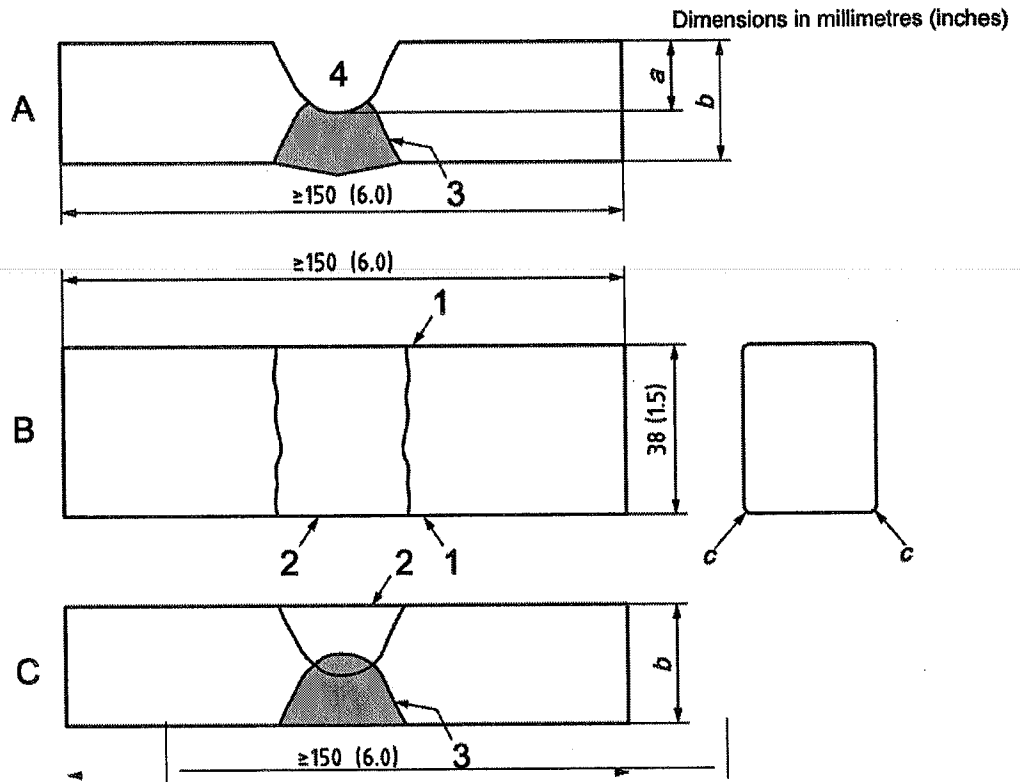
D.2.3.4.3 The CVN impact test shall be carried out in accordance with the requirements of 9.8 and 10.2.4.3 of this Standard.

D.2.3.4.4 The minimum average absorbed energy (of a set of three test pieces) for each repaired pipe weld and its associated HAZ, based on full size test pieces and a test temperature of 0 °C (32 °F), or if agreed, a lower test temperature shall be not less than that specified in 9.8.3 for the pipe seam weld metal and HAZ.

Where pipe dimensions do not permit the preparation and testing of full size CVN test pieces from repair welding procedure qualification tests and sub-size CVN test pieces are used, the requirements of 10.2.3.3 and Table 22 shall apply.

D.2.4 NDT of weld repair procedure qualification test

The weld-repair-procedure qualification test piece shall be inspected in accordance with Clause E.3, by using either the radiographic inspection technique in accordance with Clause E.4 or the ultrasonic inspection technique in accordance with Clause E.5 or a combination of both techniques. The weld-repaired area shall meet the same acceptance criteria specified in E.4.5 and/or E.5.5 as appropriate.

**Key**

- A before repair welding – Section view
- B after repair welding – Plan view
- C after repair welding – Section view
- 1 longitudinal edges machined, cold sawn, thermally cut, or any combination thereof
- 2 repair weld metal with weld reinforcement removed
- 3 pre-existing SAW/COW weld (if applicable) with weld reinforcement removed
- 4 repair groove
- a Groove depth.
- b Wall thickness (see D.2.2 b) 2).
- c The radius, r , shall be less than or equal to 1,6 (0.063).

Figure D.1 — Guided-bend test piece

Table D.1 — Guided-bend test jig dimensions

Pipe grade	Dimension ^a			
	r_a^b	r_b^b	A_{gb}^b	B^b
≤ L290 or X42	3,0 <i>t</i>	4,0 <i>t</i> + 1,6 (0.063)	6,0 <i>t</i>	8,0 <i>t</i> + 3,2 (0.125)
L320 or X46	3,5 <i>t</i>	4,5 <i>t</i> + 1,6 (0.063)	7,0 <i>t</i>	9,0 <i>t</i> + 3,2 (0.125)
L360 or X52	4,0 <i>t</i>	5,0 <i>t</i> + 1,6 (0.063)	8,0 <i>t</i>	10,0 <i>t</i> + 3,2 (0.125)
L390 or X56	4,0 <i>t</i>	5,0 <i>t</i> + 1,6 (0.063)	8,0 <i>t</i>	10,0 <i>t</i> + 3,2 (0.125)
L415 or X60	4,5 <i>t</i>	5,5 <i>t</i> + 1,6 (0.063)	9,0 <i>t</i>	11,0 <i>t</i> + 3,2 (0.125)
L450 or X65	4,5 <i>t</i>	5,5 <i>t</i> + 1,6 (0.063)	9,0 <i>t</i>	11,0 <i>t</i> + 3,2 (0.125)
L485 or X70	5,0 <i>t</i>	6,0 <i>t</i> + 1,6 (0.063)	10,0 <i>t</i>	12,0 <i>t</i> + 3,2 (0.125)
L555 or X80	5,0 <i>t</i>	6,0 <i>t</i> + 1,6 (0.063)	10,0 <i>t</i>	12,0 <i>t</i> + 3,2 (0.125)
L620 or X90	5,5 <i>t</i>	6,5 <i>t</i> + 1,6 (0.063)	11,0 <i>t</i>	13,0 <i>t</i> + 3,2 (0.125)
L690 or X100	6,0 <i>t</i>	7,0 <i>t</i> + 1,6 (0.063)	12,0 <i>t</i>	14,0 <i>t</i> + 3,2 (0.125)
L830 or X120	7,0 <i>t</i>	8,0 <i>t</i> + 1,6 (0.063)	14,0 <i>t</i>	16,0 <i>t</i> + 3,2 (0.125)

^a For intermediate grades, the dimensions shall be as specified for the next lower grade, or shall be obtained by interpolation.

^b r_a , r_b , A_{gb} , and B are as shown in Figure 9.

D.3 Welding personnel performance qualification

D.3.1 Qualification

D.3.1.1 General

Each repair welder and operator shall be qualified according to the requirements of this Clause. Alternatively, at the option of the manufacturer, welders and operators may be qualified to ISO 9606-1^[25], ASME Section IX^[26], API Spec 5L, 43rd Edition ^[17], Appendix C, or EN 287-1^[24].

A repair welder or operator qualified on one pipe grade category [see D.2.2 b)] is qualified for any lower pipe grade category, provided that the same welding process is used.

D.3.1.2 Inspection

To qualify, a repair welder or operator shall produce welds that are acceptable by inspection as follows:

- a) film radiographic inspection in accordance with Annex E;
- b) two transverse guided-bend tests (see D.2.3.3).

D.3.1.3 Inspection failures

If one or more of the inspections in D.3.1.2 fail to meet the specified requirements, the welder or operator may make one additional qualification weld. If that weld fails one or more of the inspections in D.3.1.2, the welder or operator is disqualified. No further retests shall be permitted until the welder has completed additional training.

D.3.2 Re-qualification

Re-qualification in accordance with D.3.1 shall be required if one or more of the following applies.

- a) One year has elapsed since the last prior applicable qualification.
- b) The welder or operator has not been welding using qualified procedures for a period of three months or more.
- c) There is reason to question the welder's or operator's ability.

Annex E (normative)

Non-destructive inspection for other than sour service or offshore service

E.1 Qualification of personnel

E.1.1 ISO 9712, ISO 11484 or ASNT SNT-TC-1A or an equivalent, shall be the basis for the qualification of non-destructive inspection personnel (excluding visual inspection). Such personnel shall be re-qualified for any method previously qualified, if they have not performed non-destructive inspection in that method for a period exceeding 12 months.

E.1.2 Non-destructive inspection shall be conducted by Level 1, 2 or 3 personnel.

E.1.3 Evaluation of indications shall be performed by Level 2 or 3 personnel, or by Level 1 personnel under the supervision of Level 2 or 3 personnel.

E.2 Standard practices for inspection

Except as specifically modified in this annex, the required non-destructive inspection, other than for surface inspection (see 10.2.7) and wall-thickness verification, shall be performed in accordance with one of the following standards or an equivalent:

- | | |
|--------------------------------------|----------------------------------------------------------------------------|
| a) electromagnetic (flux leakage): | ISO 10893-3 or ASTM E570; |
| b) electromagnetic (eddy-current): | ISO 10893-2 or ASTM E309; |
| c) ultrasonic: | ISO 10893-8, ISO 10893-9, ISO 10893-10, ASTM A435, ASTM A578 or ASTM E213; |
| d) automated ultrasonic (weld seam): | ISO 10893-11 or ASTM E273; |
| e) manual ultrasonic (weld seam) : | ISO 10893-11, ASTM E164, ASTM E587; |
| f) magnetic particle: | ISO 10893-5 or ASTM E709; |
| g) radiographic (film): | ISO 10893-6 or ASTM E94; |
| h) radiographic (digital): | ISO 10893-7, ASTM E2698, or ASTM E2033; |
| i) liquid penetrant: | ISO 10893-4 or ASTM E165. |

E.3 Methods of inspection

E.3.1 General

E.3.1.1 For Grades \geq L210 or A, the weld seams of welded pipe with $D \geq 60,3$ mm (2.375 in) shall be non-destructively inspected, full length (100 %) for the entire thickness, as given in Table E.1. In addition, the coil/plate end weld in finished helical-seam pipe shall be non-destructively inspected, full length (100 %) for the entire thickness, as given in Table E.1.

Table E.1 — Pipe weld seam non-destructive inspection

Weld seam type	Non-destructive inspection method ^a		
	Electromagnetic	Ultrasonic	Radiographic
EW	one method or a combination of methods is required		not applicable
LW	not applicable	required	not applicable
SAW	not applicable	required ^b	if agreed
COW	not applicable	required	not applicable
Coil/plate end	not applicable	required ^b	if agreed
^a The weld seam at the pipe ends may require additional inspection (see E.3.2).			
^b Required unless the manufacturer and the purchaser have agreed to replace it by radiographic inspection.			

E.3.1.2 All PSL 2 SMLS pipe and PSL 1 Grade L245 or B quenched and tempered SMLS pipe shall be non-destructively inspected full length (100 %), as given in Table E.2. If agreed, other PSL 1 SMLS pipe shall be non-destructively inspected as given in Table E.2.

Table E.2 — SMLS pipe body non-destructive inspection

Item	Non-destructive inspection method		
	Electromagnetic	Ultrasonic	Magnetic particle (circular field)
PSL 2 pipe, any grade	one method or a combination of methods is required		
PSL 1 pipe, Grade L245 or B, quenched and tempered	one method or a combination of methods is required		
PSL 1 pipe, other than above	if agreed, one method or a combination of methods is required		

E.3.1.3 The location of equipment in the manufacturer's facility shall be at the discretion of the manufacturer, except that

- a) the required non-destructive inspection of weld seams of cold-expanded pipe shall take place after cold expansion; the required non-destructive inspection of SMLS pipe shall take place after all heat treating and cold-expansion operations, if performed, but may take place before cropping, bevelling and end sizing;
- b) by agreement, the weld seams in LFW and HFW pipes shall be inspected following hydrostatic test.

E.3.2 Pipe end inspection — Welded pipe

E.3.2.1 If an automated ultrasonic or electromagnetic inspection system is applied to meet the requirements of E.3.1.1, the weld at any pipe end not covered by the automated inspection system shall be inspected for defects by the manual or semi-automatic ultrasonic angle beam method or by the radiographic method, whichever is appropriate, or such non-inspected pipe end shall be cut off. Records in accordance with E.5.4 shall be maintained.

E.3.2.2 For SAW and COW pipes, the weld at each pipe end for a minimum distance of 200 mm (8.0 in) shall be inspected by the radiographic method. The results of such radiographic inspection shall be recorded on either film or another imaging medium.

E.3.2.3 If agreed, ultrasonic inspection in accordance with the method described in ASTM A578 and ASTM A435, or ISO 10893-8 shall be used to verify that the 25 mm (1.0 in) wide zone at each pipe end is free of laminar imperfections > 6,4 mm (0.25 in) in the circumferential direction.

E.3.3 Pipe end inspection — SMLS pipe

E.3.3.1 If an automated ultrasonic or electromagnetic inspection system (combined equipment, operating procedures and personnel) is applied to meet the requirements of E.3.1.2, the portion at the pipe end that is not covered by the automated inspection system shall be inspected for defects by the manual or semi-automatic ultrasonic angle beam method or the magnetic particle method, otherwise such non-inspected pipe ends shall be cut off. Records in accordance with E.5.4 shall be maintained.

E.3.3.2 If agreed for pipe with $t \geq 5,0$ mm (0.197 in), ultrasonic inspection in accordance with ISO 10893-8 or ASTM A578 and ASTM A435 shall be used to verify that the 25 mm (1.0 in) wide zone at each pipe end is free of laminar imperfections > 6,4 mm (0.25 in) in the circumferential direction.

E.4 Radiographic inspection of weld seams

E.4.1 Radiographic technique

When applicable, radiographic inspection of the weld seam shall be conducted in accordance with the following:

- For Film Radiographic Inspection: ISO 10893-6 image quality class A or B, or ASTM E94.
- For Digital Radiographic Inspection: ISO 10893-7, ASTM E2698 or ASTM E2033.

E.4.2 Radiographic inspection equipment

E.4.2.1 The homogeneity of weld seams examined by radiographic methods shall be determined by means of X-rays directed through the weld material in order to create a suitable image on a radiographic film or digital imaging medium (i.e. CR, DDA), provided that the required sensitivity is demonstrated.

E.4.2.2 The radiographic films used shall be in accordance with ISO 11699-1:2008, class C4 or C5 or ASTM E1815-08, class I or class II, and shall be used with lead screens.

E.4.2.3 The density of the radiograph shall be not less than 2,0 (excluding the weld seam) and shall be chosen such that:

- a) the density through the thickest portion of the weld seam is not less than 1,5;
- b) the maximum contrast for the type of film used is achieved.

E.4.3 Image quality indicators (IQIs)

E.4.3.1 Unless otherwise agreed, wire-type IQIs shall be used. If other standard image quality indicators are used, equivalent or better sensitivity shall be achieved.

E.4.3.2 If ISO wire-type IQIs are used, they shall be W 1 FE, W 6 FE or W 10 FE, in accordance with ISO 19232-1:2004, and the essential wire diameters shall be as given in Table E.3 for the applicable weld thickness.

E.4.3.3 If ASTM wire-type IQIs are used, they shall be in accordance with ASTM E747 and the essential wire diameters shall be as given in Table E.4 for the applicable weld thickness.

E.4.3.4 Except as allowed by E.4.3.5, the IQI used shall be placed across the weld at a location representative of full weld reinforcement and shall contain both essential wire diameters, with one being determined based upon the weld thickness with full reinforcement and the other being determined based upon the weld thickness without reinforcement.

E.4.3.5 Two IQIs may be used; one placed across the weld and the other placed on the parent metal.

E.4.3.6 IQI's shall be placed on the source side. When the source side is inaccessible, the IQIs may be placed on the film /detector side of the object. In these circumstances a letter "F" shall be placed near the IQIs and this procedural change shall be recorded in the test report.

NOTE A trial exposure with IQIs on both source and detector sides of a piece of pipe is an effective means to assess relative sensitivity.

Table E.3 — ISO wire-type IQI for radiographic inspection

Weld thickness ^a mm (in)	Essential wire diameter mm (in)	FE wire set	Wire number
≤ 8 (0.3)	0,16 (0.006)	W 10 to W 16	14
> 8 (0.3) to 11 (0.4)	0,20 (0.008)	W 10 to W 16	13
> 11 (0.4) to 14 (0.6)	0,25 (0.010)	W 10 to W 16 or W 6 to W 12	12
> 14 (0.6) to 18 (0.7)	0,32 (0.013)	W 10 to W 16 or W 6 to W 12	11
> 18 (0.7) to 25 (1.0)	0,40 (0.016)	W 10 to W 16 or W 6 to W 12	10
> 25 (1.0) to 32 (1.2)	0,50 (0.020)	W 6 to W 12	9
> 32 (1.2) to 41 (1.6)	0,63 (0.025)	W 6 to W 12	8
> 41 (1.6) to 50 (2.0)	0,80 (0.032)	W 6 to W 12	7
> 50 (2.0)	1,00 (0.039)	W 6 to W 12	6

^a The weld thickness is the sum of the specified wall thickness and the estimated thickness of the weld reinforcement.

Table E.4 — ASTM wire-type IQI for radiographic inspection

Weld thickness ^a mm (in)	Essential wire diameter mm (in)	Wire set	Wire identity
≤ 8 (0.3)	0,16 (0.006)	A	4
> 8 (0.3) to 11 (0.4)	0,20 (0.008)	A	5
> 11 (0.4) to 14 (0.6)	0,25 (0.010)	A or B	6
> 14 (0.6) to 18 (0.7)	0,33 (0.013)	B	7
> 18 (0.7) to 25 (1.0)	0,41 (0.016)	B	8
> 25 (1.0) to 32 (1.2)	0,51 (0.020)	B	9
> 32 (1.2) to 41 (1.6)	0,64 (0.025)	B	10
> 41 (1.6) to 50 (2.0)	0,81 (0.030)	B or C	11
> 50 (2.0)	1,02 (0.040)	C	12

^a The weld thickness is the sum of the specified wall thickness and the estimated thickness of the weld reinforcement.

E.4.4 Verification of instrument standardization

E.4.4.1 For dynamic methods at operational speeds, an image quality indicator shall be used to verify the sensitivity and adequacy of the technique on one pipe in every test unit of not more than 50 pipes, but at least once per 4 h per operating shift.

NOTE 1 Proper definition and sensitivity is attained when the essential wire diameters of the image quality indicator used are clearly visible to the operator in the applicable area (weld or parent metal).

NOTE 2 In some of the referenced ISO Standards for non-destructive inspection, the term "calibration" is used to denote the term "standardization" as used in this Standard.

For initial adjustment of the technique using the image quality indicator, the pipe may be held in a stationary position.

E.4.4.2 For film radiographic methods, an image quality indicator shall appear on each exposure.

E.4.4.3 For stationary digital radiographic systems and processes it is sufficient to prove the image quality twice per shift. This sensitivity check shall be carried out at least once in every four hour period and at the start and end of each inspection shift, as long as pipe dimensions, material and testing parameters remain unchanged between calibrations. Once the system achieves the requirements of Clause E.4.3, no alteration to the testing parameters is allowed. The image quality check shall only be performed with source-side IQIs. During initial system validation, the spatial resolution (SR_b) of the detector shall be determined with a duplex wire IQI in addition to the IQI in E.4.3. The duplex wire shall be positioned directly in front of the detector at approximately 5° angle to avoid the aliasing effects. IQI placement for system validation shall be on the same side as used during production testing.

If there are any required changes to the system testing parameters (e.g. voltage, current, exposure time or distance between detector and subject), or changes to the pipe dimensions or material under test during the inspection shift, then the sensitivity of the system shall be re-calculated by the re-application of all required IQIs according to the requirements of E.4.3.

Where the image quality fails to meet the requirements of Clause E.4.3, then all pipes inspected since the previous successful sensitivity check shall undergo radiographic re-inspection at the new test parameters.

E.4.5 Acceptance limits for imperfections found by radiographic inspection

The size and distribution of slag-inclusion-type and/or gas-pocket-type imperfections shall not exceed the values given in Table E.5 or E.6, with elongated inclusions defined as those with length/width ratio of greater than or equal to 3:1.

NOTE 1 The important factors to be considered in determining if imperfections are acceptable are the size and spacing of the imperfections and the sum of their diameters in an established distance. For simplicity, the distance is established as any 150 mm (6,0 in) length of weld. Imperfections of this type usually occur in an aligned pattern, but no distinction is made between aligned and scattered patterns. Also, the distribution pattern can be of assorted sizes.

NOTE 2 Unless the imperfections are elongated, it cannot be determined with assurance whether the radiological indications represent slag inclusions or gas pockets. Therefore, the same limits apply to all circular-type imperfections.

E.4.6 Defects found by radiographic inspection

Cracks, lack of complete penetration and lack of complete fusion found by radiographic inspection shall be classified as defects. Imperfections found by radiographic inspection that are greater in size and/or distribution than the values given in Tables E.5 or E.6, whichever is applicable, shall be classified as defects. Pipe containing such defects shall be given one or more of the dispositions specified in Clause E.10.

E.4.7 Traceability of radiographic images

Radiographic images shall be traceable to the applicable pipe identity.

Table E.5 — Elongated slag-inclusion-type imperfections

Maximum dimensions mm (in)	Separation (minimum) mm (in)	Number of imperfections in any 150 mm (6.0 in) length of weld (maximum)	Accumulated length of imperfections in any 150 mm (6.0 in) length of weld (maximum) mm (in)
1,6 (0.063) × 13 (0.50)	150 (6.0)	1	13 (0.50)
1,6 (0.063) × 6,4 (0.25)	75 (3.0)	2	13 (0.50)
1,6 (0.063) × 3,2 (0.125)	50 (2.0)	3	13 (0.50)

Table E.6 — Circular slag-inclusion-type and gas-pocket-type imperfections

Size mm (in)	Adjacent size mm (in)	Separation (minimum) mm (in)	Number of imperfections in any 150 mm (6.0 in) length of weld (maximum)	Accumulated diameters of imperfections in any 150 mm (6.0 in) length of weld (maximum) mm (in)
3,2 (0.125) ^a	3,2 (0.125) ^a	50 (2.0)	2	6,4 (0.25)
3,2 (0.125) ^a	1,6 (0.063)	25 (1.0)	varies	6,4 (0.25)
3,2 (0.125) ^a	0,8 (0.031)	13 (0.5)	varies	6,4 (0.25)
3,2 (0.125) ^a	0,4 (0.016)	9,5 (0.4)	varies	6,4 (0.25)
1,6 (0.063)	1,6 (0.063)	13 (0.5)	4	6,4 (0.25)
1,6 (0.063)	0,8 (0.031)	9,5 (0.4)	varies	6,4 (0.25)
1,6 (0.063)	0,4 (0.016)	6,4 (0.25)	varies	6,4 (0.25)
0,8 (0.031)	0,8 (0.031)	6,4 (0.25) ^b	8	6,4 (0.25)
0,8 (0.031)	0,4 (0.016)	4,8 (0.188)	varies	6,4 (0.25)
0,4 (0.016)	0,4 (0.016)	3,2 (0.125)	16	6,4 (0.25)

^a 2,4 mm (0.094 in) for pipe with $t \leq 6,4$ mm (0.250 in).

^b Two imperfections $\leq 0,8$ mm (0.031 in) in diameter may be as close as one diameter apart, provided that they are separated from any other imperfection by at least 13 mm (0.5 in).

E.5 Ultrasonic and electromagnetic inspection

E.5.1 Equipment

E.5.1.1 Equipment using ultrasonic or electromagnetic principles and capable of continuous and uninterrupted inspection of the weld seam of welded pipe or the outside and/or inside surface of SMLS pipe shall be used, as appropriate.

E.5.1.2 For welded pipe, the equipment shall be capable of inspecting through the entire thickness of the weld seam as follows:

- a) for EW and LW seams, the weld line plus 1,6 mm (0.063 in) of adjacent parent metal on each side of the weld line;
- b) for SAW and COW seams, the weld metal plus 1,6 mm (0.063 in) of adjacent parent metal on each side of the weld metal.

