



International
Standard

ISO 13680

**Oil and gas industries including
lower carbon energy — Corrosion-
resistant alloy seamless products
for use as casing, tubing, coupling
stock and accessory material —
Technical delivery conditions**

Industries du pétrole et du gaz y compris les énergies à faible teneur en carbone — Produits sans soudure en acier allié résistant à la corrosion utilisés comme tubes de cuvelage, tubes de production, tubes-ébauches pour manchons et matériau pour accessoires — Conditions techniques de livraison

**Fifth edition
2024-05**

Reference number
ISO 13680:2024(en)

Full document details: [ISO 13680-2024](#)

© ISO 2024  **Documents**
Document Sharing Hub



COPYRIGHT PROTECTED DOCUMENT

© ISO 2024

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword	vi
1 Scope	1
2 Normative references	1
3 Terms, definitions, abbreviated terms and symbols	4
3.1 Terms and definitions	4
3.2 Abbreviated terms	6
3.3 Symbols	7
4 General	8
4.1 Dual normative references	8
4.2 Units of measurement	8
5 Information supplied by the purchaser	8
6 Manufacturing process	10
6.1 Melting practices	10
6.2 Product manufacturing process	10
6.3 Pipe end sizing	11
6.4 Straightening	11
6.5 Processes requiring validation	11
6.6 Traceability	12
6.7 Manufacturing procedure qualification test	12
6.8 Process for update of alloys and/or grades	12
7 Material requirements	12
7.1 Chemical composition	12
7.2 Tensile properties	13
7.3 Hardness properties	13
7.4 Charpy V-notch test properties — General requirements	13
7.4.1 Evaluation of test results	13
7.4.2 Critical thickness	13
7.4.3 Specimen size, orientation and hierarchy	13
7.4.4 Alternative size impact test specimens	14
7.4.5 Sub-size test specimens	14
7.4.6 Test temperature	14
7.5 Charpy V-notch — Absorbed energy requirements for coupling stock and accessory material — All grades	14
7.5.1 General	14
7.5.2 Requirements for all grades	14
7.6 Charpy V-notch — Absorbed energy requirements for pipe — All grades	15
7.7 Flattening requirements	16
7.8 Charpy V-notch test properties at low temperature for group 2	16
7.8.1 General	16
7.8.2 Evaluation of test results	16
7.8.3 Selection of test specimens	17
7.8.4 Test temperature	17
7.8.5 Absorbed energy requirements	17
7.9 Corrosion properties	17
7.9.1 General	17
7.9.2 Pitting corrosion properties for group 2	17
7.10 Microstructure properties	17
7.10.1 Group 1	17
7.10.2 Group 2	17
7.10.3 Groups 3 and 4	18
7.11 Surface condition	18
7.12 Defects	18
7.12.1 Pipe	18

	7.12.2	Coupling stock and accessory material.....	19
	7.12.3	Process control plan.....	19
8		Dimensions, masses and tolerances.....	19
	8.1	Outside diameter, wall thickness and mass.....	19
	8.2	Length.....	19
	8.3	Tolerances.....	19
	8.3.1	Tolerance on outside diameter, wall thickness and mass.....	19
	8.3.2	Inside diameter, <i>d</i>	20
	8.3.3	Straightness.....	20
	8.3.4	Drift requirements.....	20
	8.4	Product ends.....	20
9		Inspection and testing.....	20
	9.1	Test equipment.....	20
	9.2	Type and frequency of tests.....	20
	9.3	Testing of chemical composition.....	20
	9.3.1	Chemical analysis.....	20
	9.3.2	Test method.....	21
	9.3.3	Chromium depletion test — Groups 2, 3 and 4.....	21
	9.4	Testing of mechanical characteristics.....	21
	9.4.1	Test lot.....	21
	9.4.2	Selection and preparation of samples and test pieces.....	21
	9.5	Tensile test.....	21
	9.5.1	Orientation and size of test pieces.....	21
	9.5.2	Test method.....	21
	9.5.3	Invalidation of test.....	22
	9.5.4	Retest.....	22
	9.6	Hardness test.....	22
	9.6.1	Test pieces.....	22
	9.6.2	Test method.....	22
	9.6.3	Invalidation of tests.....	23
	9.6.4	Periodic checks of hardness-testing machines.....	23
	9.6.5	Verification of hardness-testing machines and indenters.....	24
	9.6.6	Retests.....	25
	9.7	Impact or flattening test.....	25
	9.7.1	Test pieces.....	25
	9.7.2	Frequency of testing.....	25
	9.7.3	Impact test method.....	26
	9.7.4	Flattening test method.....	26
	9.7.5	Impact test retest.....	26
	9.7.6	Flattening test retest.....	27
	9.7.7	Invalidation of tests.....	27
	9.8	Impact test at low temperature for group 2.....	27
	9.9	Pitting corrosion test for group 2.....	27
	9.10	Microstructural examination.....	28
	9.10.1	Test pieces.....	28
	9.10.2	Test method.....	28
	9.10.3	Retest.....	29
	9.11	Dimensional testing.....	29
	9.11.1	General.....	29
	9.11.2	Outside diameter.....	29
	9.11.3	Wall thickness at end of products.....	29
	9.11.4	Wall thickness of product body.....	30
	9.12	Drift test.....	30
	9.12.1	Non-upset and external upset pipe.....	30
	9.12.2	Internal upset pipe.....	30
	9.12.3	Drift mandrel coating.....	30
	9.13	Length.....	30
	9.14	Straightness.....	30

9.15	Mass determination	30
9.16	Visual inspection	30
9.16.1	General	30
9.16.2	Pipe body, coupling stock and accessory material	31
9.16.3	Pipe ends	31
9.16.4	Disposition	31
9.17	Non-destructive examination	31
9.17.1	General	31
9.17.2	NDE personnel	32
9.17.3	Products	32
9.17.4	Pup joints	32
9.17.5	Untested ends	32
9.17.6	Upset ends	33
9.17.7	Reference standards	33
9.17.8	NDE system capability records	33
9.17.9	All product group 1	34
9.17.10	Full-body NDE of product — Groups 2, 3 and 4	34
9.17.11	Pipe, coupling stock and accessory material requiring further evaluation	34
9.17.12	Evaluation of indications (prove-up)	35
9.17.13	Disposition of pipe containing defects	35
9.17.14	Disposition of coupling stock and accessory material containing defects	36
9.18	Positive material identification	37
10	Surface treatment	37
10.1	Group 1	37
10.2	Groups 2, 3 and 4	37
11	Marking	38
11.1	General	38
11.2	Colour-code identification	38
11.3	Marking content and sequence	38
11.4	Marking for couplings, pup joints and accessories after threading	39
12	Surface protection — Group 1	39
13	Documents	40
13.1	Electronic media	40
13.2	Retention of records	40
13.3	Test certificates	40
14	Handling, packaging and storage	41
14.1	General	41
14.2	Handling	41
14.3	Packaging	41
14.3.1	General	41
14.3.2	Identification	41
14.4	Storage	42
Annex A (normative)	Tables in SI units	43
Annex B (normative)	Figures in SI (USC) units	66
Annex C (normative)	Tables in USC units	71
Annex D (normative)	Purchaser inspection	94
Annex E (normative)	Cleanliness requirements	95
Annex F (normative)	Coupling blanks and accessory material from bar	97
Annex G (normative)	Product specification level 2 (PSL-2)	111
Annex H (normative)	Standardized manufacturing procedure qualification test	113
Annex I (informative)	Photographic examples of microstructures, groups 2, 3 and 4	117
Bibliography	121	

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 67, *Oil and gas industries including lower carbon energy*, Subcommittee SC 5, *Casing, tubing and drill pipe*.