E.5.2 Ultrasonic and electromagnetic inspection reference standards

E.5.2.1 Each reference standard shall have its outside diameter and wall thickness within the tolerances specified for the production pipe to be inspected.

NOTE In some of the referenced ISO Standards for non-destructive inspection, the term "tubular test piece" or "reference tube" or "test piece" is used to denote the term "reference standard" as used in this Standard.

E.5.2.2 Reference standards may be of any convenient length, as determined by the manufacturer.

E.5.2.3 Reference standards shall contain as reference indicators one or more machined notches or one or more radially drilled holes as given in Table E.7.

E.5.2.4 Reference indicators shall be separated in the reference standard by an amount sufficient to enable separate and distinguishable indications to be produced.

NOTE In some of the referenced ISO Standards for non-destructive inspection, the term "reference standard" is used to denote the term "reference indicator" as used in this Standard.

E.5.2.5 Reference standards shall be identified. The dimensions and type of reference indicators shall be verified by a documented procedure.

Table E.7 — Reference indicators

Item	Reference indicators ^a							
	Notch location		Notch orientation		Notch dimensions			Diameter of radially drilled hole ^b
	OD	ID	Longitudinal	Transverse	Depth ^c %	Length ^d (maximum) mm (in)	Width (maximum) mm (in)	
EW seam	e,l	e,l	e,l	f	10,0	50 (2.0)	1,0 (0.040)	3,2 (0.125) ^l
LW seam	e	e	e	f	5,0 ^g	50 (2.0)	1,0 (0.040)	1,6 (0.063) ^g
SAW seam ^h	e	e	e	i	5,0 ^g	50 (2.0)	1,0 (0.040)	1,6 (0.063) ^g
COW seam ^h	e	e	e	i	5,0 ^g	50 (2.0)	1,0 (0.040)	1,6 (0.063) ^g
Coil/plate end seam ^h	e	e	e	i	5,0 ^g	50 (2.0)	1,0 (0.040)	1,6 (0.063) ^g
Jointer seam ^h	e	e	e	i	5,0 ^g	50 (2.0)	1,0 (0.040)	1,6 (0.063) ^g
PSL 2 SMLS pipe	e	e	j	f	12,5	50 (2.0)	1,0 (0.040)	3,2 (0.125)
PSL 1 SMLS pipe, quenched and tempered	k	k	j	f	12,5	50 (2.0)	1,0 (0.040)	3,2 (0.125)
PSL 1 SMLS pipe, other	k	f	j	f	12,5	50 (2.0)	1,0 (0.040)	3,2 (0.125)

NOTE 1 Notches are rectangular or U-shaped.

NOTE 2 For electromagnetic inspection, it might be necessary for the reference standard to contain OD notches, ID notches and a radially drilled hole. (See E.5.3.4.)

^a It is not necessary to locate reference indicators in the weld.

^b Drilled hole diameters are based upon standard drill-bit sizes. A hole is not required if a notch is used to establish the reject threshold.

^c Depth is expressed as a percentage of the specified wall thickness. It is not necessary that the depth be less than 0,3 mm (0.012 in). The depth tolerance is $\pm 15\%$ of the specified notch depth or $\pm 0,05$ mm (0.002 in), whichever is the greater.

^d Length at full depth.

^e Required if a notch is used to establish reject threshold.

^f Not required.

^g At the option of the manufacturer, N10 notches or 3,2 mm (0.125 in) holes may be used (see Table E.8 for applicable acceptance limits).

^h At the option of the manufacturer, for SAW and COW seams, the reject threshold may be established using weld-edge notches or weld-edge radially drilled holes.

ⁱ Either a transverse notch or a 1,6 mm (0.063 in) radially drilled hole is required.

^j At the option of the manufacturer, the notches may be oriented at an angle that would facilitate the detection of anticipated defects.

^k Required for pipe with $D \geq 60,3$ mm (2.375 in) if a notch is used to establish the reject threshold.

^l If agreed, the reference standard shall contain OD and ID notches and a radially drilled hole.

E.5.3 Instrument standardization

E.5.3.1 The manufacturer shall use a documented procedure to establish the reject threshold for ultrasonic or electromagnetic inspection whichever is applicable. The applicable reference indicators given in Table E.7 shall be capable of being detected under normal operating conditions. Such capability shall be demonstrated dynamically, either on-line or off-line at the option of the manufacturer, using a speed of movement between the pipe and the transducer that simulates the inspection to be used for the production pipe.

E.5.3.2 The instrument shall be standardized with an appropriate reference standard (see E.5.2) at least twice per operating shift, with the second standardization being conducted 3 h to 4 h after the first to demonstrate its effectiveness and the effectiveness of the inspection procedures. Instrument standardization shall be confirmed prior to turning the unit off at the end of the inspection cycle.

NOTE In one or more of the referenced ISO Standards for non-destructive inspection, the term "calibration" is used to denote the term "standardization" as used in this Standard.

E.5.3.3 The instrument shall be adjusted to produce well-defined indications from the applicable reference indicators when the reference standard is inspected.

E.5.3.4 If a drilled hole is used to establish the reject threshold for electromagnetic inspection of pipe with $D \geq 60,3$ mm (2.375 in) and the intended application is either the inspection of the weld seam of welded pipe or the concurrent inspection of the OD and ID surfaces of SMLS pipe, it shall additionally be verified that the equipment as so standardized produces indications, from both ID and OD notches in the reference standard that are equal to or greater than the reject threshold established using the drilled hole.

E.5.4 Records verifying system capability

E.5.4.1 The manufacturer shall maintain NDT system records verifying the system(s) capabilities in detecting the reference indicators used to establish the equipment test sensitivity.

The verification shall cover, as a minimum, the following criteria:

- a) coverage calculation (i.e. scan plan);
- b) capability for the intended wall thickness;
- c) repeatability;
- d) transducer orientation that provides detection of defects typical of the manufacturing process [see Table E.7, Note j)];
- e) documentation demonstrating that defects typical of the manufacturing process are detected using the NDT methods described in Clause E.4 or E.5 as appropriate;
- f) threshold-setting parameters.

E.5.4.2 In addition, the manufacturer shall maintain documentation relating to

- a) NDT system operating procedures;
- b) NDT equipment description;
- c) NDT personnel qualification information;
- d) dynamic test data demonstrating the NDT system/operation capabilities under production test conditions.

E.5.5 Acceptance limits

E.5.5.1 The acceptance limit for indications produced by reference indicators shall be as given in Table E.8.

E.5.5.2 For ultrasonic inspection of welded pipe in the dynamic mode, any imperfection that produces an indication greater than the applicable acceptance limit given in Table E.8 shall be classified as a defect unless one of the following applies.

- a) Ultrasonic inspection of the imperfection in the static mode produces an indication that is less than the applicable acceptance limit given in Table E.8 and that it is ascertained that the maximum signal has been obtained.
- b) It is determined that the imperfection causing the indication is a surface imperfection that is not a defect as described in 9.10.
- c) For SAW and COW pipes, it is determined by radiographic inspection that the imperfection causing the indication is a slag-inclusion type or gas-pocket type of imperfection that meets the requirements of E.4.5.

E.5.5.3 Except as allowed by E.5.5.2 b & c, defects found by ultrasonic inspection shall not be classified as imperfections by subsequent radiographic testing.

E.5.5.4 For SMLS pipe, any surface imperfection that produces an indication greater than the applicable acceptance limit given in Table E.8 shall be classified as a defect unless it is determined that the imperfection causing the indication is not a defect as described in 9.10.

E.5.5.5 For COW seams, any continuous indication greater than 25 mm (1,0 in) in length, regardless of the indication height, provided that it is greater than the background noise, shall be re-inspected by radiographic methods in accordance with Clause E.4 or, if agreed, other techniques.

E.5.6 Disposition of defects found by ultrasonic and electromagnetic inspection

Pipe containing defects shall be given one or more of the dispositions specified in Clause E.10.

E.5.7 Weld repair

For SAW and COW seams, defects found by ultrasonic inspection may be repaired by welding and re-inspected in accordance with C.4. Inspection of the repair shall be performed using manual UT or a combination of automatic and manual UT.

Table E.8 — Acceptance limit

Item	Notch type	Hole size	Acceptance limit ^a
		mm (in)	(maximum) %
SAW, COW, LW or repair weld	N5	1,6 (0.063)	100
	N10	3,2 (0.125)	33
Electric weld	N10	3,2 (0.125)	100
SMLS pipe	N12,5	3,2 (0.125)	100

^a Expressed as a percentage of the indication produced by the reference indicator. The reject threshold (see E.5.3) shall not exceed the applicable acceptance limit.

E.6 Magnetic particle inspection

E.6.1 Magnetic particle inspection of SMLS pipe

E.6.1.1 If magnetic particle inspection is used to inspect for longitudinal defects, the entire outside surface of the pipe shall be so inspected.

E.6.1.2 Surface imperfections revealed by magnetic particle inspection shall be investigated, classified and treated as follows.

- a) Imperfections that have a depth $\leq 0,125 t$ and do not encroach on the minimum permissible wall thickness shall be classified as acceptable imperfections and shall be treated in accordance with Clause C.1.
- b) Imperfections that have a depth $> 0,125 t$ and do not encroach on the minimum permissible wall thickness shall be classified as defects and shall be dressed-out by grinding in accordance with Clause C.2 or shall be treated in accordance with Clause C.3.
- c) Imperfections that encroach on the minimum permissible wall thickness shall be classified as defects and shall be treated in accordance with Clause C.3.

NOTE Imperfections that encroach on the minimum permissible wall thickness implies that the portion of the wall thickness that is beneath the surface imperfection is less than the minimum permissible wall thickness.

E.6.2 Equipment

The equipment used for magnetic particle inspection shall produce a magnetic field of sufficient intensity to indicate imperfections of the following character in the external surface of the pipe: cracks, seams and slivers.

E.6.3 Magnetic particle inspection reference standard

If requested by the purchaser, arrangements shall be made by the manufacturer to perform a demonstration for the purchaser's representative during production of the purchaser's order. Such a demonstration shall be based upon pipe in process or sample lengths of similar pipe retained by the manufacturer for that purpose, that exhibit natural or artificially produced defects of the character stated in E.6.2.

E.7 Residual magnetism

E.7.1 The requirements for residual magnetism shall apply only to testing within the pipe manufacturing facility.

NOTE Values of the residual magnetism of the pipe, subsequent to leaving the pipe manufacturing facility, can be affected by procedures and conditions imposed on the pipe during and after shipment.

E.7.2 The longitudinal magnetic field shall be measured on plain-end pipe with $D \geq 168,3$ mm (6.625 in) and all smaller plain-end pipe that is inspected full length by magnetic methods or is handled by magnetic equipment prior to loading. Such measurements shall be taken on the root face or square cut face of finished plain-end pipe.

NOTE Measurements made on pipe in stacks are not considered valid.

E.7.3 Measurements shall be made using a Hall-effect gaussmeter or other type of calibrated instrument; however, in case of dispute, measurements made with a Hall-effect gaussmeter shall govern.

The gaussmeter shall be operated in accordance with written instructions demonstrated to produce accurate results.

E.7.4 Measurements shall be made on each end of a pipe, selected at least once per 4 h per operating shift.

E.7.5 Pipe magnetism shall be measured subsequent to any inspection that uses a magnetic field, prior to loading for shipment from the manufacturer's facility. For pipe handled with electromagnetic equipment after measurement of magnetism, such handling shall be performed in a manner demonstrated not to cause residual magnetism in excess of the limits in E.7.6.

E.7.6 Four readings shall be taken approximately 90° apart around the circumference of each end of the pipe. The average of the four readings shall be $\leq 3,0$ mT (30 Gs), and no one reading shall exceed 3,5 mT (35 Gs) when measured with a Hall-effect gaussmeter or equivalent values when measured with another type of instrument.

E.7.7 Any pipe that does not meet the requirements of E.7.6 shall be considered defective. Except as allowed by E.7.8, all pipe produced between the defective pipe and the last acceptable pipe shall be individually measured.

E.7.8 If the pipe production sequence is documented, pipe may be measured in reverse sequence, beginning with the pipe produced prior to the defective pipe, until at least three consecutively produced pipes meet the requirements.

NOTE It is not necessary to measure pipe produced prior to the three acceptable pipes.

E.7.9 Pipe produced after the defective pipe shall be measured individually until at least three consecutive pipes meet the requirements.

E.7.10 All defective pipe shall be de-magnetized full length and then their magnetism shall be re-measured until at least three consecutive pipes meet the requirements of E.7.6.

E.8 Laminar imperfections in the pipe body of EW, SAW and COW pipes

E.8.1 For EW pipe, if agreed, ultrasonic inspection shall be used to verify that the pipe body is free of laminar imperfections greater than those permitted by

- a) ISO 10893-9 acceptance level U2, if such inspection is done prior to pipe forming; or
- b) ISO 10893-8, acceptance level U3, if such inspection is done after seam welding.

E.8.2 For SAW and COW pipes, if agreed, ultrasonic inspection shall be used to verify that the strip/plate or the pipe body is free of laminar imperfections greater than those permitted by, ISO 10893-9 acceptance level U2.

E.9 Laminar imperfections along the strip/plate edges or pipe weld seam of EW, SAW and COW pipes

For EW, SAW and COW pipes, if agreed, ultrasonic inspection shall be used to verify that the 15 mm (0.6 in) wide zone along each of the strip/plate edges or along each side of the pipe weld seam is free of laminar imperfections greater than those permitted by

- a) ISO 10893-9 acceptance level U2, if such inspection is done prior to pipe forming; or
- b) ISO 10893-8 acceptance level U2, if such inspection is done after seam welding.

E.10 Disposition of pipes containing defects

Pipes containing defects shall be given one or more of the following dispositions.

- c) The defects shall be removed by grinding in accordance with Annex C.
- d) The defective areas shall be repaired by welding in accordance with Annex C.
- e) The sections of pipe containing defects shall be cut off within the applicable limits for length.
- f) The entire pipe shall be rejected.

Annex F (normative)

Requirements for couplings (PSL 1 only)

F.1 Material

F.1.1 Finished couplings shall meet the applicable requirements of PSL 1 for the grades specified in this annex with regard to chemical composition, mechanical properties, and non-destructive inspection.

F.1.2 Couplings for Grade L175, L175P, A25 and A25P pipe shall be seamless or welded.

F.1.3 Except as allowed by F.1.4, couplings for Grades L210, L245, A and B pipe shall be seamless and shall be made of a grade of material with mechanical properties equal to or greater than, that of the pipe.

F.1.4 If agreed, welded couplings may be supplied on pipe with $D \geq 355,6$ mm (14.000 in), provided that the couplings are properly marked.

F.2 Dimensions

Couplings shall conform to the dimensions and tolerances given in Table F.1 and as shown in Figure F.1.

NOTE Coupling sizes in Table F.1 are suitable for pipe having dimensions as given in Tables 24 and 25.

F.3 Inspection

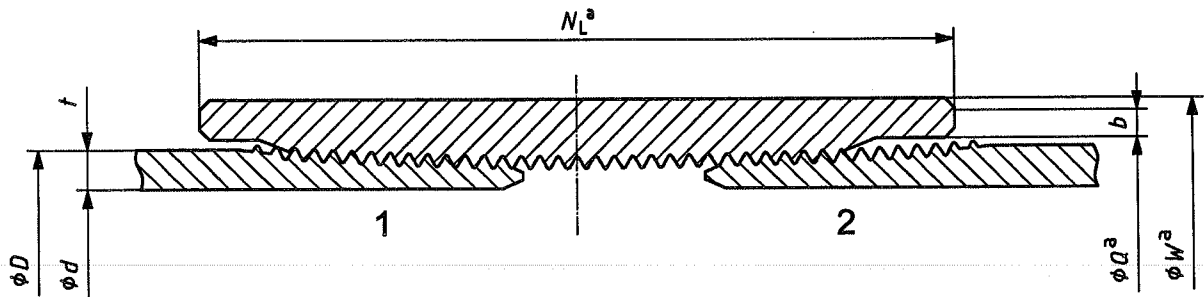
Couplings shall be free from blisters, pits, cinder marks and other imperfections that can impair the efficiency of the coupling or break the continuity of the thread.

Table F.1 — Coupling dimensions, masses and tolerances

Specified outside diameter of pipe D mm (in)	Coupling dimensions mm (in)				Calculated coupling mass kg (lb)
	Specified outside diameter ^a W^b	Specified minimum length N_L^b	Specified diameter of recess Q^b	Specified width of bearing face b	
10,3 (0.405)	14,3 (0.563)	27,0 (1.063)	11,9 (0.468)	0,8 (0.031)	0,02 (0.04)
13,7 (0.540)	18,3 (0.719)	41,3 (1.625)	15,3 (0.603)	0,8 (0.031)	0,04 (0.09)
17,1 (0.675)	22,2 (0.875)	41,3 (1.625)	18,8 (0.738)	0,8 (0.031)	0,06 (0.13)
21,3 (0.840)	27,0 (1.063)	54,0 (2.125)	22,9 (0.903)	1,6 (0.063)	0,11 (0.24)
26,7 (1.050)	33,4 (1.313)	54,0 (2.125)	28,3 (1.113)	1,6 (0.063)	0,15 (0.34)
33,4 (1.315)	40,0 (1.576)	66,7 (2.625)	35,0 (1.378)	2,4 (0.093)	0,25 (0.54)
42,2 (1.660)	52,2 (2.054)	69,8 (2.750)	43,8 (1.723)	2,4 (0.093)	0,47 (1.03)
48,3 (1.900)	55,9 (2.200)	69,8 (2.750)	49,9 (1.963)	2,4 (0.093)	0,41 (0.90)
60,3 (2.375)	73,0 (2.875)	73,0 (2.875)	62,7 (2.469)	3,2 (0.125)	0,84 (1.86)
73,0 (2.875)	85,7 (3.375)	104,8 (4.125)	75,4 (2.969)	4,8 (0.188)	1,48 (3.27)
88,9 (3.500)	101,6 (4.000)	108,0 (4.250)	91,3 (3.594)	4,8 (0.188)	1,86 (4.09)
101,6 (4.000)	117,5 (4.625)	111,1 (4.375)	104,0 (4.094)	4,8 (0.188)	2,69 (5.92)
114,3 (4.500)	132,1 (5.200)	114,3 (4.500)	116,7 (4.594)	6,4 (0.250)	3,45 (7.60)
141,3 (5.563)	159,9 (6.296)	117,5 (4.625)	143,7 (5.657)	6,4 (0.250)	4,53 (9.99)
168,3 (6.625)	187,7 (7.390)	123,8 (4.875)	170,7 (6.719)	6,4 (0.250)	5,87 (12.93)
219,1 (8.625)	244,5 (9.625)	133,4 (5.250)	221,5 (8.719)	6,4 (0.250)	10,52 (23.20)
273,1 (10.750)	298,4 (11.750)	146,0 (5.750)	275,4 (10.844)	9,5 (0.375)	14,32 (31.58)
323,9 (12.750)	355,6 (14.000)	155,6 (6.125)	326,2 (12.844)	9,5 (0.375)	22,37 (49.32)
355,6 (14.000)	381,0 (15.000)	161,9 (6.375)	358,0 (14.094)	9,5 (0.375)	20,81 (45.88)
406,4 (16.000)	431,8 (17.000)	171,4 (6.750)	408,8 (16.094)	9,5 (0.375)	23,35 (55.89)
457 (18.000)	482,6 (19.000)	181,0 (7.125)	459,6 (18.094)	9,5 (0.375)	30,20 (66.61)
508 (20.000)	533,4 (21.000)	193,7 (7.625)	510,4 (20.094)	9,5 (0.375)	36,03 (79.45)

^a Tolerances for outside diameter of couplings are $\pm 0,01 W$.

^b These symbols have been retained on the basis of their long-standing use by API in API Spec 5L^[17] and API Spec 5CT^[21].

**Key**

- 1 basic power-tight make-up
- 2 hand-tight make-up
- N_L specified minimum length
- W specified outside diameter of coupling
- Q specified diameter of recess
- b specified width of bearing face
- D specified outside diameter of pipe
- t wall thickness of pipe
- d inside diameter pipe

^a These symbols have been retained on the basis of their long-standing use by API in API Spec 5L and API Spec 5CT^[21].

Figure F.1 — Line pipe and coupling

Annex G **(normative)**

PSL 2 pipe with resistance to ductile fracture propagation

G.1 Introduction

G.1.1 This annex specifies additional provisions that apply for PSL 2 pipe that can be CVN impact tested (see Table 22) and is ordered with resistance in the pipe body to ductile fracture propagation in gas pipelines [see 7.2 c) 54]. This annex also provides guidance on determining of CVN impact values for the arrest of ductile pipe fractures.

NOTE 1 A combination of sufficient shear-fracture area and sufficient CVN absorbed energy is an essential pipe-body property to ensure the avoidance of brittle fracture propagation and the control of ductile fracture propagation in gas pipelines (see 9.8.2.2).

NOTE 2 It is important that the user take all reasonable steps to ensure that the operating parameters, including gas composition and pressure, of any gas pipeline to which the requirements of this Annex apply are comparable or consistent with the test condition on which the respective guidance method was established. Application of the guidance methods to pipeline conditions outside of the validity of the respective method can result in a non-conservative assessment of the resistance of the material to running fracture.

G.1.2 The guidance methods described in Clauses G.7 to G.10 for determining the pipe body CVN absorbed energy values necessary to control ductile fracture propagation in buried onshore gas pipelines, originate and are supported by extensive theoretical and test work conducted mainly, or exclusively, on welded line pipe. If use is made of these methods to determine the CVN absorbed energy values required to control ductile fracture in seamless pipe, the user should exercise caution with respect to the calculated values obtained and verification by full-scale burst testing, see Clause G.11, may be required.

G.2 Additional information to be supplied by the purchaser

G.2.1 The purchase order shall specify which of the following provisions apply for the specific order item:

- a) CVN minimum average absorbed energy value (based on full-size test pieces) for each test; or
- b) CVN minimum average absorbed energy value (based on full-size test pieces) for the order item.

G.2.2 The purchase order shall also specify:

- a) CVN impact test temperature,
- b) DWT test temperature [for $D \geq 508$ mm (20.000 in) only].

G.3 Acceptance criteria

G.3.1 For each CVN impact test of the pipe body of pipe with $D < 508$ mm (20.000 in), the average shear fracture area shall be ≥ 85 %, based upon the test temperature specified in the purchase order.

G.3.2 If the purchase order specifies provision G.2.1 a), the average (of a set of three test pieces) absorbed energy for each pipe body test shall not be less than specified in the purchase order based on full-size test pieces and the test temperature specified in the purchase order.

G.3.3 If the purchase order specifies provision G.2.1 b), the average (of all tests performed on the order item) absorbed energy for the order item shall not be less than specified in the purchase order based on full-size test pieces.

G.3.4 For each DWT test of the pipe body, the average shear fracture area shall be $\geq 85\%$, based upon the test temperature specified in the purchase order.

NOTE The DWT test is customarily specified by users when ordering pipe for gas pipeline service. When the shear area in the DWT test is $\geq 85\%$, the test provides assurance that the steel fractures in a predominantly ductile manner at the test temperature. In order to determine the resistance of the line pipe to running fracture under service conditions, it is important that the steel be assessed further using one of the guidance methods described in this annex within the limits of its validity.

G.4 Test frequency

G.4.1 For welded pipe with $D < 508$ mm (20.000 in), CVN testing of the pipe body shall be carried out at the frequency given in Table 18.

G.4.2 For welded pipe with $D \geq 508$ mm (20.000 in), CVN and DWT testing of the pipe body shall be carried out at the frequency given in Table 18.