This fifth edition cancels and replaces the fourth edition (ISO 13680:2020), which has been technically revised.

The main changes are as follows:

- adjustment of the scope and title to make it clear that bar material is now included (removal of the word "tubular");
- update of normative references;
- review of straightening requirements, including addition of [Figure B.9](#);
- clarification on the use of alternative method for visual inspection;
- clarification of PMI requirements;
- clarification of marking content and sequence;
- extension of records retention period to five years;
- review of [Annex H](#).

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Oil and gas industries including lower carbon energy — Corrosion-resistant alloy seamless products for use as casing, tubing, coupling stock and accessory material — Technical delivery conditions

WARNING — It is the purchaser's responsibility to specify the product specification level (PSL), corrosion-resistant alloy (CRA) group, category, grade, delivery conditions and any other requirement in addition to those specified herewith to ensure that the product is adequate for the intended service environment. The ISO 15156 series or NACE MR0175 should be considered when making specific requirements for H₂S-containing environments; see [Annex G](#). It is the product user's responsibility to ensure that the product is suitable for the intended application with consideration of all environmental degradation threats during both normal operation and system upsets. There are other sources of hydrogen besides H₂S-containing environments, which are not addressed by the ISO 15156 series or NACE MR0175. Not all PSL-1 categories and grades can be made cracking resistant in accordance with the ISO 15156 series or NACE MR0175 and are, therefore, not included in PSL-2.

1 Scope

This document specifies the technical delivery conditions for corrosion-resistant alloy seamless products for casing, tubing, coupling stock and accessory material (including coupling stock and accessory material from bar) for two product specification levels:

- PSL-1, which is the basis of this document;
- PSL-2, which provides additional requirements for a product that is intended to be both corrosion and cracking resistant for the environments and qualification method specified in [Annex G](#) and in the ISO 15156 series or NACE MR0175.

This document contains no provisions relating to the connection of individual lengths of pipe. Demonstration of conformance to ISO 15156-3:2020 or NACE MR0175-2021 of material affected by end sizing, connection manufacture or welding operations is outside the scope of this document.

This document contains provisions relating to marking of tubing and casing after threading.

This document is applicable to the following five groups of products:

- a) group 1, which is composed of stainless alloys with a martensitic or martensitic/ferritic structure;
- b) group 2, which is composed of stainless alloys with a ferritic-austenitic structure, such as duplex and super-duplex stainless alloy;
- c) group 3, which is composed of stainless alloys with an austenitic structure (iron base);
- d) group 4, which is composed of nickel-based alloys with an austenitic structure (nickel base);
- e) group 5, which is composed of bar only ([Annex F](#)) in age-hardened (AH) nickel-based alloys with austenitic structure.

2 Normative references

The following documents, as applicable for the product, are referred to in the text in such a way that some or all of their content constitutes requirements 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 377, *Steel and steel products — Location and preparation of samples and test pieces for mechanical testing*

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

ISO 525, *Bonded abrasive products — General requirements*

ISO 643, *Steels— Micrographic determination of the apparent grain size*

ISO 3452-1, *Non-destructive testing — Penetrant testing — Part 1: General principles*

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

ISO 4948-1, *Steels — Classification — Part 1: Classification of steels into unalloyed and alloy steels based on chemical composition*

ISO 4948-2, *Steels — Classification — Part 2: Classification of unalloyed and alloy steels according to main quality classes and main property or application characteristics*

ISO 6508-1, *Metallic materials — Rockwell hardness test — Part 1: Test method*

ISO 6508-2, *Metallic materials — Rockwell hardness test — Part 2: Verification and calibration of testing machines and indenters*

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

ISO 6892-2, *Metallic materials — Tensile testing — Part 2: Method of test at elevated temperature*

ISO 6929, *Steel products — Vocabulary*

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 NDT personnel*

ISO 9934-1, *Non-destructive testing — Magnetic particle testing — Part 1: General principles*

ISO 10423, *Petroleum and natural gas industries — Drilling and production equipment — Wellhead and tree equipment*

ISO 10474, *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 seamless and 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 ferromagnetic steel tubes for the detection of surface 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 10893-10, *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 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 14284, *Steel and iron — Sampling and preparation of samples for the determination of chemical composition*

ISO 15156 (all parts), *Petroleum and natural gas industries — Materials for use in H₂S-containing environments in oil and gas production*

ISO 15156-3:2020, *Petroleum and natural gas industries — Materials for use in H₂S-containing environments in oil and gas production — Part 3: Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys*

ISO 21920-2, *Geometrical product specifications (GPS) — Surface texture: Profile — Part 2: Terms, definitions and surface texture parameters*

ISO 80000-1, *Quantities and units — Part 1: General*

API RP 578, *Guidelines for a Material Verification Program (MVP) for New and Existing Assets*

API Spec 6A, *Specification for Wellhead and Christmas Tree Equipment*

API Standard 6ACRA, *Age-hardened Nickel-based Alloys for Oil and Gas Drilling and Production Equipment*

ASNT SNT-TC-1A, *Recommended Practice — Non-Destructive Testing*

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

ASTM A604/A604M, *Standard Practice for Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets*

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

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

ASTM E21, *Standard Test Methods for Elevated Temperature Tension Tests of Metallic Materials*

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

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

ASTM E45, *Standard Test Methods for Determining the Inclusion Content of Steel*

ASTM E110, *Standard Test Method for Rockwell and Brinell Hardness of Metallic Materials by Portable Hardness Testers*

ASTM E112, *Standard Test Methods for determining the average Grain Size*

ASTM E165, *Standard Practice for Liquid Penetrant Examination for General Industry*

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

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

ASTM E340, *Standard Test Method for Macroetching Metals and Alloys*

ASTM E381, *Standard Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings*

ASTM E562, *Standard Test Method for Determining Volume Fraction by Systematic Manual Point Count*

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

ASTM E1245, *Standard Practice for Determining the Inclusion or Second-Phase Constituent Content of Metals by Automatic Image Analysis*

ASTM E1476, *Standard Guide for Metals Identification, Grade Verification, and Sorting*

ASTM E3024, *Standard Practice for Magnetic Particle Testing for General Industry*

ASTM G48, *Standard Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution*

NACE MR0175, *Petroleum and Natural Gas Industries — Materials for Use in H₂S-containing Environments in Oil and Gas Production*

3 Terms, definitions, abbreviated terms and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 377, ISO 404, ISO 4885, ISO 4948-1, ISO 4948-2, ISO 6929, ISO 10474, ASTM A941 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1.1

accessory material

seamless *casing* (3.1.3) or *tubing* (3.1.23) or seamless thick-walled tube or *bar stock* (3.1.2) or hot forging used for the manufacture of accessories

3.1.2

bar stock

bar

material with a solid uniform cross-section along its whole *length* (3.1.14)

3.1.3

casing

tube intended to line the walls of a drilled well

3.1.4

cold-hardened

CH

material condition where the mechanical properties are obtained by a cold finishing process not followed by heat treatment

Note 1 to entry: Cold finishing is a plastic deformation of material at a temperature below the recrystallization temperature such that permanent strain hardening occurs.

3.1.5

corrosion-resistant alloy

CRA

alloy intended to be resistant to general and localized corrosion and/or environmental cracking in environments that are corrosive to carbon and low-alloy steels

Note 1 to entry: The corrosion-resistant alloys included in this document are special alloys in accordance with ISO 4948-1 and ISO 4948-2.

3.1.6

coupling blank

unthreaded material used to produce an individual coupling

3.1.7

coupling stock

seamless thick-wall *product* ([3.1.18](#)) used for the manufacture of *coupling blanks* ([3.1.6](#))

3.1.8

defect

imperfection ([3.1.11](#)) having sufficient magnitude to warrant rejection of the *length* ([3.1.14](#))

Note 1 to entry: Based on criteria defined in this document.

3.1.9

heat

material of the same category melted in the same manufacturing process at the same time sequence poured into multiple ingots or continuous strand cast

Note 1 to entry: In case of a remelted alloy, each ingot shall be considered a different heat.

3.1.10

hot-finished

HF

material condition obtained by deforming metal plastically at such a temperature and strain rate that recrystallization takes place simultaneously with the deformation, thus preventing permanent strain hardening

3.1.11

imperfection

discontinuity on the *product* ([3.1.18](#)) surface or in the product wall that can be detected by visual inspection or non-destructive examination

3.1.12

label 1

dimensionless designation for the size or specified outside diameter that can be used when ordering *pipe* ([3.1.17](#))

3.1.13

label 2

dimensionless designation for the linear density that can be used when ordering *pipe* ([3.1.17](#))

Note 1 to entry: Linear density is sometimes designated by the deprecated term “mass per unit length”.

3.1.14

length

piece of *product* ([3.1.18](#))

3.1.15

linear imperfection

imperfection ([3.1.11](#)) including, but not limited to, seams, laps, cracks, plug scores, cuts and gouges

3.1.16

manufacturer

firm, company or corporation that operates facilities for making seamless tubes for *casing* ([3.1.3](#)), *tubing* ([3.1.23](#)), *coupling stock* ([3.1.7](#)) or *accessory material* ([3.1.1](#))

3.1.17

pipe

plain end, either upset or non-upset, furnished without threads, *casing* ([3.1.3](#)), *tubing* ([3.1.23](#)) and *pup joint* ([3.1.19](#)) as group

3.1.18

product

pipe ([3.1.17](#)) and/or *coupling stock* ([3.1.7](#)) and/or *accessory material* ([3.1.1](#)), either individually or collectively, as applicable

3.1.19**pup joint**

casing (3.1.3) or *tubing* (3.1.23) shorter than range 1

3.1.20**solution annealing**

heat treatment requiring heating to a suitable temperature, holding at that temperature long enough to cause one or more constituents to enter into solid solution, then cooling rapidly enough to hold such constituents in solution

Note 1 to entry: Solution annealing may be performed as a part of the hot forming process or as a separate operation.

3.1.21**test lot****lot**

<products other than bars or drilled bars> unit formed by *lengths* (3.1.14) from the same *heat* (3.1.9), with the same specified outside diameter and wall thickness, the same grade, the same manufacturing process, the same final heat-treatment conditions, process facilities and parameters for all heat-treatment stages, processed sequentially for continuous furnaces or simultaneously for batch furnaces, the same cold hardening parameters (if applicable) and the same range length

Note 1 to entry: The maximum number of lengths in a test lot is given in [Table A.22](#) or [Table C.22](#).

3.1.22**test lot****lot**

<bars or drilled bars> unit formed by *lengths* (3.1.14) from the same *heat* (3.1.9), with the same specified outside diameter, the same wall thickness (if applicable), the same grade, the same manufacturing process facilities and parameters for all heat-treatment stages, processed sequentially for continuous furnaces or simultaneously for batch furnaces

Note 1 to entry: The maximum number of lengths in a test lot is given in [F.5.1](#).

3.1.23**tubing**

tube placed in a well to produce or inject fluids

3.2 Abbreviated terms

AOD	argon oxygen decarburization
EDI	electronic data interchange
EMI	electromagnetic inspection
ESR	electro-slag remelting
HBW	Brinell hardness, when testing with a tungsten carbide ball
HRC	Rockwell hardness C-scale
ID	inside diameter
MPQT	manufacturing procedure qualification test
MT	magnetic-particle inspection
NDE	non-destructive examination
OD	outside diameter

PMI	positive material identification
PREN	pitting-resistance equivalent number
PSL	product specification level
QT	quenched and tempered
SA	solution-annealed
SI	International System of Units
UNS	unified numbering system
USC	United States customary system
UT	ultrasonic testing
VAD	vacuum arc degassing
VAR	vacuum arc remelting
VIM	vacuum induction melting
VOD	vacuum oxygen decarburization

3.3 Symbols

A	cross-sectional area of the tensile test specimen, expressed in square millimetres (square inches), based on specified outside diameter or nominal specimen width and specified wall thickness, rounded to the nearest 10 mm ² (0.01 in ²), or 490 mm ² (0.75 in ²), whichever is smaller
C_v	Charpy V-notch energy requirement, expressed in joules (foot pounds)
D	outside diameter of the product, expressed in millimetres (inches)
d	inside diameter of the product, expressed in millimetres (inches)
e	minimum elongation in 50 mm (2.0 in) gauge length for strip specimens or in $4D$ or $5D$ for round bar specimens, expressed in per cent
m	mass
R_a	average surface roughness as defined in ISO 21920-2
R_m	tensile strength
$R_{p0,2}$	yield strength (0,2 % non-proportional elongation), expressed in megapascals (thousand pounds per square inch)
t	wall thickness of the product, expressed in millimetres (inches)
w_x	mass fraction of element x , expressed in per cent
$Y_{S,min}$	minimum specified yield strength, expressed in megapascals (thousand pounds per square inch)
$Y_{S,max}$	maximum specified yield strength, expressed in megapascals (thousand pounds per square inch)

4 General

4.1 Dual normative references

In the interests of worldwide application of this document, certain normative references listed in [Clause 2](#) are interchangeable in the context of the relevant requirement with the relevant document prepared by the American Petroleum Institute (API) or the American Society for Testing and Materials (ASTM), as recognized by the American National Standards Institute (ANSI). These latter documents are cited in the running text following the ISO reference and preceded by “or”, for example “ISO XXXX or API YYYY”.