G.5 Pipe markings and inspection documents

G.5.1 In addition to the pipe markings required in 11.2, the product specification level designation shall be followed by the letter "G" to indicate that Annex G applies.

G.5.2 In addition to the requirements of 10.1.3.2, the inspection document shall include:

- the DWT and CVN (as applicable) test temperature(s);
- the minimum average absorbed CVN energy value for each test;
- the minimum average absorbed CVN energy value for the order item.

G.6 Guidance for determining CVN absorbed energy values in buried onshore gas pipelines

G.6.1 Clauses G.7 to G.11 describe five approaches that may be adopted for determining the pipe body CVN absorbed energy values to control ductile fracture propagation in buried onshore gas pipelines. For each of the approaches, details concerning the range of applicability are given.

NOTE It is not intended that this annex exclude other approaches to be adopted by the designer of the pipeline.

G.6.2 The CVN absorbed energy value derived by the approaches described in Clauses G.7 to G.11, or a higher value, can be specified either as a minimum value for each test or as a minimum average value for the order item.

NOTE 1 The predicted length of fracture propagation is longer if the derived CVN value is specified as a minimum average absorbed energy value for the order item rather than as a minimum average absorbed energy value for each test. See reference [12] for additional information.

NOTE 2 The requirements herein were developed for buried onshore pipelines transporting lean gas. These requirements might be conservative for buried offshore pipelines.

G.7 EPRG guidelines — Approach 1

G.7.1 This approach is based upon the European Pipeline Research Group (EPRG) guidelines for fracture arrest in gas transmission pipelines^[10]. The applicability of this approach is limited to welded pipe. The values given in Tables G.1, G.2 and G.3 are the minimum average (of a set of three test pieces) absorbed energy values and are applicable for gas pipelines with operating pressures up to 8,0 MPa (1 160 psi), $D \leq 1\,430$ mm (56.000 in) and $t \leq 25,4$ mm (1.000 in), conveying fluids that exhibit single-phase behaviour during sudden decompression. The minimum full-size CVN absorbed energy values, K_V , expressed in joules (foot-pounds force), in those tables are the greater of 40 J (for pipe Grades < L555 or X80) or 80 J (for Grade L555 or X80) and the values derived using whichever of Equations (G.1) to (G.3) is applicable for the pipe grade:

- a) grade \leq L450 or X65:

$$K_V = C_1 \times \sigma_h^{1,5} \times D^{0,5} \quad (\text{G.1})$$

- b) grades $>$ L450 or X65, but \leq L485 or X70:

$$K_V = C_2 \times \sigma_h^{1,5} \times D^{0,5} \quad (\text{G.2})$$

- c) grades $>$ L485 or X70, but \leq Grade L555 or X80:

$$K_V = C_3 \times \sigma_h^2 \times \left(\frac{Dt}{2}\right)^{1/3} \quad (\text{G.3})$$

where

- σ_h is the design hoop stress, expressed in megapascals (kilo pounds per square inch);
- D is the specified outside diameter, expressed in millimetres (inches);
- t is the specified wall thickness, expressed in millimetres (inches);
- C_1 is $2,67 \times 10^{-4}$ for calculations using SI units and $1,79 \times 10^{-2}$ for calculations using USC units;
- C_2 is $3,21 \times 10^{-4}$ for calculations using SI units and $2,16 \times 10^{-2}$ for calculations using USC units;
- C_3 is $3,57 \times 10^{-5}$ for calculations using SI units and $1,08 \times 10^{-2}$ for calculations using USC units.

NOTE The values derived using Equation (G.1) are 0,75 times the values derived using Equation (G.5) in Approach 4. The values derived using Equation (G.2) are 0,9 times the values derived using Equation (G.5) in Approach 4. The values derived using Equation (G.3) are identical to the values derived using Equation (G.4) in Approach 2.

G.7.2 For the application of this approach, safety margins and length of fracture propagation can be taken from the EPRG report^[11].

Table G.1 — Minimum CVN absorbed energy requirements for a design factor of 0,625

Specified outside diameter <i>D</i> mm (in)	Full-size CVN absorbed energy, minimum						
	K_V J (ft·lbf)						
	Pipe grade						
	≤ L245 or B	> L245 or B to L290 or X42	> L290 or X42 to L360 or X52	> L360 or X52 to L415 or X60	> L415 or X60 to L450 or X65	> L450 or X65 to L485 or X70	> L485 or X70 to L555 or X80
≤ 508 (20.000)	40 (30)	40 (30)	40 (30)	40 (30)	40 (30)	40 (30)	80 (59)
> 508 (20.000) to 610 (24.000)	40 (30)	40 (30)	40 (30)	40 (30)	40 (30)	41 (30)	80 (59)
> 610 (24.000) to 711 (28.000)	40 (30)	40 (30)	40 (30)	40 (30)	40 (30)	45 (33)	80 (59)
> 711 (28.000) to 813 (32.000)	40 (30)	40 (30)	40 (30)	40 (30)	40 (30)	48 (35)	80 (59)
> 813 (32.000) to 914 (36.000)	40 (30)	40 (30)	40 (30)	40 (30)	40 (30)	51 (38)	80 (59)
> 914 (36.000) to 1 016 (40.000)	40 (30)	40 (30)	40 (30)	40 (30)	40 (30)	53 (39)	80 (59)
> 1 016 (40.000) to 1 118 (44.000)	40 (30)	40 (30)	40 (30)	40 (30)	42 (31)	56 (41)	82 (60)
> 1 118 (44.000) to 1 219 (48.000)	40 (30)	40 (30)	40 (30)	40 (30)	43 (32)	58 (43)	87 (64)
> 1 219 (48.000) to 1 422 (56.000)	40 (30)	42 (31)	42 (31)	42 (31)	47 (35)	63 (46)	96 (71)

Table G.2 — Minimum CVN absorbed energy requirements for a design factor of 0,72

Specified outside diameter D mm (in)	Full-size CVN absorbed energy, minimum						
	K_V J (ft·lbf)						
	Pipe grade						
	≤ L245 or B	> L245 or B to L290 or X42	> L290 or X42 to L360 or X52	> L360 or X52 to L415 or X60	> L415 or X60 to L450 or X65	> L450 or X65 to L485 or X70	> L485 or X70 to L555 or X80
≤ 508 (20.000)	40 (30)	40 (30)	40 (30)	40 (30)	40 (30)	46 (34)	80 (59)
> 508 (20.000) to 610 (24.000)	40 (30)	40 (30)	40 (30)	40 (30)	40 (30)	50 (37)	80 (59)
> 610 (24.000) to 711 (28.000)	40 (30)	40 (30)	40 (30)	40 (30)	41 (30)	55 (41)	80 (59)
> 711 (28.000) to 813 (32.000)	40 (30)	40 (30)	40 (30)	40 (30)	43 (32)	58 (43)	83 (61)
> 813 (32.000) to 914 (36.000)	40 (30)	40 (30)	40 (30)	41 (30)	46 (34)	62 (46)	90 (66)
> 914 (36.000) to 1 016 (40.000)	40 (30)	40 (30)	40 (30)	44 (32)	48 (35)	65 (48)	96 (71)
> 1 016 (40.000) to 1 118 (44.000)	40 (30)	40 (30)	40 (30)	46 (34)	51 (38)	68 (50)	102 (75)
> 1 118 (44.000) to 1 219 (48.000)	40 (30)	40 (30)	40 (30)	48 (35)	53 (39)	71 (52)	108 (80)
> 1 219 (48.000) to 1 422 (56.000)	40 (30)	42 (31)	42 (31)	51 (38)	57 (42)	77 (57)	120 (89)

Table G.3 — Minimum CVN absorbed energy requirements for a design factor of 0,80

Specified outside diameter <i>D</i> mm (in)	Full-size CVN absorbed energy, minimum						
	K_V J (ft·lbf)						
	Pipe grade						
	≤ L245 or B	> L245 or B to L290 or X42	> L290 or X42 to L360 or X52	> L360 or X52 to L415 or X60	> L415 or X60 to L450 or X65	> L450 or X65 to L485 or X70	> L485 or X70 to L555 or X80
≤ 508 (20.000)	40 (30)	40 (30)	40 (30)	40 (30)	41 (30)	55 (41)	80 (59)
> 508 (20.000) to 610 (24.000)	40 (30)	40 (30)	40 (30)	40 (30)	45 (33)	60 (44)	84 (62)
> 610 (24.000) to 711 (28.000)	40 (30)	40 (30)	40 (30)	43 (32)	49 (36)	65 (48)	93 (69)
> 711 (28.000) to 813 (32.000)	40 (30)	40 (30)	40 (30)	46 (34)	52 (38)	68 (50)	102 (75)
> 813 (32.000) to 914 (36.000)	40 (30)	40 (30)	40 (30)	49 (36)	55 (41)	73 (54)	110 (81)
> 914 (36.000) to 1 016 (40.000)	40 (30)	40 (30)	42 (31)	52 (38)	58 (43)	77 (57)	118 (87)
> 1 016 (40.000) to 1 118 (44.000)	40 (30)	40 (30)	44 (32)	54 (40)	61 (45)	81 (60)	125 (92)
> 1 118 (44.000) to 1 219 (48.000)	40 (30)	40 (30)	46 (34)	56 (41)	64 (47)	84 (62)	133 (98)
> 1 219 (48.000) to 1 422 (56.000)	40 (30)	42 (31)	49 (36)	61 (45)	69 (51)	91 (67)	148 (109)

G.8 Battelle simplified equation — Approach 2

This approach uses the Battelle simplified equation, which is based upon the Battelle two-curve approach (see Clause G.9). The applicability of this approach is limited to welded pipe. It is suited for natural gas mixtures that exhibit single-phase decompression behaviour at operating pressures up to 7,0 MPa (1 015 psi), Grades ≤ L555 or X80 and $40 < D/t < 115$. The minimum full-size CVN absorbed energy values, K_V , expressed in joules (foot·pounds force), can be calculated as given in Equation (G.4):

$$K_V = C_3 \times \sigma_h^2 \times \left(\frac{Dt}{2} \right)^{1/3} \quad (\text{G.4})$$

where

σ_h is the design hoop stress, expressed in megapascals (kilo pounds per square inch);

D is the specified outside diameter, expressed in millimetres (inches);

t is the specified wall thickness, expressed in millimetres (inches);

C_3 is $3,57 \times 10^{-5}$ for calculations using SI units and $1,08 \times 10^{-2}$ for calculations using USC units.

If the CVN absorbed energy value derived by this approach exceeds 100 J (74 ft·lbf), based upon full-size test pieces, the arrest toughness value requires correction. Specialist advice should be obtained to determine such corrections.

G.9 Battelle two-curve method — Approach 3

This approach is based upon the Battelle two-curve method, which matches the fracture-speed curve (the driving force) with the pipe toughness or resistance curve. When these two curves are tangent, the minimum level of fracture toughness for fracture arrest is defined. The Battelle two-curve method is described in Pipeline Research Committee International (PRCI) Report 208, PR-3-9113^[12], which also gives the range of test data against which it was calibrated. The applicability of this method is limited to welded pipe. It is suited for fluids that exhibit single-phase decompression behaviour and for rich gases that decompress into the two-phase boundary^[13], for operating pressures up to 12,0 MPa (1 740 psi), Grades \leq L555 or X80 and $40 < D/t < 115$. If the CVN absorbed energy value derived by this method exceeds 100 J (74 ft·lbf), based upon full-size test pieces, the arrest toughness value requires correction. Specialist advice should be obtained to determine such corrections.

G.10 AISI method — Approach 4

This approach is based upon the following equation, which was statistically fitted to the full-scale burst test data by AISI^[14] and is suited for fluids that exhibit single-phase behaviour during decompression. The application of this approach is limited to the range of test data against which it was originally calibrated, approximately pipe grades \leq L485 or X70 and $D \leq 1\,219$ mm (48.000 in). Although wall thickness is not a factor in the equation, the heaviest specified wall thickness tested was 18,3 mm (0.720 in). The applicability of this approach is limited to welded pipe. The minimum full-size CVN absorbed energy values, K_V , expressed in joules (foot-pounds force), can be calculated as given in Equation (G.5):

$$K_V = C_4 \times \sigma_h^{1.5} \times D^{0.5} \quad (\text{G.5})$$

where

σ_h is the design hoop stress, expressed in megapascals (thousand of pounds per square inch);

D is the specified outside diameter, expressed in millimetres (inches);

C_4 is $3,57 \times 10^{-4}$ for calculations using SI units and $2,40 \times 10^{-2}$ for calculations using USC units.

If the CVN absorbed energy value derived by this approach exceeds 100 J (74 ft·lbf), based upon full-size test pieces, the arrest toughness value requires correction. Specialist advice should be obtained to determine such corrections.

G.11 Full-scale burst testing — Approach 5

This approach is based upon full-scale burst testing to validate the arrest toughness for a specific pipeline design and fluid. Typically, a range of pipe toughness is installed in the burst test section, with the pipe toughness increasing on each side of the test section as the distance from the fracture origin increases. The CVN absorbed energy needed for arrest is established based upon the actual CVN absorbed energy of the pipe in which arrest is observed to occur. The pipeline-specific gas composition, temperature and pressure level are used for the burst test. Thus, it is the most general approach and is applicable for pipeline designs that are outside the existing database of test results.

Annex H (normative)

PSL 2 pipe ordered for sour service

H.1 Introduction

This annex specifies additional provisions that apply for PSL 2 pipe that is ordered for sour service [see 7.2 c) 55)].

WARNING — Annex H shall not be applied to PSL 1 pipe as PSL 1 pipe is not considered suitable for sour service.

NOTE The consequences of sudden failures of metallic components used for the oil and gas production associated with their exposure to H₂S-containing production fluids led to the development of NACE MR0175 and subsequently EFC Publication 16^[15]. NACE MR0175/ISO 15156-1^[20] and -2 was developed using those sources to provide requirements and recommendations for materials qualification and selection for application in environments containing wet H₂S in oil and gas production systems. Carbon and low alloy steels selected using ISO 15156-2 are resistant to cracking in defined H₂S-containing environments in oil and gas production but are not necessarily immune to cracking under all service conditions. Different service conditions might necessitate the alternative testing that is dealt with in ISO 15156-2:2003, Annex B. That annex specifies requirements for qualifying carbon and low alloy steels for H₂S service by laboratory testing.

It is the purchaser's responsibility to select the carbon and low-alloy steels suitable for the intended service.

H.2 Additional information to be supplied by the purchaser

In addition to items a) to g) as specified by 7.1, the purchase order shall indicate which of the following provisions apply for the specific order item:

- a) steel casting method for strip or plate used for the manufacture of welded pipe (see H.3.3.2.1);
- b) ultrasonic inspection of strip or plate for laminar imperfections (see H.3.3.2.4);
- c) supply of helical-seam pipe containing coil/plate end welds (see H.3.3.2.5);
- d) chemical composition for intermediate grades (see H.4.1.1);
- e) chemical composition for pipe with $t > 25,0$ mm (0.984 in) (see H.4.1.2);
- f) chemical composition limits [see Table H.1, footnotes c), d), e), f), i), j) and k)];
- g) frequency of hardness testing of the longitudinal seam weld of HFW or SAW pipe (see Table H.3);
- h) SSC test for manufacturing procedure qualification (see Table H.3);
- i) alternative HIC/SWC test methods and associated acceptance criteria (see H.7.3.1.3);

- j) photomicrographs of reportable HIC cracks (see H.7.3.1.4);
- k) alternative SSC test methods and associated acceptance criteria for manufacturing procedure qualification (see H.7.3.2.2);
- l) deviation from hardness test (see H.7.3.3.2 and H.7.3.3.3);
- m) deviation from 4 hardness impressions [see H.7.3.3.2 c)];
- n) for pipe with $t \geq 5,0$ mm (0.197 in), ultrasonic inspection for laminar imperfections within extended length of 100 mm (4.0 in) at the pipe ends (see K.2.1.3);
- o) supplementary end NDT lamination criteria (see K.2.1.3 and K.2.1.4);
- p) magnetic particle inspection for laminar imperfections at each pipe end face/bevel (see K.2.1.4);
- q) verification of lamination size/density (see K.3.2.2);
- r) increased coverage for ultrasonic thickness measurements for SMLS pipe (see K.3.3);
- s) application of one or more of the supplementary non-destructive inspection operations for SMLS pipe (see K.3.4);
- t) ultrasonic inspection of SMLS pipe for the detection of transverse imperfections (see K.3.4.1);
- u) full-body inspection of SMLS pipe the flux leakage method for the detection of longitudinal and transverse imperfections (see K.3.4.2);
- v) full-body inspection of SMLS pipe by the eddy current method (see K.3.4.3);
- w) full-body magnetic particle inspection of pipe (see K.3.4.4);
- x) limitation of individual lamination size to 100 mm^2 (0.16 in²) (see Table K.1);
- y) acceptance level U2/U2H for non-destructive inspection of the weld seam of HFW pipe (see K.4.1);
- z) alternate ISO 10893-10 HFW weld seam UT acceptance criteria [see K.4.1 b)];
- aa) ultrasonic inspection of the pipe body of HFW pipe for laminar imperfections (see K.4.2);
- bb) ultrasonic inspection of the strip/plate edges or areas adjacent to the weld for laminar imperfections (see K.4.3);
- cc) non-destructive inspection of the pipe body of HFW pipe using the ultrasonic or flux leakage method (see K.4.4);
- dd) use of fixed depth notches for equipment standardization [see K.5.1.1 c)];
- ee) radiographic inspection of pipe ends (non-inspected ends) and repaired areas [see K.5.3 a)];
- ff) magnetic particle inspection of the weld seam at the pipe ends of SAW pipe (see K.5.4).

H.3 Manufacturing

H.3.1 Manufacturing procedure

All pipes shall be manufactured in accordance with a manufacturing procedure that has been qualified in accordance with Annex B, possibly supplemented with additional testing (see Table H.3).

H.3.2 Steel making

H.3.2.1 The steel shall be made to a clean steel practice using either the basic oxygen steel-making process or the electric furnace process and shall be killed.

H.3.2.2 Vacuum degassing or alternative processes to reduce the gas content of the steel should be applied.

H.3.2.3 The molten steel shall be treated for inclusion shape control. A procedure (e.g. metallographic examination) may be agreed between the purchaser and the manufacturer to assess the effectiveness of inclusion shape control. For S levels $\leq 0.001\%$, inclusion shape control may be waived by agreement.

H.3.3 Pipe manufacturing

H.3.3.1 SMLS pipe

SMLS pipe shall be manufactured from continuously cast (strand cast) or ingot steel. If the process of cold finishing was used, this shall be stated in the inspection document.

H.3.3.2 Welded pipe

H.3.3.2.1 Unless otherwise agreed, coil and plate used for the manufacture of welded pipe shall be rolled from continuously cast (strand cast) or pressure cast slabs. The pipe shall be SAWL, SAWH or HFW.

H.3.3.2.2 For HFW pipe, the abutting edges of the coil or plate should be sheared, milled or machined before welding.

H.3.3.2.3 Coil and plate used for the manufacture of welded pipe shall be inspected visually after rolling. Visual inspection of coil used for the manufacture of welded pipe may be either of the uncoiled strip or of the coil edges.

H.3.3.2.4 If agreed for HFW pipe, such coil and plate shall be inspected ultrasonically for laminar imperfections or mechanical damage in accordance with Clause K.4, either before or after cutting the coil or plate, or the completed pipe shall be subjected to full-body inspection, including ultrasonic inspection.

H.3.3.2.5 If agreed, helical-seam pipe made from coil/plate and containing coil/plate end welds may be delivered, provided that such welds are located at least 300 mm from the pipe ends and have been subjected to the same non-destructive inspection required in Annex K for coil/plate edges and welds.

H.3.3.2.6 Intermittent tack welding of the SAWL or SAWH groove shall not be used, unless the purchaser has approved data furnished by the manufacturer to demonstrate that all mechanical properties specified for the pipe are obtainable at both the tack weld and intermediate positions.

H.3.3.3 Jointers

Jointers shall not be delivered, unless otherwise agreed.

NOTE It is the responsibility of the purchaser and the manufacturer to agree procedures for welding and qualification tests for specific sour-service jointers.

H.4 Acceptance criteria

H.4.1 Chemical composition

H.4.1.1 For pipe with $t \leq 25,0$ mm (0.984 in), the chemical composition for standard grades shall be as given in Table H.1 and the chemical composition for intermediate grades shall be as agreed, but consistent with those given for the standard grades in Table H.1. The pipe designation shall be as given in Table H.1 and consists of an alpha or alphanumeric designation that identifies the grade, followed by a suffix that consists of a letter (N, Q or M) that identifies the delivery condition and a second letter (S) that identifies the service condition.

H.4.1.2. For pipe with $t > 25,0$ mm (0.984 in), the chemical composition shall be as agreed, with the requirements given in Table H.1 being amended as appropriate.

Table H.1 — Chemical composition for pipe with $t \leq 25,0$ mm (0.984 in)

Steel grade	Mass fraction, based upon heat and product analyses									Carbon equivalent ^a	
	C ^b	Si	Mn ^b	P	% maximum S V Nb			Ti	Other ^{c,d}	CE _{IW}	CE _{Pcm}
SMLS and welded pipes											
L245NS or BNS	0,14	0,40	1,35	0,020	0,003 ^e	f	f	0,04	g	0,36	0,19 ^h
L290NS or X42NS	0,14	0,40	1,35	0,020	0,003 ^e	0,05	0,05	0,04	—	0,36	0,19 ^h
L320NS or X46NS	0,14	0,40	1,40	0,020	0,003 ^e	0,07	0,05	0,04	g	0,38	0,20 ^h
L360NS or X52NS	0,16	0,45	1,65	0,020	0,003 ^e	0,10	0,05	0,04	g	0,43	0,22 ^h
L245QS or BQS	0,14	0,40	1,35	0,020	0,003 ^e	0,04	0,04	0,04	—	0,34	0,19 ^h
L290QS or X42QS	0,14	0,40	1,35	0,020	0,003 ^e	0,04	0,04	0,04	—	0,34	0,19 ^h
L320QS or X46QS	0,15	0,45	1,40	0,020	0,003 ^e	0,05	0,05	0,04	—	0,36	0,20 ^h
L360QS or X52QS	0,16	0,45	1,65	0,020	0,003 ^e	0,07	0,05	0,04	g	0,39	0,20 ^h
L390QS or X56QS	0,16	0,45	1,65	0,020	0,003 ^e	0,07	0,05	0,04	g	0,40	0,21 ^h
L415QS or X60QS	0,16	0,45	1,65	0,020	0,003 ^e	0,08	0,05	0,04	g,i,k	0,41	0,22 ^h
L450QS or X65QS	0,16	0,45	1,65	0,020	0,003 ^e	0,09	0,05	0,06	g,i,k	0,42	0,22 ^h
L485QS or X70QS	0,16	0,45	1,65	0,020	0,003 ^e	0,09	0,05	0,06	g,i,k	0,42	0,22 ^h
Welded pipe											
L245MS or BMS	0,10	0,40	1,25	0,020	0,002 ^e	0,04	0,04	0,04	—	—	0,19
L290MS or X42MS	0,10	0,40	1,25	0,020	0,002 ^e	0,04	0,04	0,04	—	—	0,19
L320MS or X46MS	0,10	0,45	1,35	0,020	0,002 ^e	0,05	0,05	0,04	—	—	0,20
L360MS or X52MS	0,10	0,45	1,45	0,020	0,002 ^e	0,05	0,06	0,04	—	—	0,20
L390MS or X56MS	0,10	0,45	1,45	0,020	0,002 ^e	0,06	0,08	0,04	g	—	0,21
L415MS or X60MS	0,10	0,45	1,45	0,020	0,002 ^e	0,08	0,08	0,06	g,i	—	0,21
L450MS or X65MS	0,10	0,45	1,60	0,020	0,002 ^e	0,10	0,08	0,06	g,i,j	—	0,22
L485MS or X70MS	0,10	0,45	1,60	0,020	0,002 ^e	0,10	0,08	0,06	g,i,j	—	0,22

^a Based upon product analysis (see 9.2.4 and 9.2.5). The CE_{IW} limits apply if C > 0,12 % and the CE_{Pcm} limits apply if C ≤ 0,12 %.