Application of an alternative normative document cited in this manner can lead to technical results that differ from the use of the preceding ISO reference. However, both results are acceptable and these documents are, thus, considered interchangeable in practice.

4.2 Units of measurement

In this document, data are expressed in both the International System (SI) of units and the United States Customary (USC). For a specific order item, it is intended that only one system of units be used, without combining data expressed in the other system.

Products manufactured to specifications expressed in either of these unit systems shall be considered equivalent and totally interchangeable. Consequently, conformance to the requirements of this document as expressed in one system provides conformance to requirements expressed in the other system.

For data expressed in SI units, a comma is used as the decimal separator and a space as the thousands separator.

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

In the text, data in SI units are followed by data in USC in parentheses.

Separate tables for data expressed in SI units and USC units are given in [Annex A](#) and [Annex C](#), respectively.

Figures are contained in [Annex B](#) and express data in both SI and USC units.

5 Information supplied by the purchaser

5.1 The purchaser shall state the minimum information as given in [Table 1](#), as applicable, in the enquiry and purchase agreement.

Table 1 — Minimum information to be supplied by purchaser

Requirement		Reference
a)	Quantity of product	—
b)	Product designation: coupling stock or accessory material or plain end casing or tubing or upset product	For upset product, upset drawing and drift dimension shall be supplied by the purchaser
c)	Reference to this document	—
d)	Material category/grade	Table A.2 or Table C.2 and Table A.3 or Table C.3
e)	Label 1 and label 2 or specified outside diameter and specified wall thickness	Table A.16 or Table C.16 or as specified in purchase agreement per 8.1.2
f)	Coupling stock or accessory material dimensions, expressed in millimetres (inches)	As specified in purchase agreement
g)	Length requirements	8.2 ; Table A.17 or Table C.17 or as specified in purchase agreement

Table 1 (continued)

Requirement		Reference
h)	Length for coupling stock or accessory material	As specified in purchase agreement
i)	Tolerances on outside diameter, wall thickness and mass of coupling stock or accessory material	8.3.1
j)	Handling, packaging and storage	14.1
k)	Inspection by the purchaser	Annex D
l)	Purchase requirements for bars intended for accessory material	F.2.1

5.2 The purchaser shall also state on the purchase agreement the requirements, where applicable, concerning the stipulations listed in [Table 2](#). These stipulations are at the purchaser's option; if PSL-2 is not specified, the product will be supplied according to the requirements of PSL-1.

Table 2 — Additional requirements on purchase agreements

Requirement		Reference
a)	Cold end sizing exceeding 3 % plastic strain without subsequent heat treatment for group 1	6.3.1
b)	End sizing by cold swaging or cold expansion Maximum deformation, validation method and acceptance criteria for cold end sizing	6.3.2
c)	Group 1 higher hot straightening temperature	6.4
d)	MPQT program	6.7 and Annex H
e)	Chemical composition	7.1
f)	Difference between measured tensile strength and measured yield strength smaller than 34 MPa (5 ksi)	7.2
g)	Mechanical properties at elevated temperature	7.2 ; 9.5.2
h)	Other tensile properties for PSL-2 products	7.2 , Table A.28 or Table C.28 , G.2
i)	Other hardness properties for PSL-2 products	7.3 , Table A.28 or Table C.28 , G.2
j)	Critical thickness for impact testing of coupling stock or accessory material	7.4.2
k)	Impact test temperature if lower than -10 °C (14 °F)	7.4.6
l)	Additional flattening tests for groups 3 and 4 materials	7.7
m)	Distance between plates when $D/t < 3$ or $D/t > 15$	7.7
n)	Charpy V-notch testing at low temperature for group 2	7.8 ; 9.8
o)	Corrosion testing	7.9
p)	Pitting corrosion testing for group 2	7.9.2 ; 9.9
q)	Ferrite content for material 13-1-0	7.10.1
r)	Special surface condition	7.11
s)	Alternative drift mandrel	8.3.4
t)	Chemical analysis on semi-finished product	9.3.1
u)	Chromium depletion; minimum chromium content higher than 12,0 %	9.3.3
v)	Transverse impact test pieces from flattened material for cold hardened groups 2, 3 and 4 materials	9.7.1
w)	Specimen preparation (grinding/polishing/pickling) for group 2 pitting corrosion test	9.9
x)	Retest provision for group 2 pitting corrosion test	9.9
y)	Wall thickness verification for accessory material	9.11.4
z)	Condition for NDE operations	9.17.3

Table 2 (continued)

Requirement		Reference
aa)	Minimum signal-to-noise ratio lower than 3 to 1	9.17.9 ; 9.17.10
bb)	Second outside surface NDE method for group 1 materials	9.17.9
cc)	Band colour for marking the area of defect	9.17.14 b)
dd)	PMI for group 1	9.18
ee)	Low-stress die-stamping or vibro-etching marking requirements	11.1 ; 11.3
ff)	Additional marking that is consistent with general marking	11.1
gg)	Modification or elimination of colour code identification	11.2
hh)	Colour code identification of couplings and accessories	11.4
ii)	Surface protection for group 1 materials	12.2
jj)	Content of EDI-transmitted document	13.1
kk)	Alternative transportation or packaging system	14.3.1
ll)	For UNS N06975, $w_{Mo} + W \geq 6$ % mass fraction	Table A.29 or Table C.29
mm)	Alternative place for inspection	D.2
nn)	Treatment of rejected lengths	D.4
oo)	Purchase agreements for bars intended for accessory material	F.2.2
pp)	PSL-2	Annex G
qq)	Minimum quantities, heats and lots to undergo MPQT Additional validation requirements Product dimension representative of a range of product sizes	H.3.1
rr)	Statistical criteria for an in-control process	H.3.2
ss)	Other test methods for MPQT	H.3.2

6 Manufacturing process

6.1 Melting practices

The alloys covered by this document shall be made by the basic oxygen process or the electric furnace process or blast furnace (group 1 only) or the VIM process, followed by further refining operations such as AOD, VOD, VAR, ESR, and VAD.

6.2 Product manufacturing process

Product manufacturing processes, starting material and heat-treatment or cold-hardened conditions are listed in [Table A.1](#) or [Table C.1](#).

Group 1 pipes and group 2 solution-annealed pipes shall be full-length heat-treated after any upsetting.

The manufacturer shall apply a process control plan that precludes the occurrence of phenomenon that can create surface effects (e.g. chromium depletion below 12,0 % mass fraction for groups 2, 3 and 4) on products where heat treatment is part of the manufacturing process, which can affect the corrosion resistance.

For group 2, the product shall be in the

- a) solution-annealed and liquid-quenched condition, or
- b) solution-annealed and liquid-quenched and cold-hardened condition.

6.3 Pipe end sizing

6.3.1 Group 1 pipe may be end-sized such as swaging or expanding after final heat treatment for purposes of threading. When end sizing exceeds 3 % plastic strain, group 1 pipe shall be either stress relieved at suitable temperature or full-length heat-treated in accordance with a documented procedure.

When the manufacturer has demonstrated and documented that the end sizing process has not detrimentally affected the corrosion properties, by agreement between the purchaser and the manufacturer, group 1 pipe may be cold end-sized exceeding 3 % plastic strain without subsequent heat treatment.

If end sizing is performed before final full-length heat treatment, stress relief is not required.

6.3.2 For groups 2, 3 and 4 pipe, end sizing by cold swaging or cold expansion for purpose of threading is allowed by agreement between the purchaser and the manufacturer. Maximum deformation, validation method and acceptance criteria for cold end sizing shall be by agreement between the purchaser and the manufacturer.

NOTE 1 It is very difficult to stress relieve duplex stainless steels without causing sigma-phase formation.

NOTE 2 End sizing can result in mechanical properties and hardness out of the ranges specified in this document. See Warning 1 in [Annex G](#) in case of PSL-2 products.

6.4 Straightening

6.4.1 When straightening is performed after heat treatment for group 1, products shall be hot-rotary straightened at 400 °C (750 °F) minimum at the end of rotary straightening, unless a higher minimum temperature is specified in the purchase agreement. If hot rotary straightening is not possible, the product may be cold straightened, provided it is then stress-relieved at 510 °C (950 °F) or higher. Light gag-press straightening shall be permitted, without subsequent stress relieving, if the induced maximum fibre strain is not exceeding the value validated by the manufacturer at the time of process validation (see [6.5](#)).

6.4.2 When straightening is performed for groups 2, 3 and 4, products shall be straightened, either using rotary straightening, gag-press straightening or a combination of both when necessary, utilizing parameters not exceeding the limits defined during validation of the process (see [6.5](#)).

6.5 Processes requiring validation

6.5.1 Those processes requiring validation are

- non-destructive examination (see [9.17.8](#)),
- final heat treatment for group 1 (excluding stress relieving) and solution annealed group 2 materials,
- final solution annealing before last cold hardening operations for groups 2, 3 and 4 cold hardened material,
- stress relieving, if applicable,
- cold straightening, if applicable, for group 1 [except when cold straightening is followed by stress relieving (see [6.4](#))] and solution annealed group 2 materials (see [6.5.3](#)), and
- cold finishing processes not followed by heat treatment for groups 2, 3 and 4 CH materials, including deformation induced by cold straightening (if applicable).

6.5.2 Validation of heat treatment shall include verification of chromium depletion as per [6.2](#).

6.5.3 Validation of cold straightening shall include verification of mechanical properties.

For rotary cold straightening, validation shall be for all quadrants at both ends and the mid-length of the product. When required, flattening tests shall be performed at both ends and the mid-length of the product.

For gag straightening, validation shall be at the longitudinal location of the product where deformation is greatest and shall include testing at the maximum tensile and compressive strain locations (see [Figure B.9](#)). The tested length shall be representative of material that has been subject to the maximum induced fibre strain typical for the straightening operation, as determined by the manufacturer.

Manufacturers shall document the extent of the validation and the method used for validation, including but not limited to the validation data, analyses, conclusions and range of products, size range, wall thickness and manufacturing facilities. For gag straightening, the documentation of maximum induced fibre strain shall take into account maximum deflection, equipment set-up such as distance between supports and product dimensional range.

6.6 Traceability

The manufacturer shall establish and follow procedures for maintaining heat, re-melt ingot and/or lot identity until all required heat, re-melt ingot and/or lot tests and inspections are performed and conformance with specification requirements has been shown.

Each length of product shall be uniquely identified so that test and inspection data can be related to individual lengths. It is the responsibility of the manufacturer to maintain the identification of material until it is received by the purchaser.

6.7 Manufacturing procedure qualification test

If so specified in the purchase order, the purchaser may request that an MPQT program be conducted for qualification of a range of products for the specific purchaser or a change in the manufacturing process. Alternatively, the manufacturer may by agreement provide qualification data from a previous MPQT.

[Annex H](#) may be considered for the definition of the MPQT scope.

6.8 Process for update of alloys and/or grades

Applications for new entries or alteration to existing entries shall be accompanied by supporting evidence as per [Annex H](#).

For PSL-2, the process of update of alloys and/or grades shall be in accordance with [G.5](#).

7 Material requirements

7.1 Chemical composition

In [Table A.2](#) or [Table C.2](#), generic types of alloy are listed with their nominal content of key chemical elements for PSL-1 products.

For PSL-1 products, the chemical composition and tolerances as agreed between the purchaser and the manufacturer shall be included in the purchase agreement.

In [Table A.29](#) or [Table C.29](#), the chemical analysis requirements for PSL-2 products are listed.

For group 2 material only, products in accordance with this document shall have a pitting-resistance equivalent number as stated in [Table A.2](#) or [Table C.2](#) for PSL-1 products or in [Table A.29](#) or [Table C.29](#) for PSL-2 products.

7.2 Tensile properties

Tensile properties at room temperature of pipes covered by this document shall meet the requirements given in [Table A.3](#) or [Table C.3](#) for PSL-1 products or in [Table A.28](#) or [Table C.28](#) for PSL-2 products.

In addition, the requirements in [7.2](#) a) or b) shall also be met.

- a) The measured tensile strength shall be 69 MPa (10 ksi) greater than the specified minimum yield strength.
- b) If the requirement in [7.2](#) a) is not met, then there shall be a 34 MPa (5 ksi) or greater difference between the measured tensile strength and the measured yield strength. By agreement between the purchaser and the manufacturer, the 34 MPa (5 ksi) requirement may be reduced.

When tensile properties at elevated temperature are requested by the purchaser, the values and the verification procedures shall be agreed between the purchaser and the manufacturer.

7.3 Hardness properties

The hardness of products covered by this document shall meet the requirements given in [Table A.3](#) or [Table C.3](#) for PSL-1 products or in [Table A.28](#) or [Table C.28](#) for PSL-2 products.

The through-wall hardness variation shall meet the requirements specified in [Table A.4](#) or [Table C.4](#).

No individual hardness number may be greater than 2 HRC units above the specified mean hardness number.

7.4 Charpy V-notch test properties — General requirements

7.4.1 Evaluation of test results

A test shall consist of a set of three specimens taken from one location from a single tubular product length. The average value of the three impact specimens shall equal or exceed the absorbed energy requirement specified in [7.5](#) and [7.6](#). In addition, not more than one impact specimen shall exhibit an absorbed energy below the absorbed energy requirement, and in no case shall an individual impact specimen exhibit an absorbed energy below two-thirds of the absorbed energy requirement.