^b For each reduction of 0,01 % below the specified maximum for C, an increase of 0,05 % above the specified maximum for Mn is permissible, up to a maximum increase of 0,20 %.

^c Al_{total} ≤ 0,060 %; N ≤ 0,012 %; Al/N ≥ 2:1 (not applicable to titanium-killed or titanium-treated steel); Cu ≤ 0,35 % (if agreed, Cu ≤ 0,10 %); Ni ≤ 0,30 %; Cr ≤ 0,30 %; Mo ≤ 0,15 %; B ≤ 0,0005 %.

^d For welded pipe where calcium is intentionally added, unless otherwise agreed, Ca/S ≥ 1,5 if S > 0,0015 %. For SMLS and welded pipes, Ca ≤ 0,006 %.

^e The maximum limit for S may be increased to ≤ 0,008 % for SMLS pipe and, if agreed, to ≤ 0,006 % for welded pipe. For such higher S levels in welded pipe, lower Ca/S ratios may be agreed.

^f Unless otherwise agreed, Nb + V ≤ 0,06 %.

^g Nb + V + Ti ≤ 0,15 %.

^h For SMLS pipe, the listed CE_{Pcm} value may be increased by 0,03.

ⁱ If agreed, Mo ≤ 0,35 %.

^j If agreed, Cr ≤ 0,45 %.

^k If agreed, Cr ≤ 0,45% and Ni ≤ 0,50%.

H.4.2 Tensile properties

H.4.2.1 The tensile properties shall be as given in Table H.2.

Table H.2 — Requirements for the results of tensile tests

Pipe steel grade	Pipe body of SMLS and welded pipes					Weld seam of HFW and SAW pipes	
	Yield strength ^a		Tensile strength ^a		Ratio ^b	Elongation (on 50 mm or 2 in)	Tensile strength ^c
	$R_{t0,5}$ MPa (psi)		R_m MPa (psi)		$R_{t0,5}/R_m$	A_f %	R_m MPa (psi)
	minimum	maximum	minimum	maximum	maximum	minimum	minimum
L245NS or BNS L245QS or BQS L245MS or BMS	245 (35 500)	450 ^d (65 300) ^d	415 (60 200)	655 (95 000)	0,93	e	415 (60 200)
L290NS or X42NS L290QS or X42QS L290MS or X42MS	290 (42 100)	495 (71 800)	415 (60 200)	655 (95 000)	0,93	e	415 (60 200)
L320NS or X46NS L320QS or X46QS L320MS or X46MS	320 (46 400)	525 (76 100)	435 (63 100)	655 (95 000)	0,93	e	435 (63 100)
L360NS or X52NS L360QS or X52QS L360MS or X52MS	360 (52 200)	530 (76 900)	460 (66 700)	760 (110 200)	0,93	e	460 (66 700)
L390QS or X56QS L390MS or X56MS	390 (56 600)	545 (79 000)	490 (71 100)	760 (110 200)	0,93	e	490 (71 100)
L415QS or X60QS L415MS or X60MS	415 (60 200)	565 (81 900)	520 (75 400)	760 (110 200)	0,93	e	520 (75 400)
L450QS or X65QS L450MS or X65MS	450 (65 300)	600 (87 000)	535 (77 600)	760 (110 200)	0,93	e	535 (77 600)
L485QS or X70QS L485MS or X70MS	485 (70 300)	635 (92 100)	570 (82 700)	760 (110 200)	0,93	e	570 (82 700)

^a For intermediate grades, the difference between the specified maximum yield strength and the specified minimum yield strength shall be as given in the table for the next higher grade, and the difference between the specified minimum tensile strength and the specified minimum yield strength shall be as given in the table for the next higher grade. For intermediate grades, the tensile strength shall be ≤ 760 MPa (110 200 psi).

^b This limit applies for pipe with $D > 323,9$ mm (12.750 in).

^c For intermediate grades, the specified minimum tensile strength for the weld seam shall be the same value as was determined for the pipe body using footnote a).

^d For pipe requiring longitudinal testing, the maximum yield strength shall be ≤ 495 MPa (71 800 psi).

^e The specified minimum elongation, A_f , on 50 mm or 2 in, expressed in percent and rounded to the nearest percent, shall be as determined using the following equation:

$$A_f = C \frac{A_{xc}^{0,2}}{U^{0,9}}$$

where

C is 1 940 for calculations using SI units and 625 000 for calculations using USC units;

A_{xc} is the applicable tensile test piece cross-sectional area, expressed in square millimetres (square inches), as follows:

- for circular cross-section test pieces, 130 mm² (0.20 in²) for 12,7 mm (0.500 in) and 8,9 mm (0.350 in) diameter test pieces; and 65 mm² (0.10 in²) for 6,4 mm (0.250 in) diameter test pieces;
- for full-section test pieces, the lesser of a) 485 mm² (0.75 in²) and b) the cross-sectional area of the test piece, derived using the specified outside diameter and the specified wall thickness of the pipe, rounded to the nearest 10 mm² (0.01 in²);
- for strip test pieces, the lesser of a) 485 mm² (0.75 in²) and b) the cross-sectional area of the test piece, derived using the specified width of the test piece and the specified wall thickness of the pipe, rounded to the nearest 10 mm² (0.01 in²);

U is the specified minimum tensile strength, expressed in megapascals (pounds per square inch).

H.4.3 HIC/SWC test

The test for evaluation of resistance to hydrogen-induced cracking shall meet the following acceptance criteria, with each ratio being the maximum permissible average for three sections per test specimen when tested in Solution (Environment) A (see ISO 15156-2:2003, Table B.3):

- a) crack sensitivity ratio (CSR) $\leq 2\%$;
- b) crack length ratio (CLR) $\leq 15\%$;
- c) crack thickness ratio (CTR) $\leq 5\%$.

If HIC/SWC tests are conducted in alternative media (see H.7.3.1.3) to simulate specific service conditions, alternative acceptance criteria may be agreed.

H.4.4 Hardness test

For test pieces subjected to a hardness test (see H.7.3), the hardness in the pipe body, the weld and HAZ shall be ≤ 250 HV10 or 22 HRC (70,6 HR 15N).

If agreed by the end user and if the specified wall thickness is greater than 9 mm, the maximum acceptable hardness measured on indents in the row that is 1,5 mm from the OD pipe surface (see Figure H.1) shall be ≤ 275 HV10 or 26 HRC (73,0 HR 15N).

NOTE 1 ISO 15156-2 provides further guidance to the end user. Requirements for the alternative hardness limits for the weld cap in ISO 15156-2 include that the weld cap is not exposed directly to the sour environment.

NOTE 2 The test is performed using the Vickers hardness test or using the Rockwell HR 15N indenter and, where the latter is used, a conversion of hardness values can be made to Rockwell C scale if required.

H.4.5 SSC test

After removal of the SSC test specimens (see H.7.3.2) from the test medium, the specimen surface previously under tension shall be examined under a low-power microscope at X10 magnification. The occurrence of any surface breaking fissures or cracks on the tension surface of the test specimen shall constitute failure of the specimen unless it can be demonstrated that these are not the result of sulfide stress cracking.

H.5 Surface conditions, imperfections and defects

H.5.1 Surface imperfections, other than undercuts in SAW pipe, disclosed by visual inspection shall be investigated, classified and treated as follows.

- a) Imperfections that have a depth $\leq 0,05 t$ and do not encroach on the minimum permissible wall thickness shall be classified as acceptable imperfections and treated in accordance with Clause C.1.

NOTE There is a possibility of special requirements for disposition of surface imperfections being specified in the purchase order if the pipe is subsequently to be coated.

- b) Imperfections that have a depth $> 0,05 t$ and do not encroach on the minimum permissible wall thickness shall be classified as defects and shall be treated in accordance with Clause C.2, C.3 b) or C.3 c).
- c) Imperfections that encroach on the minimum permissible wall thickness shall be classified as defects and treated in accordance with C.3 b) or C.3 c).

H.5.2 For welded pipe, any hard spot larger than 50 mm (2.0 in) in any direction shall be classified as a defect if its hardness, based upon individual indentations, exceeds

- a) 250 HV10, 22 HRC or 240 HBW on the internal surface of the pipe or repair to internal seam weld bead, or
- b) 275 HV10, 27 HRC or 260 HBW on the external surface of the pipe or repair to external seam weld bead.

Pipes that contain such defects shall be treated in accordance with C.3 b) or C.3 c).

H.6 Weld flash of HFW pipe

The inside flash shall not extend above the contour of the pipe by more than 0,3 mm (0.012 in) + 0,05 t .

H.7 Inspection

H.7.1 Specific inspection

The frequency of inspection shall be as given in Table 18, except as specifically modified in Table H.3.

Table H.3 — Inspection frequency

No	Type of inspection	Type of pipe	Frequency of inspection
1	Hardness testing of pipe with $D < 508$ mm (20.000 in)	SMLS, HFW, SAWL or SAWH	Once per test unit of not more than 100 lengths of pipe with the same cold-expansion ratio ^a
2	Hardness testing of pipe with $D \geq 508$ mm (20.000 in)	SMLS, HFW, SAWL or SAWH	Once per test unit of not more than 50 lengths of pipe with the same cold-expansion ratio ^a
3	Hardness testing of hard spots in welded pipe	HFW, SAWL or SAWH	Each hard spot found on the internal or external surface of the pipe
4	If agreed, hardness testing of the longitudinal or helical-seam weld of welded pipe	HFW, SAWL or SAWH	As specified in the purchase order
5	Pipe diameter and out-of-roundness for pipe with $D \leq 168,3$ mm (6.625 in)	SMLS, HFW, SAWL or SAWH	Once per test unit of not more than 100 lengths of pipe
6	Pipe diameter and out-of-roundness for pipe with $D > 168,3$ mm (6.625 in)	SMLS, HFW, SAWL or SAWH	Once per test unit of not more than 20 lengths of pipe
7	Non-destructive inspection	SMLS, HFW, SAWL or SAWH	In accordance with Annex K
8	HIC test	SMLS, HFW, SAWL or SAWH	One test for each of the first three heats applied; thereafter, not less than one test per each ten heats of steel
9	If agreed, SSC test	SMLS, HFW, SAWL or SAWH	One test for each pipe provided for manufacturing procedure qualification

^a The cold-expansion ratio is designated by the manufacturer and is derived using the designated before-expansion outside diameter or circumference and the after-expansion outside diameter or circumference. An increase or decrease in the cold-expansion ratio of more than 0,002 requires the creation of a new test unit.

H.7.2 Samples and test pieces for mechanical and technological tests

H.7.2.1 General

H.7.2.1.1 For tensile tests, CVN impact tests, DWT tests, guided bend tests, flattening tests, hardness tests, HIC tests, bead on pipe tests, bead on plate tests and SSC tests, the samples shall be taken, and the corresponding test pieces shall be prepared, in accordance with the applicable reference standard.

H.7.2.1.2 Samples and test pieces for the various types of test shall be taken from locations as shown in Figures 5 and 6 and as given in Table H.4, taking into account the supplementary details in 10.2.3.2 to 10.2.3.7, 10.2.4 and H.7.2.2 to H.7.2.4.

H.7.2.2 Samples for HIC/SWC tests

Samples for HIC/SWC tests shall be taken in accordance with NACE TM0284.

H.7.2.3 Samples and test pieces for SSC tests

H.7.2.3.1 Three test pieces shall be taken from each pipe sample.

H.7.2.3.2 Unless agreed otherwise, test pieces for four-point bending SSC tests shall be ≥ 115 mm (4.5 in) long \times 15 mm (0.59 in) wide \times 5 mm (0.20 in) thick. For welded pipe, the test piece shall contain the longitudinal or helical-seam weld in the middle of the tested area and the test piece shall be oriented transverse to the weld seam (Figure 5 b) & c) key 1). For seamless pipe, the sample shall be oriented longitudinal to the pipe body (Figure 5 a) key 1). If agreed, samples may be flattened. Unless otherwise agreed, samples shall be machined from the inside surface of the pipe.

H.7.2.4 Samples for hardness tests

Samples for hardness tests shall be taken from the end of selected pipes and, for welded pipe, each sample shall contain a section of the longitudinal or helical seam at its centre (see Figure H.1).

Table H.4 — Number, orientation and location of test pieces per sample for hardness tests

Type of pipe	Sample location	Number, orientation and location of test pieces per sample ^a	
		Specified outside diameter <i>D</i> mm (in)	
		< 508 (20.000)	\geq 508 (20.000)
SMLS ^b [see Figure 5 a)]	Pipe body	1T	1T
SAWL [see Figure 5 b)]	Seam weld	1W	1W ^c
SAWH [see Figure 5 c)]	Seam weld	1W	1W
SAWH [see Figure 5 c)]	Coil/plate end weld	1WS	1WS
HFV [see Figure 5 b)]	Seam weld	1W	1W

^a See Figure 5 for an explanation of the symbols used to designate orientation and location.

^b Applies for both cold-expanded and non-expanded SMLS pipe.

^c For double-seam pipe, both longitudinal weld seams in the pipe selected to represent the test unit shall be tested.

H.7.3 Test methods

H.7.3.1 HIC/SWC test

H.7.3.1.1 HIC/SWC tests shall be carried out and reported in accordance with NACE TM0284.

H.7.3.1.2 Except as allowed by H.7.3.1.3, HIC/SWC tests shall be conducted in a medium complying with NACE TM0284:2003, Solution A.

H.7.3.1.3 If agreed, HIC/SWC tests may be conducted

- a) in an alternative medium (see ISO 15156-2:2003, Table B.3) including NACE TM0284:2003, Solution B,
- b) with a partial pressure of H₂S appropriate to the intended application, and
- c) with acceptance criteria that are equal to or more stringent than those specified in H.4.3.

H.7.3.1.4 Values of crack-length ratio, crack-thickness ratio and crack-sensitivity ratio shall be reported. If agreed, photographs of any reportable crack shall be provided with the report.

H.7.3.2 SSC test

H.7.3.2.1 Except as allowed by H.7.3.2.2, SSC tests shall be performed as follows:

- the test method solution control shall be in accordance with NACE TM0177:2005 Method C;
- the test piece shall be as defined in either ISO 7539-2, ASTM G39, or clause H.7.2.3.2 of this standard;
- the test solution shall be Solution A as defined in NACE TM0177:2005;
- the test duration shall be 720 h.

Except as allowed by H.7.3.2.2, the test pieces shall be stressed to 0,72 times the specified minimum yield strength of the pipe.

NOTE The use of an applied stress equal to 0,72 times the specified minimum yield strength in the SSC test does not necessarily provide sufficient technical justification that the material has been pre-qualified for all sour service applications. For further advice on prequalification, refer to ISO 15156-2.

H.7.3.2.2 If agreed, alternative SSC test methods, alternative environments (including a partial pressure of H₂S appropriate for the intended application) and associated acceptance criteria may be used (see ISO 15156-2:2003, Table B.1). If such tests are used, full details of the test environment and conditions shall be reported together with the test results.

H.7.3.3 Hardness test

H.7.3.3.1 Hardness testing on parent metal shall be performed using the Vickers test in accordance with ISO 6507-1 or ASTM E384 or using Rockwell test HR 15N in accordance with ISO 6508-1 or ASTM E18. In case of dispute, the Vickers method shall apply.

Hardness testing on the HAZ and weld shall be carried out in accordance with ISO 6507-1 or ASTM E384.

For pipe body tests and parent metal tests, individual hardness readings exceeding the applicable acceptance limit may be considered acceptable if the average of a minimum of three and maximum of six additional readings taken within close proximity does not exceed the applicable acceptance limit, and if no such individual reading exceeds the acceptance limit by more than 10 HV10 units or 2 HRC units, whichever is applicable.

NOTE The test is performed using the Vickers hardness test or using the Rockwell HR 15N indenter and, where the latter is used, a conversion of hardness values can be made to Rockwell C scale if required.

H.7.3.3.2 Hardness test locations for SMLS pipe shall be as shown in Figure H.1 a), except that

- a) for pipe with $t < 4,0$ mm (0.156 in), it is necessary to carry out only the mid-thickness traverse,
- b) for pipe with $4,0$ mm (0.156 in) $\leq t < 6$ mm (0.236 in), it is necessary to carry out only the inside and outside surface traverses, and
- c) if agreed, three impressions at each through-thickness location shown in Figure H.1 a) are acceptable.

H.7.3.3.3 Hardness test locations for welded pipe shall include the weld cross-section. Indentations shall be made in the parent metal, in the visible HAZ and at the weld centreline, as shown in Figure H.1 b) and c), except that

- a) for pipe with $t < 4,0$ mm (0.156 in) it is necessary to carry out only the mid-thickness traverse,
- b) for pipe with $4,0$ mm (0.156 in) $\leq t < 6$ mm (0.236 in), it is necessary to carry out only the inside and outside surface traverses, and
- c) if agreed, the distance from the weld line to the indentations in the parent metal may be less than shown in Figure H.1 c) provided these indentations remain located in the parent metal.

H.7.4 Non-destructive inspection

For non-destructive inspection, see H.3.3.2.3 to H.3.3.2.5 and Annex K.

H.7.5 HIC/SWC retests

In the event that a set of HIC/SWC test specimens fail to meet the acceptance criteria, provision for retesting shall be agreed by purchaser and manufacturer. If applicable, reprocessing shall be as defined in 10.2.11.

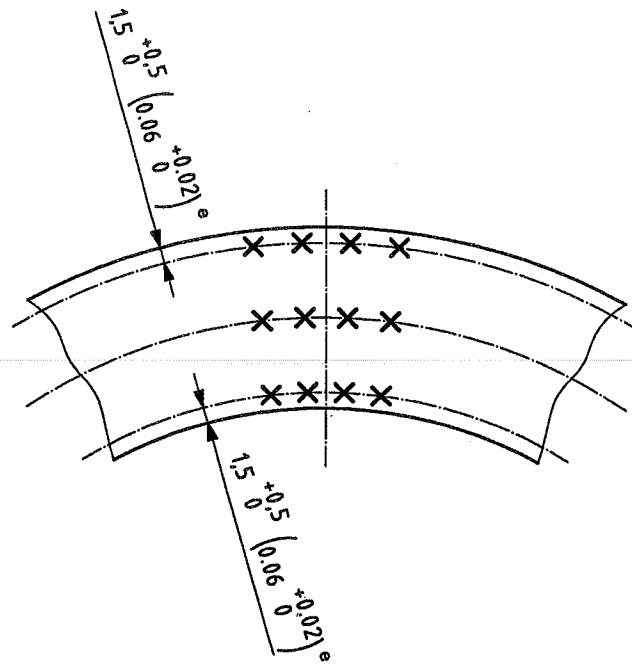
H.8 Pipe markings

In addition to the pipe markings required in 11.2, the pipe markings shall include an identification number that permits the correlation of the product or delivery unit with the related inspection document.

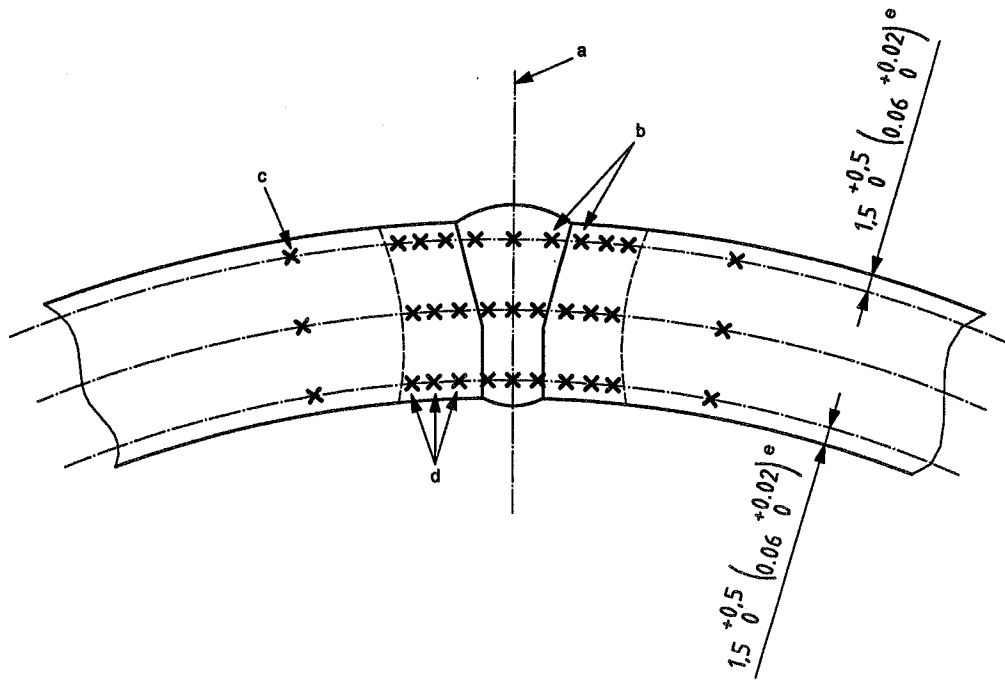
Only pipe conforming to the requirements of this Standard for PSL 2 together with the supplementary requirements of Annex H may be marked as complying with this standard and carry the letter "S" within the grade name to indicate that the pipe is intended for sour service.

Pipes meeting requirements of both Annex H & J shall be marked with both grade name suffix markings S & O (e.g. X52MS/X52MO or L360MS/L360MO).

Dimensions in millimetres (inches)



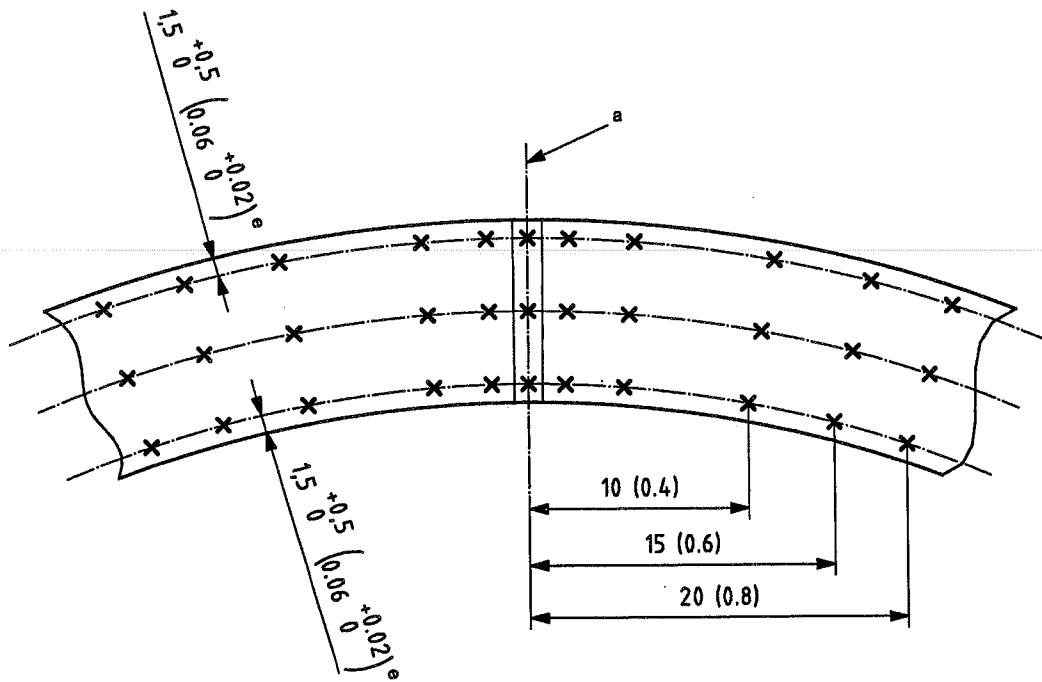
a) SMLS pipe



b) SAW pipe

Figure H.1 — Location of hardness tests

Dimensions in millimetres (inches)



c) HFW pipe

- a Weld centreline.
- b 0,75 mm (0.03 in) from fusion line.
- c $1\ r$ from fusion line.
- d 1,0 mm (0.04 in) spacing in visible HAZ.
- e From inside and outside surfaces.