For the purpose of determining conformance with these requirements, the observed result of a test shall be rounded to the nearest whole number. The impact energy value for a set of test specimens (i.e. average of three tests) shall be expressed as a whole number, rounded if necessary. Rounding shall be in accordance with the rounding method of ISO 80000-1 or ASTM E29.

7.4.2 Critical thickness

The absorbed energy requirements are based on the critical thickness. For pipe, the critical thickness is the specified wall thickness. For coupling stock and accessory material, the critical thickness shall be the specified wall thickness, unless otherwise specified on the purchase agreement.

NOTE As a guideline, the purchaser of accessory material can specify a critical thickness that is no less than the thickness of the cross-section of the intended accessory with the lowest t/D ratio, where D is the specified outside diameter and t is the calculated wall thickness at that section. For special end-finish connections, the critical thickness for externally threaded members is the specified pipe body thickness, while for internally threaded members it is the calculated thickness of the internally threaded member at the plane of the small end of the pin (when the connection is made up power-tight).

7.4.3 Specimen size, orientation and hierarchy

When the use of full-size (10 mm × 10 mm) transverse test specimens is not possible, the largest possible sub-size transverse test specimen listed in [Table A.5](#) or [Table C.5](#) shall be used. When it is not possible to test using any of these transverse test specimens, the largest possible longitudinal test specimen listed in [Table A.6](#) or [Table C.6](#) shall be used for a group 1 product and flattening test specimens shall be used for a

group 2, 3 or 4 product. The hierarchy of C_v test specimen orientation and size is specified in [Table A.6](#) or [Table C.6](#).

[Table A.7](#) or [Table C.7](#) for transverse specimens and [Table A.8](#) or [Table C.8](#) for longitudinal specimens provide the calculated wall thickness required to machine full-size or a smaller impact specimen (see [Table A.5](#) or [Table C.5](#)). The impact-test specimen size that shall be selected from these tables is the largest impact test specimen having a calculated wall thickness that is equal or less than the specified wall thickness for the pipe, coupling stock or accessory material tested.

7.4.4 Alternative size impact test specimens

At the manufacturer's option, impact-test specimens of an alternative size, listed in [Table A.5](#) or [Table C.5](#), may be used in lieu of the minimum size specified determined from [Table A.7](#) or [Table C.7](#) or from [Table A.8](#) or [Table C.8](#). However, the alternative test specimen selected shall be higher on the hierarchy [Table A.6](#) or [Table C.6](#) than the specified size, and the absorbed energy requirement shall be adjusted in a manner consistent with the orientation and size of the impact specimen.

7.4.5 Sub-size test specimens

The minimum Charpy V-notch absorbed energy requirement for sub-size test specimens shall be that specified for a full-size test specimen multiplied by the reduction factor in [Table A.5](#) or [Table C.5](#).

7.4.6 Test temperature

The test temperature shall be $-10\text{ }^{\circ}\text{C}$ ($14\text{ }^{\circ}\text{F}$). An alternative lower test temperature may be specified on the purchase agreement or selected by the manufacturer for any grade. The tolerance on the test temperature shall be $\pm 1\text{ }^{\circ}\text{C}$ ($\pm 2\text{ }^{\circ}\text{F}$).

7.5 Charpy V-notch — Absorbed energy requirements for coupling stock and accessory material — All grades

7.5.1 General

Coupling stock and accessory material suitable for more than one type of connection may be qualified by a test to demonstrate conformance to the most stringent requirements.

7.5.2 Requirements for all grades

The minimum absorbed energy requirement, C_v , for full-size test specimens is provided in [Table A.9](#) or [Table C.9](#), [Table A.10](#) or [Table C.10](#), and [Table A.11](#) or [Table C.11](#). The requirements are calculated based on the expressions given in [Table 3](#), where

- $Y_{S,\max}$ is the maximum specified yield strength, expressed in megapascals (thousand pounds per square inch);
- t is the critical wall thickness (see [7.4.2](#)), expressed in millimetres (inches).

Table 3 — Expressions for the minimum absorbed energy requirement for full-size test specimens of coupling stock and accessory material

Unit system and group		Transverse requirement C_v	Longitudinal requirement C_v
1		2	3
SI units of joules	Group 1	$Y_{S,max} \times (0,001\,18\,t + 0,012\,59)$ or 40 J, whichever is greater; see Table A.9	$Y_{S,max} \times (0,001\,18\,t + 0,012\,59)$ or 40 J, whichever is greater; see Table A.10
	Groups 2, 3 and 4	$Y_{S,max} \times (0,001\,18\,t + 0,012\,59)$ or 27 J, whichever is greater; see Table A.11	NA ^a
USC units of foot-pounds	Group 1	$Y_{S,max} \times (0,152\,t + 0,064)$ or 29 ft-lb, whichever is greater; see Table C.9	$Y_{S,max} \times (0,152\,t + 0,064)$ or 29 ft-lb, whichever is greater; see Table C.10
	Groups 2, 3 and 4	$Y_{S,max} \times (0,152\,t + 0,064)$ or 20 ft-lb, whichever is greater; see Table C.11	NA ^a

^a When transverse Charpy V-notch tests ½ size or greater are not possible for groups 2, 3 and 4, then flattening tests are required.

7.6 Charpy V-notch — Absorbed energy requirements for pipe — All grades

The minimum absorbed energy requirement, C_v , for full-size test specimens is provided in [Table A.12](#) or [Table C.12](#), [Table A.13](#) or [Table C.13](#), and [Table A.14](#) or [Table C.14](#). The requirements are calculated based on the expressions given in [Table 4](#), where

- $Y_{S,min}$ is the minimum specified yield strength, expressed in megapascals (thousand pounds per square inch);
- t is the critical wall thickness (see [7.4.2](#)), expressed in millimetres (inches).

Table 4 — Expressions for the minimum absorbed energy requirement for full-size test specimens of pipe

Unit system and group		Transverse requirement C_v	Longitudinal requirement C_v
1		2	3
SI units of joules	Group 1	$Y_{S,min} \times (0,001\,18\,t + 0,012\,59)$ or 40 J, whichever is greater; see Table A.12	$Y_{S,min} \times (0,001\,18\,t + 0,012\,59)$ or 40 J, whichever is greater; see Table A.13
	Groups 2, 3 and 4	$Y_{S,min} \times (0,001\,18\,t + 0,012\,59)$ or 27 J, whichever is greater; see Table A.14	NA ^a
USC units of foot-pounds	Group 1	$Y_{S,min} \times (0,152\,t + 0,064)$ or 29 ft-lb, whichever is greater; see Table C.12	$Y_{S,min} \times (0,152\,t + 0,064)$ or 29 ft-lb, whichever is greater; see Table C.13
	Groups 2, 3 and 4	$Y_{S,min} \times (0,152\,t + 0,064)$ or 20 ft-lb, whichever is greater; see Table C.14	NA ^a

^a When transverse Charpy V-notch tests ½ size or greater are not possible for groups 2, 3 and 4, then flattening tests are required.

7.7 Flattening requirements

For groups 2, 3 or 4, flattening tests shall be made as an alternative to impact tests when the outside diameter or wall thickness precludes the machining of transverse impact test specimens $\frac{1}{2}$ size or larger. By agreement between the purchaser and the manufacturer for groups 3 and 4, flattening tests may be performed in addition to the impact tests that are required when $\frac{1}{2}$ size or larger transverse specimens can be machined.

When flattening tests are required, products with D/t ratios between 3 and 15 shall be flattened until the distance between the plates is less than or equal to S , expressed in per cent, of the specified outside diameter, D , as calculated by [Formula \(1\)](#) for SI units and by [Formula \(2\)](#) for USC units:

$$S = 100 - \{ [3,8458 \ln(Y_{S,\max}) - 24,344] \times D/t \} \quad (1)$$

$$S = 100 - \{ [3,8458 \ln(Y_{S,\max}) - 16,919] \times D/t \} \quad (2)$$

where

$Y_{S,\max}$ is the maximum specified yield strength, expressed in megapascals (thousand pounds per square inch);

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

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

$\ln$ is the natural logarithm of the maximum specified yield strength.

When the D/t ratio is outside the above limits, the distance between the plates to be reached for flattening shall be by agreement between the purchaser and the manufacturer.

Each ring shall be flattened to the maximum distance between the plates specified above.

Occurrence of a load drop-off, before meeting the specified deflection, shall be determined from the load versus deflection test record. A load drop-off that exceeds 5 % of the instantaneous load prior to the drop-off shall be cause for rejection. When the record does not show a load drop-off above 5 %, cracks shall not be cause for rejection.

7.8 Charpy V-notch test properties at low temperature for group 2

7.8.1 General

Charpy V-notch test properties at low temperature shall be evaluated for group 2 when specified in the purchase agreement.

7.8.2 Evaluation of test results

A test shall consist of a set of three specimens taken from one location from a single tubular product length. The average value of the three impact specimens shall equal or exceed the absorbed energy requirement specified in [7.8.5](#). Not more than one impact specimen shall exhibit an absorbed energy below the absorbed energy requirement. In no case shall an individual impact specimen exhibit an absorbed energy below two-thirds of the absorbed energy requirement.

For the purpose of determining conformance with these requirements, the observed result of a test shall be rounded to the nearest whole number. The impact energy value for a set of test specimens (i.e. average of three tests) shall be expressed as a whole number, rounded if necessary. Rounding shall be in accordance with the rounding method of ISO 80000-1 or ASTM E29.

7.8.3 Selection of test specimens

When the use of full-size (10 mm × 10 mm) transverse test specimens is not possible, the largest possible sub-size transverse test specimen listed in [Table A.5](#) or [Table C.5](#) shall be used. When it is not possible to test using any of these transverse test specimens, the largest possible longitudinal test specimen listed in [Table A.6](#) or [Table C.6](#) shall be used. The hierarchy of C_v test specimen orientation and size is specified in [Table A.6](#) or [Table C.6](#).

[Table A.7](#) or [Table C.7](#) for transverse specimens and [Table A.8](#) or [Table C.8](#) for longitudinal specimens provide the calculated wall thickness required to machine full-size or a smaller impact specimen (see [Table A.5](#) or [Table C.5](#)). The impact-test specimen size that shall be selected from these tables is the largest impact test specimen having a calculated wall thickness that is equal or less than the specified wall thickness for the tubular. When longitudinal half-size test specimens cannot be machined, no test needs to be done.

For alternative size impact test specimens and sub-size test specimens [7.4.4](#) and [7.4.5](#) apply, respectively.

7.8.4 Test temperature

The test temperature shall be -46 °C (-50 °F). The tolerance on the test temperature shall be $\pm 1\text{ °C}$ ($\pm 2\text{ °F}$).

7.8.5 Absorbed energy requirements

The minimum absorbed energy requirement for full-size test specimens is provided in [Table A.15](#) or [Table C.15](#).

7.9 Corrosion properties

7.9.1 General

At the purchaser's option, quality control corrosion testing may be specified in the purchase agreement.

NOTE Corrosion testing for quality control purposes is not required.

7.9.2 Pitting corrosion properties for group 2

Pitting corrosion resistance shall be evaluated for group 2 when specified in the purchase agreement.

When required, the evaluation shall be performed at 25 °C (77 °F) for category 22-5-3 materials and at 50 °C (122 °F) for categories 25-7-3, 25-7-4 and 26-6-3 materials. Test temperature tolerance shall be $\pm 1\text{ °C}$ ($\pm 2\text{ °F}$). Higher test temperatures are acceptable. The test exposure time shall be at least 24 h.

No pitting shall be detected and mass loss shall be less than $1,0\text{ g/m}^2$ ($0,2\text{ lb/1,000 ft}^2$).

7.10 Microstructure properties

7.10.1 Group 1

For martensitic material, the delta ferrite volume fraction shall not exceed 2 %.

For category 13-1-0, the ferrite volume fraction may exceed 2 % by agreement between the purchaser and the manufacturer.

The microstructures shall have grain boundaries with no continuous precipitates or ferrite network.

7.10.2 Group 2

The microstructure shall have a ferritic-austenitic structure.

For duplex alloys, the ferrite volume fraction shall be in the range 40 % to 60 %.

For super-duplex alloys, the ferrite volume fraction shall be in the range 35 % to 55 %.

The microstructure shall be free from intermetallic precipitates, except for discrete/standalone intermetallic precipitates provided these are located in isolated areas and not homogeneously distributed throughout the test specimen, and that the maximum dimension of each precipitate does not exceed 10 µm (0,40 mil).

Micrographs included in [Annex I](#) are showing examples of microstructures.

Grain and phase boundaries shall be free from continuous networks of precipitates.

If carbide or nitride precipitates are observed, the findings shall be reported and documented, and the acceptance shall be based upon the Charpy V-notch or flattening test (see [7.4](#), [7.5](#), [7.6](#) and [7.7](#)).

NOTE While determination of the nitride phase balance is impractical, the presence of nitrides in the ferrite phase reduces the Charpy V-notch property, increases micro hardness in the ferrite phase and reduces the breakthrough pitting corrosion potential. Quality control to avoid excessive nitrides is therefore best achieved by meeting the impact and corrosion properties given in [7.8](#) and [7.9](#).

7.10.3 Groups 3 and 4

The microstructure shall be free from intermetallic phases and carbides/nitrides precipitates, except for discrete/standalone precipitates. Grain boundaries shall be free from continuous networks of precipitates.

Micrographs included in [Annex I](#) are showing examples of microstructures.

Grain size shall be reported for information.

7.11 Surface condition

The internal surface of pipes shall be free from scale and annealing residues. If the purchaser has special requirements for the pipe surface, this shall be stated at the time of enquiry and order. The purchaser shall in this case specify the method, frequency, roughness values and extent of testing.