Figure H.1 — Location of hardness tests (continued)

Annex I (normative)

Pipe ordered as “Through the Flowline” (TFL) pipe

I.1 Introduction

This annex specifies additional provisions that apply for pipe that is ordered as TFL pipe [see 7.2 c) 54)].

I.2 Additional information to be supplied by the purchaser

The purchaser order shall indicate which of the following provisions apply for the specific order item:

- a) type of length (see I.4);
- b) supply of jointers (see I.4).

I.3 Dimensions and grades

TFL pipe shall be SMLS or longitudinal seam pipe in the specified outside diameters, specified wall thicknesses and grades given in Table I.1.

I.4 Lengths and jointers

Unless otherwise agreed, TFL pipe shall be furnished in 12 m (40 ft) random lengths with no jointers.

I.5 Drift test

I.5.1 Each length of TFL pipe shall be tested throughout its entire length with a cylindrical drift mandrel conforming to the dimensions given in Table I.2. During the drift test, the pipe shall be properly supported to prevent sagging and shall be free of all foreign matter.

I.5.2 The leading edge of the drift mandrel shall be rounded to permit easy entry into the pipe. The drift mandrel shall pass freely through the pipe with a reasonable exerted force appropriate for the mass of the drift mandrel being used for the test.

I.6 Hydrostatic test

Each length of TFL pipe shall be hydrostatically tested in accordance with the requirements of 9.4, except that the minimum test pressures shall be as given in Table I.1.

NOTE The test pressures given in Table I.1 represent the lesser of 68,9 MPa (9 990 psi) and the pressures derived using Equation (6), using a hoop stress, S , equal to 80 % of the specified minimum yield strength of the pipe.

I.7 Pipe markings

In addition to the pipe markings required in 11.2, the product specification level designation shall be followed by the letter "I" to indicate that Annex I applies.

Table I.1 — Dimensions, masses per unit length and test pressures for TFL pipe

Specified outside diameter D mm (in)	Specified wall thickness t mm (in)	Calculated inside diameter d mm (in)	Grade	Mass per unit length ρ_l kg/m (lb/ft)	Hydrostatic test pressure (minimum) MPa (psi)
60,3 (2.375)	4,8 (0.188)	50,7 (1.999)	L390 or X56	6,57 (4.40)	49,2 (7 140)
73,0 (2.875)	11,1 (0.438)	50,8 (1.999)	L390 or X56	16,94 (11.41)	68,9 (9 990)
73,0 (2.875)	5,5 (0.216)	62,0 (2.443)	L390 or X56	9,16 (6.14)	46,5 (6 740)
88,9 (3.500)	13,5 (0.530)	61,9 (2.440)	L390 or X56	25,10 (16.83)	68,9 (9 990)
101,6 (4.000)	19,1 (0.750)	63,4 (2.500)	L415 or X60	38,86 (26.06)	68,9 (9 990)
101,6 (4.000)	12,7 (0.500)	76,2 (3.000)	L290 or X42	27,84 (18.71)	57,9 (8 400)
101,6 (4.000)	12,7 (0.500)	76,2 (3.000)	L415 or X60	27,84 (18.71)	68,9 (9 990)
101,6 (4.000)	6,4 (0.250)	88,8 (3.500)	L485 or X70	15,02 (10.02)	48,6 (7 050)
114,3 (4.500)	19,1 (0.750)	66,1 (3.000)	L360 or X52	44,84 (30.07)	68,9 (9 990)
114,3 (4.500)	7,1 (0.281)	100,1 (3.938)	L485 or X70	18,77 (12.67)	48,0 (6 960)

Table I.2 — Drift mandrel dimensions

Specified outside diameter of the pipe D mm (in)	Mandrel dimensions mm (in)	
	Length	Diameter
< 88,9 (3.500)	1 066 (42)	$d - 2,4$ (0.093)
≥ 88,9 (3.500)	1 066 (42)	$d - 3,2$ (0.125)

NOTE d is the calculated inside diameter of the pipe (see Table I.1).

Annex J (normative)

PSL 2 pipe ordered for offshore service

J.1 Introduction

This annex specifies additional provisions that apply for PSL 2 pipe that is ordered for offshore service [see 7.2. c) 61)].

NOTE This annex does not include requirements for specialized tests for pipe intended for applications such as pipe reeling or for pipe that will experience high ($> 0,5\%$) total, single event strain during installation. For such applications, additional testing can be necessary to prove the suitability of the pipe and the purchaser might need to supplement the requirements of this Standard with other appropriate provisions (e.g. see DNV-OS-F101 [16]).

J.2 Additional information to be supplied by the purchaser

The purchase order shall indicate which of the following provisions apply for the specific order item:

- a) steel casting method for strip or plate used for the manufacture of welded pipe (see J.3.3.2.1);
- b) ultrasonic inspection of strip or plate for laminar imperfections (see J.3.3.2.4);
- c) supply of helical-seam pipe containing coil/plate end welds (see J.3.3.2.5);
- d) chemical composition for intermediate grades (see J.4.1.1);
- e) chemical composition for pipe with $t > 25,0$ mm (0.984 in) (see J.4.1.2);
- f) carbon equivalent limit for steel Grade L555QO or X80QO, L625QO or X90QO, and L690QO or X100QO (see Table J.1);
- g) chemical composition limits [see Table J.1, footnote d)];
- h) acceptance criteria for tensile properties if determined at other than room temperature (see J.4.2.2);
- i) for grades equal to or greater than Grade L555 or X80, a lower maximum tensile strength limit may be agreed [see Table J.2, footnote b)];
- j) minimum average length other than 12,1 m (39.7 ft) and/or different range (see J.6.3);
- k) diameter and out-of-roundness tolerances for SMLS pipe with $t > 25,0$ mm (0.984 in) [see Table J.3, footnote b)];
- l) use of inside diameter to determine diameter and out-of-roundness tolerances for non expanded pipe with $D \geq 219,1$ mm (8.625 in) [see Table J.3, footnote c)];
- m) hardness test of the pipe body seam weld and HAZ of EW and SAW pipe (see Table J.7);
- n) hardness testing of pipe body for SMLS pipe (see Table J.7);

- o) CTOD testing (see J.8.2.2 and Table J.6);
- p) use of the ring expansion test for transverse yield strength determinations [see Table J.7, footnote c)];
- q) additional longitudinal tensile testing for deep-water pipelay [see Table J.7, footnote d)];
- r) deviation from hardness test [see J.8.3.2.2 c) and J.8.3.2.3];
- s) deviation from location of hardness test [J.8.3.2.2.c)];
- t) for pipe with $t \geq 5,0$ mm (0.197 in), ultrasonic inspection for laminar imperfections within extended length of 100 mm (4.0 in) at the pipe ends (see K.2.1.3);
- u) supplementary end NDT lamination criteria (see K.2.1.3 and K.2.1.4);
- v) magnetic particle inspection for laminar imperfections at each pipe end face/bevel (see K.2.1.4);
- w) ultrasonic inspection to verify conformance with the applicable requirements given in Table K.1 (see K.3.2.2);
- x) verification of lamination size/density (see K.3.2.2);
- y) increased coverage for ultrasonic thickness measurements for SMLS pipe (see K.3.3);
- z) application of one or more of the supplementary non-destructive inspection operations for SMLS pipe (see K.3.4);
- aa) ultrasonic inspection of SMLS pipe for the detection of transverse imperfections (see K.3.4.1);
- bb) full-body inspection of SMLS pipe the flux leakage method for the detection of longitudinal and transverse imperfections (see K.3.4.2);
- cc) full-body inspection of SMLS pipe by the eddy current method (see K.3.4.3);
- dd) full-body magnetic particle inspection of pipe (see K.3.4.4);
- ee) Acceptance Level U2/U2H for non-destructive inspection of the weld seam of HFW pipe (see K.4.1);
- ff) Alternate ISO 10893-10 HFW weld seam UT acceptance criteria [see K.4.1 b)];
- gg) ultrasonic inspection of the pipe body of HFW pipe for laminar imperfections (see K.4.2);
- hh) ultrasonic inspection of the strip/plate edges or areas adjacent to the weld for laminar imperfections (see K.4.3);
- ii) non-destructive inspection of the pipe body of HFW pipe using the ultrasonic or flux-leakage method (see K.4.4);
- jj) use of fixed-depth notches for equipment standardization [see K.5.1.1 c)];
- kk) radiographic inspection of the pipe ends (non-inspected pipe ends) and repaired areas [see K.5.3 a)];
- ll) magnetic particle inspection of the weld seam at the pipe ends of SAW pipe (see K.5.4);
- mm) for grades L625QO or X90QO, and L690QO or X100QO, a lower $R_{t0,5}/R_m$ (see Table J.2).

J.3 Manufacturing

J.3.1 Manufacturing procedure

All pipes shall be manufactured in accordance with a manufacturing procedure that has been qualified in accordance with Annex B, possibly supplemented with additional testing (see Table J.7).

J.3.2 Steel making

The steel shall be made to a clean steel practice, using either the basic oxygen steel-making process or the electric furnace steel-making process and shall be killed.

J.3.3 Pipe manufacturing

J.3.3.1 SMLS pipe

SMLS pipe shall be manufactured from continuously (strand) cast or ingot steel. If the process of cold finishing is used, this shall be stated in the inspection document or mill certificate.

J.3.3.2 Welded pipe

J.3.3.2.1 Unless otherwise agreed, coil and plate used for the manufacture of welded pipe shall be rolled from continuously (strand) cast or pressure cast slabs. The pipe shall be SAWL, SAWH or HFW.

J.3.3.2.2 For HFW pipe, the abutting edges of the coil or plate should be sheared, milled or machined shortly before welding.

J.3.3.2.3 Coil and plate used for the manufacture of welded pipe shall be inspected visually after rolling. Visual inspection of coil used for the manufacture of welded pipe may be either of the uncoiled strip or of the coil edges.

J.3.3.2.4 If agreed, such coil and plate shall be inspected ultrasonically for laminar imperfections or mechanical damage in accordance with Annex K, either before or after cutting the coil or plate, or the completed pipe shall be subjected to full-body inspection, including ultrasonic inspection.

J.3.3.2.5 If agreed, for helical-seam pipe made from coil or plate, pipe containing coil/plate end welds may be delivered, provided that such welds are located at least 300 mm from the pipe end and such welds have been subjected to the same non-destructive inspection that is required in Annex K for coil/plate edges and welds.

J.3.3.2.6 Intermittent tack welding of the SAWL groove shall not be used, unless the purchaser has approved data furnished by the manufacturer to demonstrate that all mechanical properties specified for the pipe are obtainable at both the tack weld and intermediate positions.

J.3.3.3 Jointers

Jointers shall not be delivered unless otherwise agreed.

NOTE It is the responsibility of the purchaser and manufacturer to agree procedures for welding and qualification tests for specific offshore service jointers.

J.4 Acceptance criteria

J.4.1 Chemical composition

J.4.1.1 For pipe with $t \leq 25,0$ mm (0.984 in), the chemical composition for standard grades shall be as given in Table J.1 and the chemical composition for intermediate grades shall be as agreed, but consistent with those given for the standard grades in Table J.1. The pipe designation shall be as given in Table J.1 and consists of an alpha or alphanumeric designation that identifies the steel grade, followed by a suffix that consists of a letter (N, Q or M) that identifies the delivery condition and a second letter (O) that identifies the service condition.

J.4.1.2 For pipe with $t > 25,0$ mm (0.984 in), the chemical composition shall be as agreed, with the requirements given in Table J.1 being amended as appropriate.

Table J.1 — Chemical composition for pipe with $t \leq 25,0$ mm (0.984 in)

Steel grade	Mass fraction, based upon heat and product analyses									Carbon equivalent ^a	
	(maximum) %									(maximum) %	
	C ^b	Si	Mn ^b	P	S	V	Nb	Ti	Other ^c	CE _{IIV}	CE _{Pcm}
SMLS and welded pipes											
L245NO or BNO	0,14	0,40	1,35	0,020	0,010	^d	^d	0,04	e,f	0,36	0,19 ^g
L290NO or X42NO	0,14	0,40	1,35	0,020	0,010	0,05	0,05	0,04	f	0,36	0,19 ^g
L320NO or X46NO	0,14	0,40	1,40	0,020	0,010	0,07	0,05	0,04	e,f	0,38	0,20 ^g
L360NO or X52NO	0,16	0,45	1,65	0,020	0,010	0,10	0,05	0,04	e	0,43	0,22 ^g
L245QO or BQO	0,14	0,40	1,35	0,020	0,010	0,04	0,04	0,04	f	0,34	0,19 ^g
L290QO or X42QO	0,14	0,40	1,35	0,020	0,010	0,04	0,04	0,04	f	0,34	0,19 ^g
L320QO or X46QO	0,15	0,45	1,40	0,020	0,010	0,05	0,05	0,04	f	0,36	0,20 ^g
L360QO or X52QO	0,16	0,45	1,65	0,020	0,010	0,07	0,05	0,04	e,h	0,39	0,20 ^g
L390QO or X56QO	0,16	0,45	1,65	0,020	0,010	0,07	0,05	0,04	e,h	0,40	0,21 ^g
L415QO or X60QO	0,16	0,45	1,65	0,020	0,010	0,08	0,05	0,04	e,h	0,41	0,22 ^g
L450QO or X65QO	0,16	0,45	1,65	0,020	0,010	0,09	0,05	0,06	e,h	0,42	0,22 ^g
L485QO or X70QO	0,17	0,45	1,75	0,020	0,010	0,10	0,05	0,06	e,h	0,42	0,23 ^g
L555QO or X80QO	0,17	0,45	1,85	0,020	0,010	0,10	0,06	0,06	e,h	as agreed	
L625QO or X90QO	0,14	0,45	1,85	0,020	0,010	0,10	0,06	0,06	e,i	as agreed	
L690QO or X100QO	0,14	0,45	1,85	0,020	0,010	0,10	0,06	0,06	e,i	as agreed	
Welded pipe											
L245MO or BMO	0,12	0,40	1,25	0,020	0,010	0,04	0,04	0,04	f	—	0,19
L290MO or X42MO	0,12	0,40	1,35	0,020	0,010	0,04	0,04	0,04	f	—	0,19
L320MO or X46MO	0,12	0,45	1,35	0,020	0,010	0,05	0,05	0,04	f	—	0,20
L360MO or X52MO	0,12	0,45	1,65	0,020	0,010	0,05	0,05	0,04	e,h	—	0,20
L390MO or X56MO	0,12	0,45	1,65	0,020	0,010	0,06	0,08	0,04	e,h	—	0,21
L415MO or X60MO	0,12	0,45	1,65	0,020	0,010	0,08	0,08	0,06	e,h	—	0,21
L450MO or X65MO	0,12	0,45	1,65	0,020	0,010	0,10	0,08	0,06	e,h	—	0,22
L485MO or X70MO	0,12	0,45	1,75	0,020	0,010	0,10	0,08	0,06	e,h	—	0,22
L555MO or X80MO	0,12	0,45	1,85	0,020	0,010	0,10	0,08	0,06	e,h	—	0,24

^a Based upon product analysis (see 9.2.4 and 9.2.5). The CE_{IIV} limits apply if C > 0,12 % and the CE_{Pcm} limits apply if C ≤ 0,12 %.

^b For each reduction of 0,01 % below the specified maximum for C, an increase of 0,05 % above the specified maximum for Mn is permissible, up to a maximum increase of 0,20 %, but up to a maximum of 2.20% for grades ≥ L625 or X90.

^c Al_{total} ≤ 0,060 %; N ≤ 0,012 %; Al/N ≥ 2:1 (not applicable to titanium-killed steel or titanium-treated steel).

^d Unless otherwise agreed, Nb + V ≤ 0,06 %.

^e Nb + V + Ti ≤ 0,15 %.

^f Cu ≤ 0,35 %; Ni ≤ 0,30 %; Cr ≤ 0,30 %; Mo ≤ 0,10 %; B ≤ 0,000 5 %.

^g For SMLS pipe, the listed value of CE_{Pcm} is increased by 0,03 percentage points, up to a maximum of 0,25 %.

^h Cu ≤ 0,50 %; Ni ≤ 0,50 %; Cr ≤ 0,50 %; Mo ≤ 0,50 %; B ≤ 0,000 5 %.

ⁱ Cu ≤ 0,50%; Ni ≤ 0,80%; Cr ≤ 0,55%; Mo ≤ 0,80%; B ≤ 0,000 5%.

J.4.2 Tensile properties

J.4.2.1 The tensile properties shall be as given in Table J.2.

J.4.2.2 If additional tensile properties are required to be determined at other than room temperature, the acceptance criteria shall be as agreed.

Table J.2 —Requirements for the results of tensile tests

Pipe grade	Pipe body of SMLS and welded pipes						Weld seam of HFW and SAW pipes
	Yield strength ^a		Tensile strength ^a		Ratio ^{a,c}	Elongation (on 50 mm or 2 in)	Tensile strength ^d
	$R_{t0,5}$ MPa (psi)		R_m MPa (psi)		$R_{t0,5}/R_m$	A_f %	R_m MPa (psi)
	minimum	maximum	minimum	maximum	maximum	minimum	minimum
L245NO or BNO L245QO or BQO L245MO or BMO	245 (35 500)	450 ^e (65 300) ^e	415 (60 200)	655 (95 000)	0,93	f	415 (60 200)
L290NO or X42NO L290QO or X42QO L290MO or X42MO	290 (42 100)	495 (71 800)	415 (60 200)	655 (95 000)	0,93	f	415 (60 200)
L320NO or X46NO L320QO or X46QO L320MO or X46MO	320 (46 400)	520 (75 000)	435 (63 100)	655 (95 000)	0,93	f	435 (63 100)
L360NO or X52NO L360QO or X52QO L360MO or X52MO	360 (52 200)	525 (76 000)	460 (66 700)	760 (110 200)	0,93	f	460 (66 700)
L390QO or X56QO L390MO or X56MO	390 (56 600)	540 (78 300)	490 (71 100)	760 (110 200)	0,93	f	490 (71 100)
L415QO or X60QO L415MO or X60MO	415 (60 200)	565 (81 900)	520 (75 400)	760 (110 200)	0,93	f	520 (75 400)
L450QO or X65QO L450MO or X65MO	450 (65 300)	570 (82 700)	535 (77 600)	760 (110 200)	0,93	f	535 (77 600)
L485QO or X70QO L485MO or X70MO	485 (70 300)	605 (87 700)	570 (82 700)	760 (110 200)	0,93	f	570 (82 700)
L555QO or X80QO L555MO or X80MO	555 (80 500)	675 (97 900)	625 (90 600)	825 (119 700) ^b	0,93	f	625 (90 600)
L625QO or X90QO	625 (90 600)	745 (108 000)	695 (100 800)	895 (129 800) ^b	0,97 ^h	f	—
L690QO or X100QO	690 ^g (100 100) ^g	810 ^g (117 500) ^g	760 (110 200)	960 (139 200) ^b	0,97 ⁱ	f	—

a For intermediate grades, the difference between the specified maximum yield strength and the specified minimum yield strength shall be as given in the table for the next higher grade, and the difference between the specified minimum tensile strength and the specified minimum yield strength shall be as given in the table for the next higher grade. For intermediate grades up to Grade L320 or X46, the tensile strength shall be ≤ 655 MPa (95 000 psi). For intermediate grades greater than Grade L320 or X46 and less than Grade L550 or X80, the tensile strength shall be ≤ 760 MPa (110 200 psi). For intermediate grades higher than Grade L550 or X80, the maximum permissible tensile strength shall be obtained by interpolation. For SI units, the calculated value shall be rounded to the nearest 5 MPa. For USC units, the calculated value shall be rounded to the nearest 100 psi.

b If agreed, for pipe in grades equal to or greater than Grade L550 or X80, more stringent maximum tensile strength limits may apply.

c This limit applies for pipe with $D > 323,9$ mm (12.750 in).

d For intermediate grades, the specified minimum tensile strength for the weld seam shall be the same value as was determined for the pipe body using footnote a).

e For pipe requiring longitudinal testing the yield strength shall be ≤ 495 MPa (71 800 psi).

f The specified minimum elongation, A_f , on 50 mm (2 in), expressed in percent and rounded to the nearest percent, shall be as determined using the following equation:

$$A_f = C \frac{A_{xc}^{0,2}}{U^{0,9}}, \text{ where}$$

C is 1 940 for calculations using SI units and 625 000 for calculations using USC units;

A_{xc} is the applicable tensile test piece cross-sectional area, expressed in square millimetres (square inches), as follows:

- for circular cross-section test pieces, 130 mm² (0.20 in²) for 12,7 mm (0.500 in) and 8,9 mm (0.350 in) diameter test pieces; and 65 mm² (0.10 in²) for 6,4 mm (0.250 in) diameter test pieces;
- for full-section test pieces, the lesser of a) 485 mm² (0.75 in²) and b) the cross-sectional area of the test piece, derived using the specified outside diameter and the specified wall thickness of the pipe, rounded to the nearest 10 mm² (0.01 in²);
- for strip test pieces, the lesser of a) 485 mm² (0.75 in²) and b) the cross-sectional area of the test piece, derived using the specified width of the test piece and the specified wall thickness of the pipe, rounded to the nearest 10 mm² (0.01 in²);

U is the specified minimum tensile strength, expressed in megapascals (pounds per square inch).

g For grades > L625QO or X90QO, $R_{p0,2}$ applies.

h Lower $R_{10,5}/R_m$ ratio values may be specified by agreement for L625 or X90

i For grades > L625 or X90, $R_{p0,2}/R_m$ applies. Lower $R_{p0,2}/R_m$ ratio values may be specified by agreement.

J.4.3 Hardness test

For test pieces subjected to a hardness test (see J.8.3.2), the hardness in the pipe body, weld and HAZ shall be

- a) ≤ 270 HV10 or ≤ 25 HRC for Grades \leq L450 or X65,
- b) ≤ 300 HV10 or ≤ 30 HRC for Grades $>$ L450 or X65 and \leq L555 or X80,
- c) ≤ 325 HV10 or ≤ 33 HRC for Grades $>$ L555 or X80.

J.5 Surface conditions, imperfections and defects

Surface imperfections, other than undercuts in SAW pipe and arc burns in any pipe, found by visual inspection shall be investigated, classified and treated as follows.

- a) Imperfections that have a depth $\leq 0,05 t$ and do not encroach on the minimum permissible wall thickness shall be classified as acceptable imperfections and treated in accordance with Clause C.1.

NOTE There is a possibility of special requirements for disposition of surface imperfections being specified in the purchase order if the pipe is subsequently to be coated.

- b) Imperfections that have a depth $> 0,05 t$ and do not encroach on the minimum permissible wall thickness shall be classified as defects and shall be treated in accordance with Clauses C.2 or C.3.
- c) Imperfections that encroach on the minimum permissible wall thickness shall be classified as defects and treated in accordance with Clause C.3.

J.6 Tolerances for diameter, wall thickness, length and straightness

J.6.1 Except as allowed by C.2.3, the diameter and out-of-roundness shall be within the tolerances given in Table J.3.

J.6.2 The wall thickness shall be within the tolerances given in Table J.4.

J.6.3 Unless otherwise agreed, the minimum average length of pipe shall be 12,1 m (39.7 ft). If requested by the purchaser, the pipe manufacturer shall confirm the maximum average length of pipe to be supplied per order item. Unless otherwise agreed, the actual length of each pipe (end face to end face) shall lie within the range 11,70 m (38.4 ft) to 12,70 m (41.7 ft). Subject to approval by the purchaser, pipes from which the test samples were taken may be delivered as short lengths.

NOTE The minimum average length of 12,1 m (39.7 ft) is based upon the optimum lengths for handling on several 'S-lay' barges in operation at the time of preparing this Standard and could change in the course of time. A minimum average length of 12,1 m (39.7 ft) is not necessarily optimum for deepwater 'J-lay' practice and can vary according to the 'J-lay' system used. It is, therefore, the responsibility of the purchaser to agree with both the manufacturer and the pipe-lay contractor the length range to be supplied.

J.6.4 The tolerances for straightness shall be as follows.

- The total deviation from a straight line over the entire pipe length shall be $\leq 0,15\%$ of the pipe length.
- The local deviation from a straight line in the 1,0 m (3.0 ft) portion at each pipe end shall be $\leq 3,0$ mm (0.120 in).

Table J.3 — Tolerances for diameter and out-of-roundness

Specified outside diameter D mm (in)	Diameter tolerances ^d mm (in)				Out-of-roundness tolerances mm (in)	
	Pipe except the end ^a		Pipe end ^{a,b,c}		Pipe except the end ^a	Pipe end ^{a,b,c}
	SMLS pipe	Welded pipe	SMLS pipe	Welded pipe		
< 60,3 (2.375)		$\pm 0,5$ (0.020)			0,9 (0.036)	0,6 (0.024)
$\geq 60,3$ (2.375) to 610 (24.000)	$\pm 0,5$ (0.020) or $\pm 0,0075 D$, whichever is the greater	$\pm 0,5$ (0.020) or $\pm 0,0075 D$, whichever is the greater, but maximum of $\pm 3,2$ (0.125)	$\pm 0,5$ (0.020) or $\pm 0,005 D$, whichever is the greater, but maximum of $\pm 1,6$ (0.063)		$0,015 D$ for $\frac{D}{t} \leq 75$; by agreement for $\frac{D}{t} > 75$	$0,01 D$ for $\frac{D}{t} \leq 75$; by agreement for $\frac{D}{t} > 75$
> 610 (24.000) to 1 422 (56.000)	$\pm 0,01 D$	$\pm 0,005 D$, but maximum of $\pm 4,0$ (0.160)	$\pm 2,0$ (0.079)	$\pm 1,6$ (0.063)	$0,01 D$ but maximum of 10 (0.4), for $\frac{D}{t} \leq 75$; by agreement for $\frac{D}{t} > 75$	$0,0075 D$ but maximum of 8 (0.3), for $\frac{D}{t} \leq 75$; by agreement for $\frac{D}{t} > 75$
> 1 422 (56.000)	as agreed					

^a The pipe end includes a length of 100 mm (4.0 in) at each of the pipe extremities.

^b For SMLS pipe, the tolerances apply for $t \leq 25,0$ mm (0.984 in) and the tolerances for heavier wall pipe shall be as agreed.

^c For expanded pipe with $D \geq 219,1$ mm (8.625 in) and for non-expanded pipe, the diameter tolerance and the out-of-roundness tolerance may be determined using the calculated inside diameter (the specified outside diameter minus two times the specified wall thickness) or measured inside diameter rather than the specified outside diameter (see 10.2.8.3).

^d For determining compliance to diameter tolerances, the pipe diameter is defined as the circumference of the pipe in any circumferential plane divided by π .

Table J.4 — Tolerances for wall thickness

Wall thickness t mm (in)	Tolerances ^a mm (in)
SMLS pipe	
< 4,0 (0.157)	+ 0,6 (0.024) - 0,5 (0.020)
4,0 (0.157) to < 10,0 (0.394)	+ 0,15 t - 0,125 t
10,0 (0.394) to < 25,0 (0.984)	+ 0,125 t - 0,125 t
\geq 25,0 (0.984)	+ 3,7 (0.146) or + 0,1 t , whichever is the greater ^b - 3,0 (0.120) or - 0,1 t , whichever is the greater ^b
HFW pipe^{c,d}	
\leq 6,0 (0.236)	\pm 0,4 (0.016)
> 6,0 (0.236) to 15,0 (0.591)	\pm 0,7 (0.028)
> 15,0 (0.591)	\pm 1,0 (0.039)
SAW pipe^{c,d}	
\leq 6,0 (0.236)	\pm 0,5 (0.020)
> 6,0 (0.236) to 10,0 (0.394)	\pm 0,7 (0.028)
> 10,0 (0.394) to 20,0 (0.787)	\pm 1,0 (0.039)
> 20,0 (0.787)	+ 1,5 (0.060) - 1,0 (0.039)
<p>^a If the purchase order specifies a minus tolerance for wall thickness smaller than the applicable value given in this table, the plus tolerance for wall thickness shall be increased by an amount sufficient to maintain the applicable tolerance range.</p> <p>^b For pipe with $D \geq 355,6$ mm (14.000 in) and $t \geq 25,0$ mm (0.984 in) the tolerance is $\begin{matrix} +12,5\% \\ -12,5\% \end{matrix}$.</p> <p>^c The plus tolerance for wall thickness does not apply to the weld area.</p> <p>^d See 9.13.2 and J.7.2 for additional restrictions.</p>	

J.7 Tolerances for the weld seam

J.7.1 Radial offset of strip/plate edges

For HFW pipe, the radial offset of the strip/plate edges [see Figure 4 a)] shall not cause the remaining wall thickness at the weld to be less than the minimum permissible wall thickness.

For SAW pipe, the inside and outside radial offsets of the strip/plate edges [see Figure 4 b)] shall not exceed the applicable value given in Table J.5.

Table J.5 — Maximum permissible radial offset for SAW pipe

Specified wall thickness t mm (in)	Maximum permissible radial offset ^a mm (in)
$\leq 13,0$ (0.512)	1,3 (0.051)
$> 13,0$ (0.512) to $20,0$ (0.787)	$0,1 t$
$> 20,0$ (0.787)	2,0 (0.079)

^a These limits apply also to strip/plate end welds.

J.7.2 Weld flash of HFW pipe

The inside flash shall not extend above the contour of the pipe by more than $0,3 \text{ mm}$ (0.012 in) + $0,05 t$.

J.8 Inspection**J.8.1 Specific inspection**

The frequency of inspection shall be as given in Table 18, except as specifically modified in Table J.6.

Table J.6 — Inspection frequency

No	Type of inspection	Type of pipe	Frequency of inspection
1	Tensile testing of the pipe body of pipe with $D < 508 \text{ mm}$ (20.000 in)	SMLS, HFW, or SAW	Once per test unit of not more than 100 lengths of pipe with the same cold-expansion ratio ^a
2	Tensile testing of the pipe body of pipe with $D \geq 508 \text{ mm}$ (20.000 in)	SMLS, HFW, or SAW	Once per test unit of not more than 50 lengths of pipe with the same cold-expansion ratio ^a
3	Tensile testing of the longitudinal or helical-seam weld of welded pipe with $219,1 \text{ mm}$ (8.625 in) $\leq D < 508 \text{ mm}$ (20.000 in)	HFW or SAW	Once per test unit of not more than 100 lengths of pipe with the same cold-expansion ratio ^{a,b}
4	Tensile testing of the longitudinal or helical-seam weld of welded pipe with $D \geq 508 \text{ mm}$ (20.000 in)	HFW or SAW	Once per test unit of not more than 50 lengths of pipe with the same cold-expansion ratio ^{a,b,c}
5	Tensile testing of the coil/plate end weld of SAW pipe with $D \geq 219,1 \text{ mm}$ (8.625 in)	SAWH	At least once per 50 coil/plate end welds from pipe with the same cold expansion ratio ^{a,b,d}
6	CVN impact testing of the pipe body of pipe with $114,3 \text{ mm}$ (4.500 in) $\leq D < 508 \text{ mm}$ (20.000 in) and specified wall thickness as given in Table 22	SMLS, HFW, or SAW	Once per test unit of not more than 100 lengths of pipe with the same cold-expansion ratio ^a
7	CVN impact testing of the pipe body of pipe with $D \geq 508 \text{ mm}$ (20.000 in) and specified wall thickness as given in Table 22	SMLS, HFW, or SAW	Once per test unit of not more than 50 lengths of pipe from the same heat of steel and with the same cold-expansion ratio ^a

No	Type of inspection	Type of pipe	Frequency of inspection
8	CVN impact testing of the longitudinal or helical-seam weld of welded pipe with $114,3 \text{ mm} (4.500 \text{ in}) \leq D < 508 \text{ mm} (20.000 \text{ in})$ and specified wall thickness as given in Table 22	HFW or SAW	Once per test unit of not more than 100 lengths of pipe with the same cold-expansion ratio ^{a,b}
9	CVN impact testing of the longitudinal or helical-seam weld of welded pipe with $D \geq 508 \text{ mm} (20.000 \text{ in})$ and specified wall thickness as given in Table 22	HFW or SAW	Once per test unit of not more than 50 lengths of with the same cold-expansion ratio ^{a,b,c}
10	CVN impact testing of the coil/plate end weld of welded pipe with $D \geq 114,3 \text{ mm} (4.500 \text{ in})$ and specified wall thickness as given in Table 22	SAWH	At least once per 50 coil/plate end welds from pipe with the same cold expansion ratio ^{a,b,d}
11	If agreed, hardness testing of pipe body and of the longitudinal or helical-seam weld and HAZ of welded pipe	HFW, SAW, or SMLS	As agreed
12	Pipe diameter and out-of-roundness for pipe with $D \leq 168,3 \text{ mm} (6.625 \text{ in})$	SMLS, HFW, or SAW	Once per test unit of not more than 100 lengths of pipe
13	Pipe diameter and out-of-roundness for pipe with $D > 168,3 \text{ mm} (6.625 \text{ in})$	SMLS, HFW, or SAW	Once per test unit of not more than 20 lengths of pipe
14	Non-destructive inspection	SMLS, HFW, or SAW	In accordance with Annex K
15	If agreed, for information purposes only, CTOD test for pipe in Grades $\geq \text{L360}$ or X52	SAW	Once; for manufacturing procedure qualification only

^a The cold-expansion ratio is designated by the manufacturer and is derived using the designated before-expansion outside diameter or circumference and the after-expansion outside diameter or circumference. An increase or decrease in the cold-expansion ratio of more than 0,002 requires the creation of a new test unit.

^b In addition, pipe produced by each welding machine shall be tested at least once per week.

^c For double-seam pipe, both longitudinal weld seams in the pipe selected to represent the test unit shall be tested.

^d Applies only to finished helical-seam pipe containing coil/plate end welds.

J.8.2 Samples and test pieces for mechanical and technological tests

J.8.2.1 General

J.8.2.1.1 For tensile tests, CVN impact tests, guided-bend tests, hardness tests, bead-on-plate tests, bead-on-pipe tests and CTOD tests, the samples shall be taken and the corresponding test pieces prepared in accordance with the applicable reference standard.

J.8.2.1.2 Samples and test pieces for the various test types shall be taken from locations as shown in Figures 5 and 6 and as given in Table J.7, taking into account the supplementary details in 10.2.3.2 to 10.2.3.7, 10.2.4, J.8.2.2 and J.8.2.3.

J.8.2.2 Test pieces for CTOD tests

Test pieces shall be taken from the weld metal, the HAZ and the parent metal and shall be prepared in accordance with ISO 12135, ASTM E1290, or BS 7448.

J.8.2.3 Samples for hardness tests

Samples for hardness tests shall be taken from the end of selected pipes and, for welded pipe, each sample shall contain a section of the longitudinal or helical seam at its centre (see Figure J.1 b).

Table J.7 — Number, orientation and location of test pieces per sample for mechanical tests

Type of pipe	Sample location	Type of test	Number, orientation and location of test pieces per sample ^a		
			Specified outside diameter		
			D mm (in)		
			< 219,1 (8.625)	≥ 219,1 (8.625) to < 508 (20.000)	≥ 508 (20.000)
SMLS, not cold-expanded [see Figure 5 a)]	Pipe body	Tensile	1L ^b	1L	1L
		CVN	3T	3T	3T
		Hardness	1T	1T	1T
SMLS, cold-expanded [see Figure 5 a)]	Pipe body	Tensile	1L ^b	1T ^c	1T ^c
		CVN	3T	3T	3T
		Hardness	1T	1T	1T
HFW [see Figure 5 b)]	Pipe body	Tensile	1L90 ^b	1T180 ^{c,d}	1T180 ^{c,d}
		CVN	3T90	3T90	3T90
	Seam weld	Tensile	—	1W	1W
		CVN	3W	3W	3W
		Hardness	1W	1W	1W
	Pipe body and weld	Flattening	As shown in Figure 6		
SAWL [see Figure 5 b)]	Pipe body	Tensile	1L90 ^b	1T180 ^{c,d}	1T180 ^{c,d}
		CVN	3T90	3T90	3T90
	Seam weld	Tensile	—	1W	1W ^e
		CVN	3W and 3HAZ	3W and 3HAZ	3W ^e and 3HAZ ^e
		Guided-bend	2W	2W	2W ^e
		Hardness	1W	1W	1W ^e
SAWH [see Figure 5 c)]	Pipe body	Tensile	1L ^b	1T	1T ^c
		CVN	3T	3T	3T
	Seam weld	Tensile	—	1W	1W
		CVN	3W and 3HAZ	3W and 3HAZ	3W and 3HAZ
		Guided-bend	2W	2W	2W
		Hardness	1W	1W	1W
	Strip/plate end weld	Tensile	—	1WS	1WS
		CVN	3WS and 3HAZ	3WS and 3HAZ	3WS and 3HAZ
		Guided-bend	2WS	2WS	2WS
		Hardness	1WS	1WS	1WS

^a See Figure 5 for an explanation of the symbols used to designate orientation and location.

^b Full-section longitudinal test pieces may be used at the option of the manufacturer.

^c If agreed, annular test pieces may be used for the determination of transverse yield strength by the hydraulic ring expansion test in accordance with ASTM A370.

^d For deep-water pipelay, additional longitudinal tests might be specified, with the requirements and test frequency being as agreed.

^e For double-seam pipe, both longitudinal weld seams in the pipe selected to represent the test unit shall be tested.

J.8.3 Test methods

J.8.3.1 CTOD test

CTOD tests shall be carried out in accordance with ISO 12135 or ASTM E1290, or BS 7448. The test temperature shall be as stated in the purchase order.

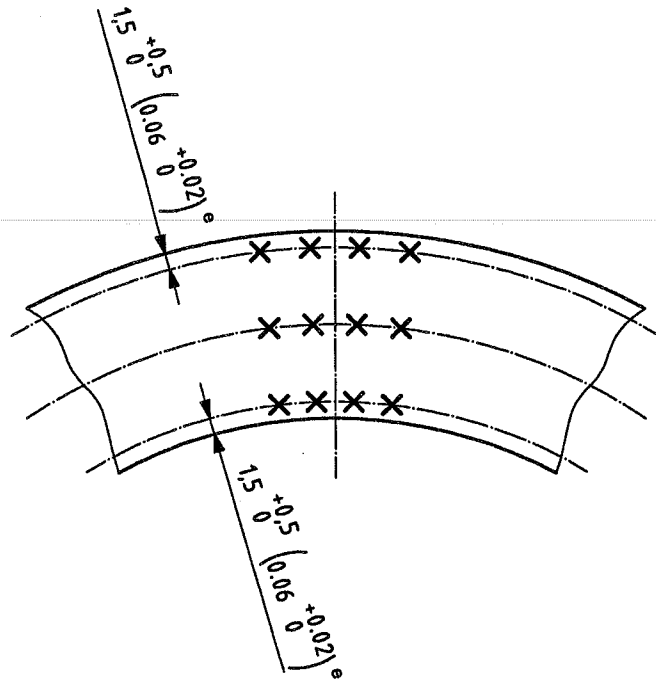
J.8.3.2 Hardness test

J.8.3.2.1 Hardness testing on the parent metal shall be performed using the Vickers test in accordance with ISO 6507-1 or ASTM E384 or using the Rockwell test HR15N in accordance with ISO 6508-1 or ASTM E18. In case of dispute, the Vickers method shall apply.

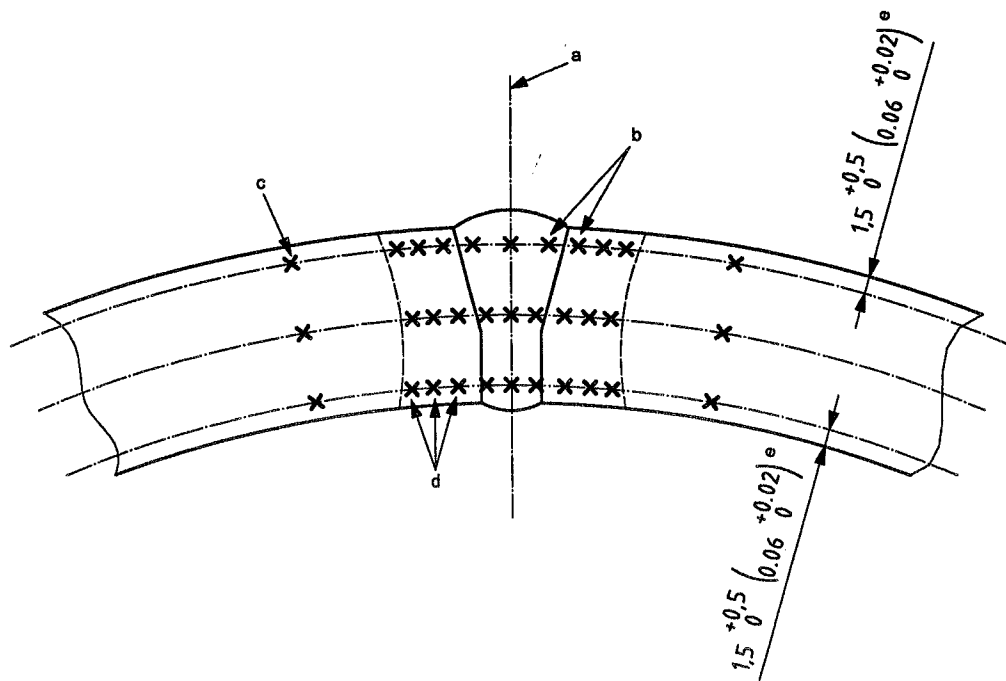
Hardness testing on the HAZ and weld shall be carried out using the Vickers test in accordance with ISO 6507-1 or ASTM E384.

For pipe body tests and parent metal tests, individual hardness readings exceeding the applicable acceptance limit may be considered acceptable if the average of a minimum of three and maximum of six additional readings taken within close proximity does not exceed the applicable acceptance limit, and no such individual reading exceeds the acceptance limit by more than 10 HV10 units or 2 HRC units, whichever is applicable.

Dimensions in millimetres (inches)



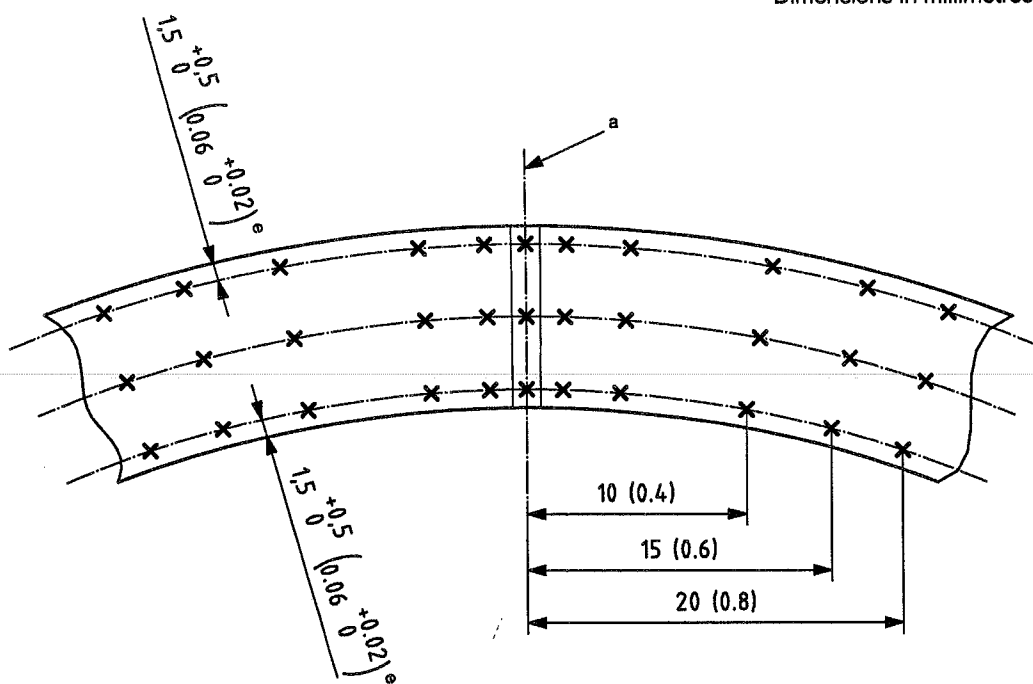
a) SMLS pipe



b) SAW pipe

Figure J.1 — Location of hardness tests

Dimensions in millimetres (inches)



c) HFW pipe

- a Weld centreline.
- b 0,75 mm (0.03 in) from fusion line.
- c $1 t$ from fusion line.
- d 1,0 mm (0.04 in) spacing in visible HAZ.
- e From inside and outside surfaces.

Figure J.1 — Location of hardness tests (continued)

J.8.3.2.2 Hardness test locations for SMLS pipe shall be as shown in Figure J.1 a), except that:

- a) for pipe with $t < 4,0$ mm (0.156 in), it is necessary to carry out only the mid-thickness traverse;
- b) for pipe with $4,0$ mm (0.156 in) $\leq t < 6$ mm (0.236 in), it is necessary to carry out only the inside and outside surface traverses;
- c) if agreed, three impressions at each through-thickness location shown in Figure J.1 a) are acceptable.

J.8.3.2.3 Hardness locations shall include the weld cross-section. Indentations shall be made in the parent metal, in the visible HAZ and at the weld centreline, as shown in Figure J.1 b) or Figure J.1 c), except that:

- a) for pipe with $t < 4,0$ mm (0.156 in), it is necessary to carry out only the mid-thickness traverse;

- b) for pipe with $4,0 \text{ mm (0.156 in)} \leq t < 6 \text{ mm (0.236 in)}$, it is necessary to carry out only the inside and outside surface traverses;
- c) if agreed, the distance from the weld line to the indentations in the parent metal may be less than shown in Figure J.1.c provided these indentations remain located in the parent metal.

J.8.4 Non-destructive inspection

For non-destructive inspection, see Clause J.2 and Annex K.

J.9 Pipe markings

In addition to the pipe markings required in 11.2, the pipe markings shall include an identification number that permits the correlation of the product or delivery unit with the related inspection document.

Only pipe conforming to the requirements of this Standard for PSL 2 together with the supplementary requirements of Annex J may be marked as complying with this standard and carry the letter "O" within the grade name to indicate that the pipe is intended for offshore service.

Pipes meeting requirements of both Annex H & J shall be marked with both grade name suffix markings S & O (e.g. X52MS/X52MO or L360MS/L360MO).

Annex K (normative)

Non-destructive inspection for pipe ordered for sour service and/or offshore service

K.1 Introduction

This annex applies if the pipe is ordered for sour service or offshore service or both [see 7.2 c) 55) and/or 7.2 c) 59)]. For such pipe, the non-destructive inspection provisions of Annex E apply, except as specifically modified by the provisions in this annex.

K.2 General non-destructive inspection requirements and acceptance criteria

K.2.1 Laminar imperfections at the pipe ends

K.2.1.1 Laminar imperfections > 6,4 mm (0.25 in) in the circumferential direction and having an area > 100 mm² (0.15 in²) shall be classified as defects.

K.2.1.2 For pipe with $t \geq 5,0$ mm (0.197 in), ultrasonic inspection with automated/semi-automated systems in accordance with ISO 10893-8 or by manual methods, as specified in Annex A of ISO 10893-8, shall be used to verify that the 50 mm (2.0 in) wide zone at each pipe end is free of such laminar defects.

K.2.1.3 If agreed for pipe with $t \geq 5,0$ mm (0.197 in), ultrasonic inspection with automated/semi-automated systems in accordance with ISO 10893-8 or by manual methods, as specified in Annex A of ISO 10893-8, shall be used to verify that the 100 mm (4.0 in) wide zone at each pipe end is free of such laminar defects.

K.2.1.4 If agreed, the end face/bevel at each pipe end shall be magnetic particle inspected for the detection of laminar imperfections in accordance with ISO 10893-5 or ASTM E709. Laminar imperfections > 6,4 mm (0.25 in) in the circumferential direction shall be classified as defects.

K.2.2 Suspect pipe

K.2.2.1 Pipe giving rise to indications producing a trigger/alarm condition as a result of the specified non-destructive inspection operation shall be deemed suspect.

K.2.2.2 Suspect pipe shall be dealt with in accordance with the applicable standard for non-destructive inspection of pipe, unless otherwise stated in this annex, Annex H or Annex J, whichever is applicable.

K.2.2.3 Repair by welding shall be in accordance with Clause C.4.

K.2.2.4 Where dressing is carried out, complete removal of defects shall be verified by local visual inspection, aided where necessary by suitable non-destructive inspection methods.

K.2.2.5 Any manual non-destructive inspection applied to local suspect areas (dressed or not) shall use the same inspection sensitivity, parameters and acceptance level (reference notch depth) as used

during the inspection that originally deemed the pipe to be suspect. For manual ultrasonic inspection, the scanning speed shall be ≤ 150 mm/s (6 in/s).

K.3 Non-destructive inspection of SMLS pipe

K.3.1 Ultrasonic inspection for longitudinal imperfections

SMLS pipe shall be full-body ultrasonically inspected for the detection of longitudinal imperfections in accordance with ISO 10893-10 or ASTM E213. The acceptance limits for such inspection shall be in accordance with ISO 10893-10, acceptance level U2/C.

K.3.2 Laminar imperfections in the pipe body

K.3.2.1 For sour service, individual laminations and/or lamination densities exceeding the acceptance limits for sour service given in Table K.1 shall be classified as defects. Compliance with such requirements shall be verified by ultrasonic inspection in accordance with ISO 10893-8 (except 4.2), ASTM A435 or ASTM A578. The coverage during automatic inspection shall be $\geq 20\%$ of the pipe surface.

K.3.2.2 For offshore service, individual laminations and/or lamination densities exceeding the acceptance limits for offshore service given in Table K.1 shall be classified as defects. If agreed, compliance with such requirements shall be verified by ultrasonic inspection in accordance with ISO 10893-8 (except 4.2), ASTM A435 or ASTM A578. The coverage during automatic inspection shall be $\geq 20\%$ of the pipe surface.

K.3.3 Ultrasonic thickness measurements

SMLS pipe shall be subjected to full peripheral ultrasonic inspection in accordance with ISO 10893-12 or ASTM E114 for verification of compliance with the applicable minimum permissible wall thickness requirement. The coverage for such inspection shall be $\geq 25\%$ of the pipe surface or, if agreed, a greater minimum coverage.

K.3.4 Supplementary non-destructive inspection

K.3.4.1 If agreed, SMLS pipe shall be ultrasonically inspected for the detection of transverse imperfections in accordance with ISO 10893-10 acceptance level U2/C, or ASTM E213.

K.3.4.2 If agreed, SMLS pipe shall be full-body inspected using the flux leakage method in accordance with ISO 10893-3 acceptance level F2, or ASTM E570 for the detection of longitudinal imperfections and/or ISO 10893-3 acceptance level F2, or ASTM E570, for the detection of transverse imperfections.

K.3.4.3 If agreed, SMLS pipe shall be full-body inspected for the detection of imperfections using the eddy current method in accordance with ISO 10893-2 acceptance level E2H/E2, or ASTM E309.

K.3.4.4 If agreed, subsequent to all other non-destructive inspection operations and visual inspection, full-body magnetic particle inspection shall be carried out in accordance with ISO 10893-5 or ASTM E709 on one SMLS pipe per heat of steel or batch of 50 pipes produced, whichever is fewer, in order to verify compliance with the requirements of 9.10. Such pipes shall be selected at random and, before inspection, subjected to abrasive blasting to produce an external surface preparation of Sa 2½ in accordance with ISO 8501-1:1988 when blasted.

Table K.1 — Acceptance criteria for laminar imperfections

Service condition	Maximum individual imperfection		Minimum imperfection size considered			Maximum population density ^a
	Area mm ² (in ²)	Length mm (in)	Area mm ² (in ²)	Length mm (in)	Width mm (in)	
Pipe body (or strip/plate body)						
Offshore	1 000 (1.6)	Not specified	300 (0.5)	35 (1.4)	8 (0.3)	10 [per 1,0 m (3.3 ft) × 1,0 m (3.3 ft) square] ^b
Sour	500 (0.8)		150 (0.2)	15 (0.6)	8 (0.3)	10 [per 500 mm (1.6 ft) × 500 mm (1.6 ft) square] ^c
Sour, if agreed	100 (0.16)		30 (0.05)	5 (0.2)	5 (0.2)	5 [per 500 mm (1.6 ft) × 500 mm (1.6 ft) square] ^c
Strip/plate edges or areas adjacent to the weld seam ^d						
Sour or offshore	100 (0.16)	20 (0.8)	—	10 (0.4)	—	3 [per 1,0 m (3.3 ft) length]
NOTE 1 For an imperfection to be larger than the minimum imperfection size, the minimum area, minimum length and minimum width given for the pipe body (or strip/plate body) all have to be exceeded.						
NOTE 2 For the purpose of determining the extent of suspect area, adjacent suspect areas separated by less than the smaller of two minor axes of the areas shall be considered as one area.						
^a Number of imperfections smaller than the maximum and greater than the minimum imperfection size.						
^b For pipe with $D < 323,9$ mm (12.375 in) or strip/plate widths less than 1 000 mm (39.4 in), the maximum population density is referred to 1,0 m ² (10.8 ft ²).						
^c For pipe with $D < 168,3$ mm (6.625 in) or strip/plate widths less than 500 mm (19.7 in), the maximum population density is referred to 0,25 m ² (2.7 ft ²).						
^d The maximum imperfection area of edges is the product of the maximum imperfection length, where length is the dimension parallel to the material edge and the transverse dimension. An imperfection is considered to be larger than the maximum imperfection size if either the length or the transverse dimension is exceeded.						

K.4 Non-destructive inspection of HFW pipe

K.4.1 Non-destructive inspection of the weld seam

The full length of the weld seam shall be ultrasonically inspected for the detection of longitudinal imperfections, with the acceptance limits being in accordance with one of the following:

- ISO 10893-11 acceptance level U2/U2H;
- ISO 10893-10 acceptance level U3, or, if agreed, acceptance level U2;
- ASTM E273.

K.4.2 Laminar imperfections in the pipe body

If agreed, the pipe or strip/plate body shall be ultrasonically inspected for the detection of laminar imperfections in accordance with ISO 10893-8 (except 4.2) or ISO 10893-9 respectively, to acceptance limits for the relevant application as given in Table K.1. The coverage during automatic inspection shall be ≥ 20 % of the pipe surface.

K.4.3 Laminar imperfections on the strip/plate edges or areas adjacent to the weld seam

If agreed, the strip/plate edges or the areas adjacent to the weld seam shall be ultrasonically inspected over a width of 15 mm (0.6 in) for the detection of laminar imperfections, in accordance with ISO 10893-9 or ISO 10893-8 respectively, to the acceptance limits as given in Table K.1 for strip/plate edges or areas adjacent to the weld seam.

K.4.4 Supplementary non-destructive inspection

If agreed, the pipe body of HFW pipe shall be inspected for the detection of longitudinal imperfections using the ultrasonic method in accordance with ISO 10893-10 with acceptance level U3/C or, if agreed, U2/C or ASTM E213, or the flux-leakage method in accordance with ISO 10893-3 acceptance level F3; or, if agreed, acceptance level F2, or ASTM E570.

K.5 Non-destructive inspection of SAW pipe

K.5.1 Ultrasonic inspection for longitudinal and transverse imperfections in seam welds

K.5.1.1 The full length of the weld seams of SAW pipe shall be ultrasonically inspected for the detection of longitudinal and transverse imperfections in accordance with ISO 10893-11 acceptance level U2, with the following modifications.

- a) The notch depth shall be $\leq 2,0$ mm (0.080 in).
- b) The use of internal and external longitudinal notches located on the centre of the weld seam for equipment standardization purposes is not permitted.
- c) As an alternative to the use of the reference hole for equipment calibration for the detection of transverse imperfections, it is permissible to use acceptance level U2 internal and external notches, lying at right angles to, and centred over, the weld seam. In this case, both internal and external weld reinforcements shall be ground flush to match the pipe contour in the immediate area and on both sides of the reference notches. The notches shall be sufficiently separated from each other in the longitudinal direction and from any remaining reinforcement, to give clearly identifiable separate ultrasonic signal responses. The full signal amplitude from each of such notches shall be used to set the trigger/alarm level of the equipment.

As an alternative to the use of acceptance Level U2 notches for equipment standardization, it is permissible, if agreed, to use a fixed-depth internal and external notch and increase the inspection sensitivity by electronic means (i.e. increase in decibels). In this case (known as the "two-lambda method"), the depth of the notches shall be twice the wavelength at the ultrasonic frequency in use. The wavelength, λ , expressed in metres (feet), is given by Equation (K.1):

$$\lambda = \frac{V_t}{f} \tag{K.1}$$

where

V_t is transverse ultrasonic velocity, expressed in metres per second (feet per second);

f is frequency, expressed in hertz (cycles per second).

EXAMPLE At 4 MHz test frequency, the wavelength is 0,8 mm (0.031 in) and the notch depth is 1,6 mm (0.063 in).

The required increase in inspection sensitivity shall be based upon pipe thickness and the manufacturer shall demonstrate to the satisfaction of the purchaser that the inspection sensitivity achieved is essentially equivalent to that achieved when using acceptance level U2 notches.

d) The manufacturer may apply the provisions of K.5.3 to retest the suspect areas.

K.5.1.2 For SAWH pipe, the full length of the coil/plate end weld shall be ultrasonically inspected using the same inspection sensitivity and parameters as used on the helical-seam weld in accordance with K.5.1.1.

In addition, the T-joints, where the extremities of the coil/plate end weld meet the helical-seam weld, shall be subjected to radiographic inspection in accordance with Clause E.4.

K.5.1.3 For jointers, the full length of the girth weld shall be ultrasonically inspected using the same inspection sensitivity and parameters as used on the helical or longitudinal seam weld in accordance with K.5.1.1.

In addition, the T-joints, where the girth weld intersects the longitudinal seam in SAWL pipe or the helical seam in SAWH pipe, shall be subjected to radiographic inspection in accordance with Clause E.4.

K.5.2 Laminar imperfections in the pipe body and on the strip/plate edges

K.5.2.1 The pipe or strip/plate body shall be ultrasonically inspected for the detection of lamina imperfections in accordance with ISO 10893-9 to acceptance limits for the relevant service condition as given in Table K.1, with a coverage of $\geq 20\%$.

Such inspection may be carried out in the strip/plate mill or in the pipe mill.

K.5.2.2 The strip/plate edges, including those adjacent to the coil/plate end weld of helical-seam pipe, shall be ultrasonically inspected over a width of 15 mm (0.6 in) for the detection of lamina imperfections in accordance with ISO 10893-9 to acceptance limits as given in Table K.1 for strip/plate edges or areas adjacent to the weld seam.

K.5.3 Non-destructive inspection of the weld seam at the pipe ends/repared areas

The length of weld seam at pipe ends that cannot be inspected by the automatic ultrasonic equipment and repared areas of the weld seam (see Clause C.4), shall be subjected to the following.

- a) For the detection of longitudinal imperfections, manual or semi-automatic ultrasonic inspection using the same inspection sensitivity and inspection parameters as is specified in K.5.1.1 or, if agreed, radiographic inspection in accordance with Clause E.4.
- b) For the detection of transverse imperfections, a manual/semi-automatic ultrasonic inspection using the same inspection sensitivity and parameters as is specified in K.5.1.1 or a radiographic inspection in accordance with Clause E.4.

For manual ultrasonic inspection, the scanning speed shall be ≤ 150 mm/s (6 in/s).

K.5.4 Supplementary non-destructive inspection operation

If agreed, the external and internal surfaces of the ultimate 50 mm (2.0 in) length of weld seam at both ends of each pipe shall be subjected to magnetic particle inspection in accordance with ISO 10893-5 or ASTM E709. Any indications in excess of 3.0 mm (0.12 in) shall be investigated and treated in accordance with Clause C.2.

Annex L (informative)

Steel designations

Table L.1 gives guidance on steel designations (steel numbers) which are used in Europe additionally to the steel name.

**Table L.1 — List of corresponding additional steel designations
(steel numbers) for use in Europe**

Steel name in accordance with API Spec 5L	Steel number in accordance with EN 10027-2 ^[22]
Steel grades for PSL 1 pipe in Table 4^a	
L175	1.8700
L175P	1.8707
L210	1.8713
L245	1.8723
L290	1.8728
L320	1.8729
L360	1.8730
L390	1.8724
L415	1.8725
L450	1.8726
L485	1.8727
Steel grades for PSL 2 pipe in Table 5^a	
L245R	1.8788
L290R	1.8789
L245N	1.8790
L290N	1.8791
L320N	1.8792
L360N	1.8793
L390N	1.8970
L415N	1.8736
L245Q	1.8737
L290Q	1.8738
L320Q	1.8739
L360Q	1.8741
L390Q	1.8740
L415Q	1.8742

Table L.1 — List of corresponding additional steel designations (steel numbers) for use in Europe (continued)

Steel name in accordance with API Spec 5L	Steel number in accordance with EN 10027-2
Steel grades for PSL 2 pipe in Table 5^a	
L450Q	1.8743
L485Q	1.8744
L555Q	1.8745
L625Q	1.8764
L690Q	1.8765
L245M	1.8746
L290M	1.8747
L320M	1.8748
L360M	1.8749
L390M	1.8971
L415M	1.8752
L450M	1.8754
L485M	1.8756
L555M	1.8758
L625M	1.8753
L690M	1.8979
L830M	1.8755
Steel grades for PSL 2 pipe for sour service in Table H.1^a	
L245NS	1.1020
L290NS	1.1021
L320NS	1.1022
L360NS	1.8757
L245QS	1.1025
L290QS	1.1026
L320QS	1.1027
L360QS	1.8759
L390QS	1.8760
L415QS	1.8761
L450QS	1.8762
L485QS	1.8763
L245MS	1.1030
L290MS	1.1031
L320MS	1.1032

Table L.1 — List of corresponding additional steel designations (steel numbers) for use in Europe (continued)

Steel name in accordance with API Spec 5L	Steel number in accordance with EN 10027-2
L360MS	1.1033
L390MS	1.1034
L415MS	1.8766
L450MS	1.8767
L485MS	1.8768
Steel grades for PSL 2 pipe for offshore service in Table J.1^a	
L245NO	1.1040
L290NO	1.1041
L320NO	1.1042
L360NO	1.8778
L245QO	1.1045
L290QO	1.1046
L320QO	1.1047
L360QO	1.8771
L390QO	1.8772
L415QO	1.8773
L450QO	1.8774
L485QO	1.8775
L555QO	1.8776
L245MO	1.1050
L290MO	1.1051
L320MO	1.1052
L360MO	1.8781
L390MO	1.8782
L415MO	1.8783
L450MO	1.8784
L485MO	1.8785
L555MO	1.8786
L625QO	1.8777
L690QO	1.8779

^a Table numbers for API Spec 5L only.

Annex M

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Annex N
(informative)

Identification/explanation of deviations

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Annex O (informative)

Use of the API Monogram by Licensees

O.1 Scope

The API Monogram Program allows an API Licensee to apply the API Monogram to products. The API Monogram Program delivers significant value to the oil and gas industry by linking the verification of an organization's quality management system with the demonstrated ability to meet specific product specification requirements. The use of the Monogram on products constitutes a representation and warranty by the Licensee to purchasers of the products that, on the date indicated, the products were produced in accordance with a verified quality management system and in accordance with an API product specification.

When used in conjunction with the requirements of the API License Agreement, API Spec Q1, in its entirety, defines the requirements for those organizations who wish to voluntarily obtain an API license to provide API monogrammed products in accordance with an API product specification.

API Monogram Program licenses are issued only after an on-site audit has verified that the Licensee conforms to the requirements described in API Spec Q1 in total, and the requirements of an API product specification. Customers/users are requested to report to API all problems with API monogrammed products. The effectiveness of the API Monogram Program can be strengthened by customers/users reporting problems encountered with API monogrammed products. A nonconformance may be reported using the API Nonconformance Reporting System available at <http://compositelist.api.org/ncr.asp>. API solicits information on new product that is found to be nonconforming with API-specified requirements, as well as field failures (or malfunctions), which are judged to be caused by either specification deficiencies or nonconformities with API-specified requirements.

This annex sets forth the API Monogram Program requirements necessary for a supplier to consistently produce products in accordance with API-specified requirements. For information on becoming an API Monogram Licensee, please contact API, Certification Programs, 1220 L Street, N. W., Washington, D.C. 20005 or call 202-962-4791 or by email at certification@api.org.

O.2 References

In addition to the referenced standards listed earlier in this document, this annex references the following standard: API Specification Q1.

For Licensees under the Monogram Program, the latest version of this document shall be used. The requirements identified therein are mandatory.

O.3 API Monogram Program: Licensee Responsibilities

O.3.1 Maintaining a License to Use the API Monogram

For all organizations desiring to acquire and maintain a license to use the API Monogram, conformance with the following shall be required at all times:

- a) the quality management system requirements of API Spec Q1;

- b) the API Monogram Program requirements of API Spec Q1, Annex A;
- c) the requirements contained in the API product specification(s) for which the organization desires to be licensed;
- d) the requirements contained in the API Monogram Program License Agreement.

O.3.2 Monogrammed Product — Conformance with API Spec Q1

When an API-licensed organization is providing an API monogrammed product, conformance with API-specified requirements, described in API Spec Q1, including Annex A, is required.

O.3.3 Application of the API Monogram

Each Licensee shall control the application of the API Monogram in accordance with the following.

- a) Each Licensee shall develop and maintain an API Monogram marking procedure that documents the marking/monogramming requirements specified by the API product specification to be used for application of the API Monogram by the Licensee. The marking procedure shall define the location(s) where the Licensee shall apply the API Monogram and require that the Licensee's license number and date of manufacture be marked on monogrammed products in conjunction with the API Monogram. At a minimum, the date of manufacture shall be two digits representing the month and two digits representing the year (e.g. 05-07 for May 2007) unless otherwise stipulated in the applicable API product specification. Where there are no API product specification marking requirements, the Licensee shall define the location(s) where this information is applied.
- b) The API Monogram may be applied at any time appropriate during the production process but shall be removed in accordance with the Licensee's API Monogram marking procedure if the product is subsequently found to be nonconforming with API-specified requirements. Products that do not conform to API-specified requirements shall not bear the API Monogram.
- c) Only an API Licensee may apply the API Monogram and its license number to API monogramable products. For certain manufacturing processes or types of products, alternative API Monogram marking procedures may be acceptable. The current API requirements for Monogram marking are detailed in the API Policy Document, Monogram Marking Requirements, available on the API Monogram Program website at <http://www.api.org/certifications/monogram/>.
- d) The API Monogram shall be applied at the licensed facility.
- e) The authority responsible for applying and removing the API Monogram shall be defined in the Licensee's API Monogram marking procedure.

O.3.4 Records

Records required by API product specifications shall be retained for a minimum of five years or for the period of time specified within the product specification if greater than five years. Records specified to demonstrate achievement of the effective operation of the quality system shall be maintained for a minimum of five years.

O.3.5 Quality Program Changes

Any proposed change to the Licensee's quality program to a degree requiring changes to the quality manual shall be submitted to API for acceptance prior to incorporation into the Licensee's quality program.

O.3.6 Use of the API Monogram in Advertising

Licensee shall not use the API Monogram on letterheads or in any advertising (including company-sponsored web sites) without an express statement of fact describing the scope of Licensee's authorization (license number). The Licensee should contact API for guidance on the use of the API Monogram other than on products.

O.4 Marking requirements for Products

O.4.1 General

These marking requirements apply only to those API Licensees wishing to mark their products with the API Monogram.

O.4.2 Product specification identification

The following marking requirements apply only to those API licensees wishing to mark their products with the API Monogram.

The complete API Monogram marking consists of the following:

- the letters "Spec 5L",
- the manufacturer's API license number,
- the API monogram,
- the date of manufacture (defined as the month and year when the monogram is applied by the manufacturer).

NOTE As defined in Clause 4, the manufacturer may be, as applicable, a pipe mill, processor, maker of couplings or threader.

The API Monogram marking shall be applied only to products complying with the requirements of the specification and only by licensed manufacturers.

O.4.3 Marking of pipe and couplings

O.4.3.1 The API monogram marking, as defined in O.4.2, shall be inserted in the markings described in 11.2.1 and 11.3 as applicable, following the manufacturer's name or mark.

O.4.3.2 Following are examples of the markings listed in Clause 11.2.1 with the monogram (API) inserted where: X represents the manufacturer; ##### represents the license number; Y represents the customer's inspection representative, if applicable; and Z represents the identification number which permits the correlation of the product or delivery unit (e.g. bundled pipe) with the related inspection document, if applicable.

EXAMPLE 1 For USC units X API Spec 5L-#### (API) (MO-YR) 20 0.500 X52M PSL 2 SAWL Y Z

EXAMPLE 2 For SI units X API Spec 5L-#### (API) (MO-YR) 508 12,7 L360M PSL 2 SAWL Y Z

O.4.3.3 For cases where the pipe also meets the requirements of a compatible standard "ABC", the following are examples of the markings listed in Clause 11.2.1 with the monogram (API) inserted where: X represents the manufacturer; ##### represents the license number; Y represents the customer's inspection representative, if applicable; and Z represents the identification number which permits the

correlation of the product or delivery unit (e.g. bundled pipe) with the related inspection document, if applicable.

EXAMPLE 3 For USC units X API Spec 5L-#### (API) (MO-YR) / ABC 20 0.500 X52M PSL 2 SAWL Y Z

EXAMPLE 4 For SI units X API Spec 5L-#### (API) (MO-YR) / ABC 508 12,7 L360M PSL 2 SAWL Y Z

O.4.4 Bundle identification

O.4.4.1 For pipe of size 48,3 mm (1.900 in) or smaller, the identification markings specified in 11.2.1 shall be placed on the tag, strap, or clip used to tie the bundle as described in 11.2.2.

For example, size 48,3mm (1.900 in), specified wall thickness 3,7 mm (0.145 in), Grade B, high frequency welded, plain-end pipe should be marked as follows, using the values that are appropriate for the pipe dimensions specified on the purchase order:

EXAMPLE 5 For USC units X API Spec 5L-#### (API) (MO-YR) 1.9 0.145 B PSL 1 HFW Y Z

EXAMPLE 6 For SI units X API Spec 5L-#### (API) (MO-YR) 48,3 3,7 L235 PSL 1 HFW Y Z

O.4.4.2 For the case where the pipe also meets the requirements of a compatible standard ABC, the following are examples of the markings:

EXAMPLE 7 For USC units X API Spec 5L-#### (API) (MO-YR) / ABC 1.9 0.145 B PSL 1 HFW Y Z

EXAMPLE 8 For SI units X API Spec 5L-#### (API) (MO-YR) / ABC 48,3 3,7 L245 PSL 1 HFW Y Z

O.4.5 Thread identification

At the manufacturer's option, threaded-end pipe may be identified by stamping or stenciling the pipe adjacent to the threaded ends, with the threader's API license number, the API Monogram (API), immediately followed by the date of threading (defined as the month and year the Monogram is applied), the specified outside diameter of the pipe, and LP to indicate the type of thread. The thread marking may be applied to products that do or do not bear the API monogram. For example, size 168,3 mm (6.625 in) threaded-end pipe may be marked as follows, using the value that is appropriate for the pipe outside diameter specified on the purchase order:

EXAMPLE 9 For USC units X API Spec 5L-#### (API) (MO-YR of threading) API Spec 5B 6.625 LP

EXAMPLE 10 For SI units X API Spec 5L-#### (API) (MO-YR of threading) API Spec 5B 168,3 LP

If the product is clearly marked elsewhere with the manufacturer's identification, his license number, as above, may be omitted.

O.4.6 Thread certification

The use of the Monogram (API) as provided in O.5 shall constitute a certification by the manufacturer that the threads so marked comply with the requirements stipulated in the latest edition of API Spec 5B but should not be construed by the purchaser as a representation that the product so marked is, in its entirety, in accordance with any API specification. Manufacturers who use the Monogram (API) for thread identification are required to have access to properly certified API reference master thread gages.

0.4.7 Units

Product should be marked with U.S. customary (USC) or metric (SI) units. Combination of dual units [metric (SI) units and USC units] is not acceptable.

0.4.8 License number

The API Monogram license number shall not be used unless it is marked in conjunction with the API Monogram.

0.5 API Monogram Program: API Responsibilities

The API shall maintain records of reported problems encountered with API monogrammed products. Documented cases of nonconformity with API-specified requirements may be reason for an audit of the Licensee involved (also known as audit for "cause").

Documented cases of specification deficiencies shall be reported, without reference to Licensees, customers or users, to API Subcommittee 18 (Quality) and to the applicable API Standards Subcommittee for corrective actions.

Annex P (informative)

Equations for Threaded and Coupled Pipe and Background Equations for Guided Bend and CVN Test Specimens

P.1 Introduction

This annex contains equations and information specific to line pipe which were contained in ISO TR 10400/API TR 5C3. The number designations in the brackets [xx] correspond to the equation number listed in the Technical Report. The P-number in the [P.x] to the right of the equations designates the equation number in this annex. For further information regarding the derivation and history of these equations, see the technical report.

P.2 Calculated threaded and coupled mass⁷⁾

The calculated threaded and coupled mass per unit length is based on a length measured from the outer face of the coupling to the end of the pipe, as shown in Figure P.1. The mill end of the coupling is assumed to be installed to the power-tight axial position.

$$w_{tc} = \{[L_j - k_{isl} (N_L + 2J)/2] w_{pe} + \text{mass of coupling} - \text{mass removed in threading two pipe ends}\}/L_j \quad [76](P.1)$$

where

k_{isl} is the length conversion factor, equal to 0,001 for SI units and 1/12 for USC units;

J is the distance from end of pipe to centre of coupling in power-tight position, in accordance with API 5B, in millimetres or inches;

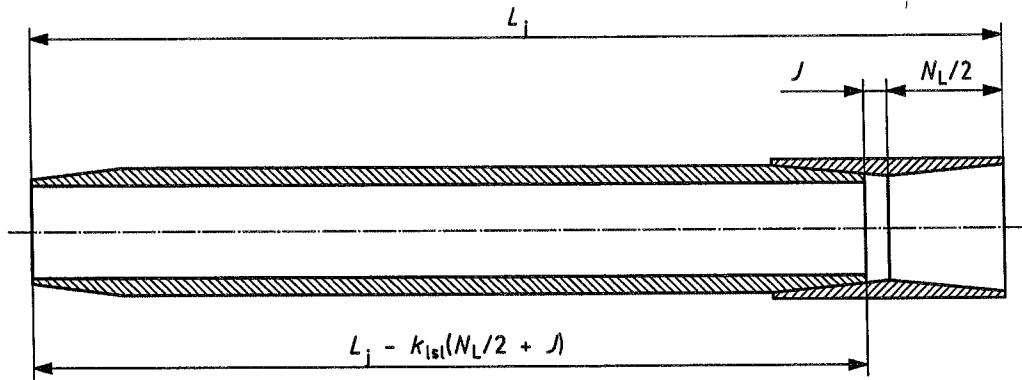
L_j is the length of a standard piece of pipe, in metres or feet;

N_L is the coupling length, in millimetres or inches;

w_{tc} is the threaded and coupled mass per unit length;

w_{pe} is the plain-end mass per unit length, in kilograms per metre or pounds per foot.

7) From ISO TR 10400/API TR 5C3 Clause 11.5.

**Key**

L_j length of standard piece of pipe, in metres or feet

N_L coupling length, in accordance with Table F.1, in millimetres or inches

J distance from end of pipe to centre of coupling in power-tight position, in accordance with API 5B

k_{isl} length conversion factor, equal to 0,001 for SI units and 1/12 for USC units

Figure P.1 — Threaded and coupled pipe

P.3 Calculated finished-end mass⁸⁾

Standards use the calculated mass gain (or loss) due to end finishing, e_m , to calculate the theoretical mass of a length of pipe; values of e_m given in Standards are calculated from Equation (P.2). For plain-end pipe, $e_m = 0$.

$$e_m = L_j (w - w_{pe}) \quad [74] \text{ (P.2)}$$

where

e_m is the mass gain due to end finishing, in kilograms or pounds;

L_j is the length of a standard piece of pipe, in metres or feet;

w is the calculated threaded and coupled mass (w_{tc}), upset and threaded mass (w_{ij}), or upset mass (w_u) based on length L_j , in kilograms per metre or pounds per foot;

w_{pe} is the plain-end mass per unit length, in kilograms per metre or pounds per foot.

The finished-end mass of a joint is calculated using Equation (P.3),

$$W_L = w_{pe} L_{ef} + k_m e_m \quad [75] \text{ (P.3)}$$

where

e_m is the mass gain due to end finishing, in kilograms or pounds;

8) From ISO TR 10400/API TR 5C3 Clause 11.4.

k_m is the mass correction factor: 1,000 for carbon steel, 0,989 for martensitic chromium steel;

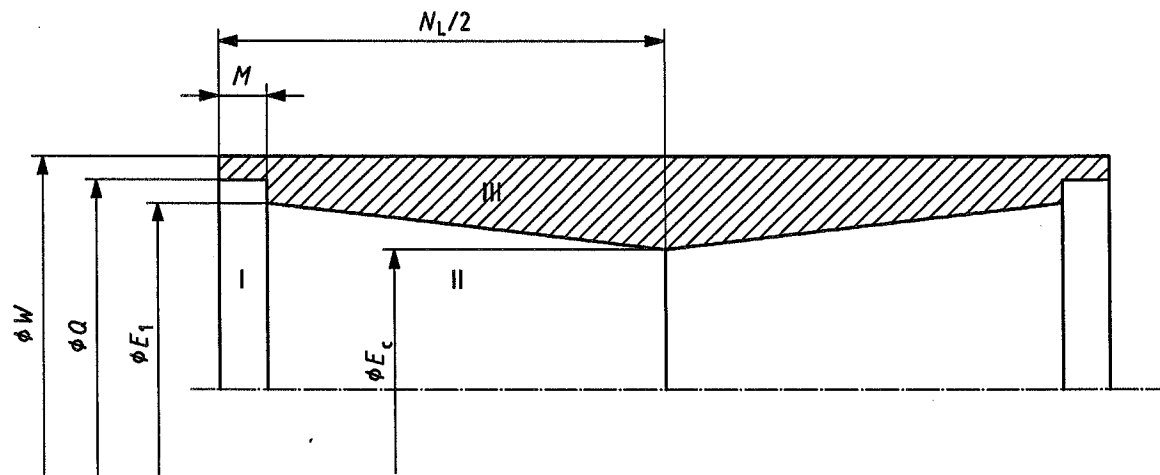
L_{ef} is the length of pipe including end finish, in metres or feet;

W_L is the calculated mass of a piece of pipe of length L , in kilograms or pounds;

w_{pe} is the plain-end mass per unit length, in kilograms per metre or pounds per foot.

P.4 Couplings without special bevel mass allowance⁹⁾

Coupling masses for line pipe are calculated on the basis of the dimensions shown in the 1942 edition of API 5L, which are identical with those shown in the 1971 edition of API 5L.



Key

N_L coupling length, in accordance with Table F.1, in millimetres or inches

M length from the face of the coupling to the hand-tight plane for line pipe, in accordance with API 5B

W specified coupling outside diameter, in accordance with Table F.1.

Q diameter of coupling recess, in accordance with API 5B

E_1 pitch diameter at the hand-tight plane, in accordance with API 5B

E_c pitch diameter, at centre of coupling

I, II, III represent Volumes I, II, III respectively [see Equations (P.6), (P.7) and (P.9)]

Figure P.2 — Pipe coupling

$$m_c = 0.5666 k_m (\text{Vol. III}) \quad [82](P.4)$$

$$E_c = E_1 - (N_L/2 - M) T_d \quad [83](P.5)$$

$$\text{Vol. I} = 0.7854 M Q^2 \quad [84](P.6)$$

$$\text{Vol. II} = 0.2618 (N_L/2 - M)(E_1^2 + E_1 E_c + E_c^2) \quad [85](P.7)$$

9) From ISO TR 10400/API TR 5C3 Clause 11.8.2.2.

$$\text{Vol. (I + II + III)} = 0.785 4N_L W^2/2 \quad [86](P.8)$$

$$\text{Vol. III} = \text{Vol. (I + II + III)} - \text{Vol. I} - \text{Vol. II.} \quad [87](P.9)$$

where

k_m is the mass correction factor: 1.000 for carbon steel, 0.989 for martensitic chromium steel;

m_c is the coupling mass;

T_d is the taper, 0.062 5.

Calculations for coupling masses are expressed in pounds. The final calculated mass is rounded to two decimals with no intermediate rounding in the calculations.

P.5 Pressure performance for couplings¹⁰⁾

P.5.1 General

Internal pressure capacity for threaded and coupled pipe is the same as for plain-end pipe, except where a lower pressure is required to avoid yielding the coupling or leakage due to insufficient internal pressure leak resistance at the E1 plane as calculated below.

P.5.2 Internal yield pressure of line pipe couplings

The internal yield pressure for the coupling is calculated from

$$p_{IYC} = f_{ymnc} (W - d_1)/W \quad [66] (P.10)$$

where

f_{ymnc} is the specified minimum yield strength of the coupling;

d_1 is the diameter at the root of the coupling thread at the end of the pipe in the power-tight position;

p_{IYC} is the internal pressure at yield for coupling;

W is the specified coupling outside diameter, in accordance with Table F.1.

$$d_1 = E_1 - (L_1 + A)T_d + H - 2s_m \quad [67] (P.11)$$

where

A is the hand-tight standoff, mm (in);

E_1 is the pitch diameter at the hand-tight plane, in accordance with API 5B;

10) From ISO TR 10400/API TR 5C3 Clause 10.

- H is the thread height equivalent Vee thread, 2,199 6 mm (0.086 60 in) for 10 TPI, 2,749 6 mm (0.108 25 in) for 8 TPI;
- L_1 is the length from the end of the pipe to the hand-tight plane, in accordance with API 5B;
- s_{rn} is the root truncation of the pipe thread of round threads, 0,36 mm (0.014 in) for 10 TPI, 0,43 mm (0.017 in) for 8 TPI;
- T_d is the taper (on diameter), 0,062 5 mm/mm (0.062 5 in/in).

Threads per 25,4mm (Threads per inch)	f_{rn} mm (in)	H mm (in)
27	0,031 (0.0012)	0,815 (0.0321)
18	0,046 (0.0018)	1,222 (0.0481)
14	0,061 (0.0024)	1,572 (0.0619)
11 ½	0,074 (0.0029)	1,913 (0.0753)
8	0,014 (0.0041)	2,784 (0.1082)

P.5.3 Internal pressure leak resistance of round thread or buttress couplings

The internal pressure leak resistance at the E_1 or E_7 plane is calculated from Equation (P.12). Equation (P.12) is based on the seal being at the E_1 plane for round threads and the E_7 plane for buttress threads where the coupling is the weakest and the internal pressure leak resistance the lowest. Also, Equation (P.12) is based on the internal leak resistant pressure being equal to the interference pressure between the pipe and coupling threads resulting from make-up and the internal pressure itself, with stresses in the elastic range.

$$P_{IL} = \frac{ET_d N_p (W^2 - E_s^2)}{2E_s W^2} \quad [69](P.12)$$

E is Young's modulus;

E_s is the pitch diameter, at plane of seal

E_1 for round thread

E_7 for buttress thread casing;

N is the number of thread turns make-up

A for round thread casing and tubing (API 5B)

$A + 1,5$ for buttress thread casing smaller than 16

$A + 1$ for buttress thread casing 16 and larger;

p is the thread pitch

3,175 mm (0.125 in) for 8-round thread casing and tubing

2,540 mm (0.100 in) for 10-round thread tubing

5,080 mm (0.200 in) for buttress thread casing;

p_L is the internal pressure at leak;

T_d is the taper (on diameter)

0,062 5 for round thread casing and tubing

0,062 5 for buttress casing smaller than 16

0,083 3 for buttress thread casing 16 and larger;

W is the specified coupling outside diameter, in accordance with ISO 11960 or API 5CT^[21];

where

A is the hand-tight standoff, mm (in);

E_1 is the pitch diameter at the hand-tight plane, in accordance with API 5B;

E_7 is the pitch diameter, in accordance with API 5B.

The interface pressure between the pin and box as a result of make-up is

$$p_1 = \frac{ET_d N_p (W^2 - E_s^2)(E_s^2 - d^2)}{E_s^2 (W^2 - d^2)} \quad [70](P.13)$$

where

E is Young's modulus;

E_s is the pitch diameter, at plane of seal

E_1 for round thread

E_7 for buttress thread casing;

d is the pipe inside diameter, $d = D - 2t$;

N is the number of thread turns make-up

A for round thread casing and tubing (API 5B)

$A + 1,5$ for buttress thread casing smaller than 16

$A + 1$ for buttress thread casing 16 and larger;

p is the thread pitch

3,175 mm (0.125 in) for 8-round thread casing and tubing

2,540 mm (0.100 in) for 10-round thread tubing

5,080 mm (0.200 in) for buttress thread casing;

T_d is the taper (on diameter)

0,062 5 for round thread casing and tubing

0,062 5 for buttress casing smaller than 16

0,083 3 for buttress thread casing 16 and larger;

W is the specified coupling outside diameter, in accordance with ISO 11960 or API 5CT^[21];

where

A is the hand-tight standoff;

E_1 is the pitch diameter at the hand-tight plane, in accordance with API 5B;

E_7 is the pitch diameter, in accordance with API 5B;

D is the specified pipe outside diameter;

t is the specified pipe wall thickness.

Subsequent to make-up, internal pressure, p_1 , causes a change in the interface pressure by an amount p_2 :

$$p_2 = \frac{p_1 d^2 (W^2 - E_s^2)}{E_s^2 (W^2 - d^2)} \quad [71](P.14)$$

where

E_s is the pitch diameter, at plane of seal

E_1 for round thread

E_7 for buttress thread casing;

d is the pipe inside diameter, $d = D - 2t$;

p_1 is the internal pressure;

W is the specified coupling outside diameter, in accordance with ISO 11960 or API 5CT^[21];

where

E_1 is the pitch diameter at the hand-tight plane, in accordance with API 5B;

E_7 is the pitch diameter, in accordance with API 5B;

D is the specified pipe outside diameter;

t is the specified pipe wall thickness.

Since the external box diameter is always greater than the contact diameter, which in turn is always greater than the internal pipe diameter, p_2 will always be less than p_1 . Therefore, when the total interface pressure $p_1 + p_2$ equals the internal pressure p_i , the connection has reached the leak resistance limit p . In other words, if p_i were greater than $p_1 + p_2$, leakage would occur:

$$p_1 + p_2 = p_i = p \quad [72](P.15)$$

Substituting the appropriate values for p_1 and p_2 into Equation (P.15) and simplifying produces Equation (P.12).

P.6 Hydrostatic test pressure for threaded and coupled pipe¹¹⁾

The hydrostatic test pressure for threaded and coupled pipe is the same as for plain-end pipe, except where a lower pressure is required to avoid leakage due to insufficient internal yield pressure of the coupling or insufficient internal pressure leak resistance at the E_1 plane as calculated in P.5.

The test pressure should be based on the lowest of the test pressure determined for plain-end pipe (Table 26), or 80 % of the internal coupling yield pressure result from Equation (P.10), or the internal pressure leak resistance result from Equation (P.12). The basis for this equation was adopted at the 1968 API Standardization Conference as shown in API Circular PS-1360.

P.7 Background on Guided Bend Test¹²⁾

This section provides the supporting background for the requirements in Clause 10.2.4.6

Values for ϵ are based on Equation ([shown in Item 4a of API Circular PS-1340 reporting the actions of the 1967 Standardization Conference except for Grade X70, which were adopted at the June 1972 Standardization Conference and shown in API Circular PS-1440. The values calculated by means of Equation (I) are rounded to the nearest multiple of 0,002 5 with the exception of the values for Grades X52 and X56, which are rounded to the next higher multiple of 0,002 5.

The engineering strain, ϵ , is calculated as

$$\epsilon = \frac{3\,000(0.64)^{0.2}}{(145 \cdot f_{umnp})^{0.9}} \quad [148] (P.16.1 - SI)$$

or

$$\epsilon = \frac{3\,000(0.64)^{0.2}}{f_{umnp}^{0.9}} \quad [148] (P.16.2 - USC)$$

where f_{umnp} is the specified minimum tensile strength of the pipe body, expressed in megapascals (pounds per square inch).

Derivation of the guided bend test equation is covered elsewhere [31].

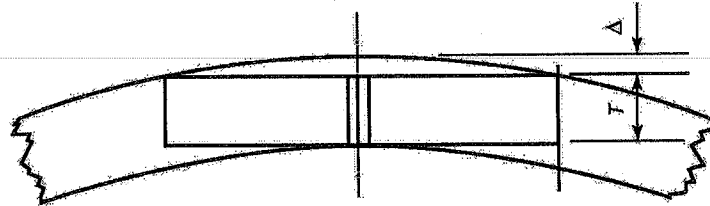
11) From ISO TR 10400/API TR 5C3 Clause 14.2.

12) From ISO TR 10400/API TR 5C3 Clause 16.2.1.

P.8 Background on CVN specimen sizes¹³⁾

P.8.1 Calculations for Minimum Wall Thickness for Standard Charpy V-Notch Specimens

This clause presents the equations for determining the minimum size transverse specimen that can be obtained from a given size and wall thickness of pipe. See Clause 10.2.3.3 and Table 22.



Transverse

$$\Delta = \frac{D}{2} - \left(\left(\frac{D}{2} \right)^2 - (27,5)^2 \right)^{\frac{1}{2}} \quad (\text{P.17 - SI})$$

or

$$\Delta = \frac{D}{2} - \left(\left(\frac{D}{2} \right)^2 - (1.083)^2 \right)^{\frac{1}{2}} \quad (\text{P.17 - USC})$$

Minimum wall thickness, mm (in). (with no machining allowance)

where

D is the outside diameter, mm (in);

Δ is tangential dimension from the OD to the intersection of the exposed OD Charpy shoulder and the end of the specimen (see Figure P.4), mm, (in);

T is the Charpy specimen thickness, mm (in)

10,0 mm (0.394 in) for full size specimens,

7,5 mm (0.295 in) for three-quarter size specimens,

6,67 mm (0.262 in) for two third size specimens,

5,0 mm (0.197 in) for one half size specimens.

Figure P.3 — Determination of Minimum Wall Thickness for Charpy Standard V-Notch Specimens

To allow for machining, add 0,5 mm (0.020 in) to each unfinished surface, or 1,0 mm (0.040 in) to each minimum wall thickness.

P.8.2 Calculations for Minimum Wall Thicknesses for Tapered Charpy V-notch Specimens

Figure P.4 and Equations P.18 and P.19 are used for determining the size of tapered specimens. See clause 10.2.3.3 which references ASTM A370 that allows tapered specimens.

NOTE The USC equations convert to the wall thickness values of Table 22 within-rounding tolerances due to the back conversion from SI.

13) From ISO TR 10400/API TR 5C3 Clause 17.

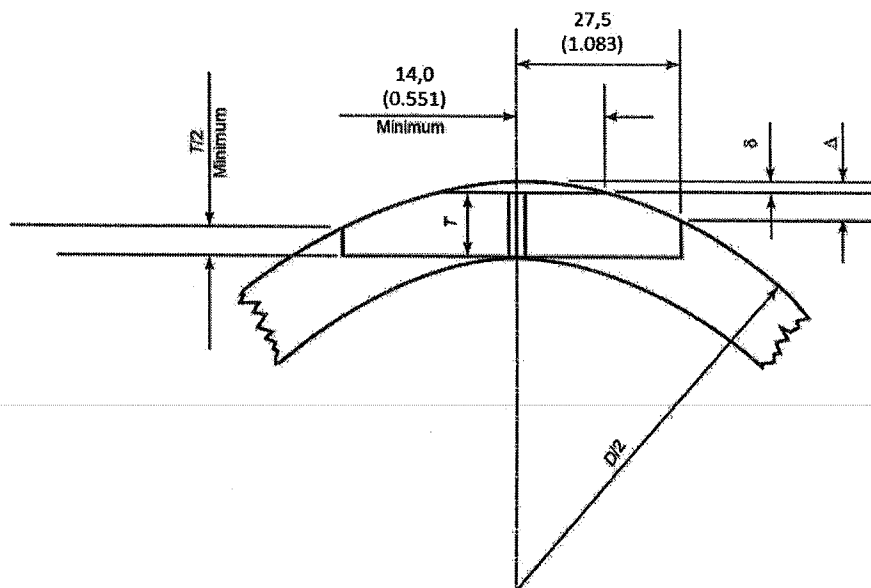


Figure P.4 — Determination of Minimum Wall Thickness for Tapered Charpy V-Notch specimens

where

- D is the outside diameter, mm, (in);
- Δ is the tangential dimension from the OD to the intersection of the exposed OD Charpy shoulder and the end of the specimen, mm, (in);
- δ is the machined depth from the OD to the Charpy surface at mid-specimen length, mm, (in);
- T is the Charpy specimen thickness, mm, (in).
 10,0 mm (0.394 in) for full size specimens,
 7,5 mm (0.295 in) for three-quarter size specimens,
 6,67 mm (0.262 in) for two third size specimens,
 5,0 mm (0.197 in) for one half size specimens.

$$\Delta = \frac{D}{2} - \left(\left(\frac{D}{2} \right)^2 - (27,5)^2 \right)^{\frac{1}{2}} \quad (\text{P.18 - SI})$$

or

$$\Delta = \frac{D}{2} - \left(\left(\frac{D}{2} \right)^2 - (1.083)^2 \right)^{\frac{1}{2}} \quad (\text{P.18 - USC})$$

$$\delta = \frac{D}{2} - \left(\left(\frac{D}{2} \right)^2 - (14,0)^2 \right)^{\frac{1}{2}} \quad (\text{P.19 - SI})$$

or

$$\delta = \frac{D}{2} - \left(\left(\frac{D}{2} \right)^2 - (0.551)^2 \right)^{\frac{1}{2}} \quad (\text{P.19 - USC})$$

Minimum wall thickness (with no machining allowance) for tapered Charpy V-Notch specimens is the larger of MinWT1 and MinWT2. To allow for machining of unfinished surfaces, add 0,5 mm (0.020 in) to each minimum wall thickness

where:

$$\text{MinWT1} = \delta + T$$

$$\text{MinWT2} = \Delta + T/2$$

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