7.12 Defects

7.12.1 Pipe

All pipes shall be free from the following defects:

- a) any quench crack or arc burn;
- b) any surface-breaking imperfection that is proven to reduce the net effective wall thickness below 87,5 % of the specified wall thickness for hot-finished products or 90 % for other products;
- c) any linear imperfection on the outside or inside surface, of any orientation, with a depth greater than 5 % of the specified wall thickness or 0,3 mm (0.012 in), whichever is greater, in the radial direction;
- d) any non-surface-breaking imperfection detected that, when outlined on the outside surface, has an area greater than 260 mm² (0.40 in²);
- e) any surface-breaking pipe-upset imperfection, of any orientation, with a depth greater than 5 % of the specified pipe body wall thickness; the minimum wall thickness in the upset run-out interval, and the maximum combined effect of coincident internal and external imperfections in all areas, shall not result in the remaining wall below the imperfections being less than 87,5 % of the specified wall thickness;
- f) on the internal upset configuration on all upset products, any sharp corner or drastic change of section that can cause a 90° hook-type tool to hang up (see [Figure B.3](#)).

7.12.2 Coupling stock and accessory material

All coupling stock and accessory material shall be free from any quench crack or arc burn. All coupling stock and accessory material shall be free from, or have clearly marked, any other outside-surface-breaking imperfection with a depth greater than 5 % of the specified wall thickness or that is proven to reduce the outside diameter or wall thickness below specified tolerances. Also, the requirement of [7.12.1 d\)](#) shall apply.

7.12.3 Process control plan

The manufacturer, based on knowledge of the production process and the requirements of [Clause 9](#), shall apply a process control plan that ensures that the requirements of [7.12.1](#) and [7.12.2](#) are fulfilled.

8 Dimensions, masses and tolerances

8.1 Outside diameter, wall thickness and mass

8.1.1 The outside diameter, wall thickness and mass of the pipes for casing and tubing covered by this document are given in [Table A.16](#) or [Table C.16](#). The masses included in [Table A.16](#) or [Table C.16](#) are calculated using a factor of 1. In order to determine the masses relating to the different materials, the masses in [Table A.16](#) or [Table C.16](#) shall be multiplied using the following multiplication factors:

- 0,989 for ferritic and martensitic steels — Group 1;
- 1 for duplex and super-duplex steels — Group 2;
- α for austenitic steels — Group 3;
- β for austenitic Ni-based alloys — Group 4.

The α and β values shall be provided by the manufacturer.

8.1.2 Dimensions other than those in [Table A.16](#) or [Table C.16](#) may be agreed at the time of enquiry and order.

8.1.3 For measurement of diameter, the accuracy shall be as follows.

a) Using SI units

An accuracy of two decimal places shall be used for sizes less than or equal to label 1:6 5/8. An accuracy of one decimal place shall be used for sizes larger than label 1:6 5/8. In this document, two decimal places are used for design purposes to ensure interchangeability (see label 1 dimensions in [Table A.16](#)).

b) Using USC units

An accuracy of three decimal places shall be used.

8.2 Length

Unless otherwise agreed between the purchaser and the manufacturer, the pipes shall be delivered with the length requirements listed in [Table A.17](#) or [Table C.17](#).

8.3 Tolerances

8.3.1 Tolerance on outside diameter, wall thickness and mass

The outside diameter, wall thickness and mass of the pipe for casing and tubing shall be within the tolerance limits given in [Table A.18](#) or [Table C.18](#).

For coupling stock and accessory material, the tolerance on outside diameter, wall thickness and mass shall be specified at the time of enquiry and agreed on in the purchaser agreement.

8.3.2 Inside diameter, d

There is no direct tolerance set on inside diameter, d .

8.3.3 Straightness

Deviation from straightness, or chord height, shall not exceed either of the following:

- 0,2 % of the total length of the pipe, measured from one end of the pipe to the other end for pipe with a diameter >101,60 mm (4 in) (see [Figure B.1](#));
- 3,18 mm (0.125 in) maximum drop at each end, in the transverse direction for a length of 1,52 m (5 ft) (see [Figure B.2](#)).

8.3.4 Drift requirements

Each pipe shall be drift-tested throughout its entire length. Standard drift sizes for casing and tubing shall be as specified in [Table A.19](#) or [Table C.19](#).

An alternative drift mandrel size may be specified by the purchaser. For common alternative drift sizes, see [Table A.20](#) or [Table C.20](#).

8.4 Product ends

All plain end product ends shall be free from burrs and out-of-squareness shall be within 0,01 D .

9 Inspection and testing

9.1 Test equipment

The manufacturer shall determine and document the appropriate calibration frequency and reference standards in order to be able to certify that all products conform to the requirements of this document.

If test or measuring equipment, whose calibration or verification is required under the provisions of this document, is subjected to unusual or severe conditions that make its accuracy questionable, recalibration or reverification shall be performed before further use of the equipment.

9.2 Type and frequency of tests

The tests carried out and the test frequency are given in [Table A.21](#) or [Table C.21](#).

No test is required for pup joints manufactured from a length of casing or tubing, provided that it has been previously tested and conforms to requirements and there is no subsequent heat treatment.

9.3 Testing of chemical composition

9.3.1 Chemical analysis

The results of the chemical analysis made on each heat shall be provided by the manufacturer.

The report shall include the results of quantitative determination of elements as follows:

- for PSL-1, the elements listed in [Table A.2](#) or [Table C.2](#) plus Si, Mn, S, P and Al;
- for PSL-2, the elements specified in [Table A.29](#) or [Table C.29](#);

— for PSL-1 and PSL-2, any other elements used by the manufacturer to control properties.

An analysis of the finished product shall be made on

- a) two samples per heat for non-remelted alloy, and
- b) one sample per remelted ingot for remelted alloy.

By agreement between the purchaser and the manufacturer, samples may be taken from the semi-finished product.

Samples shall be taken in accordance with ISO 14284.

9.3.2 Test method

Selection of a suitable method for chemical analysis shall be at the discretion of the manufacturer. Often, the method of spectrometric analysis is used.

NOTE ISO/TR 9769, ASTM A751, ASTM E1473 and ASTM B880 provide a list of available standards specifying methods for chemical analysis, including information on their fields of application and accuracy.

9.3.3 Chromium depletion test — Groups 2, 3 and 4

When specified in the purchase agreement, one sample per test lot shall be examined for surface chromium content using the EDX (energy dispersive X-ray spectrometry) or an equivalent method. The sample shall be taken on the product in its final delivery condition, but no special surface preparation shall be done before the test. The measured chromium content on the outside and inside surfaces shall not be less than 12,0 %. A higher minimum chromium content may be agreed between the purchaser and the manufacturer.

If a sample fails to meet the requirements, two additional samples from the same length shall be tested. If either of the additional samples fails, the manufacturer may elect either to test each of the remaining lengths in the test lot or to rework (e.g. additional pickling and/or grinding) and test the lot as a new lot.

9.4 Testing of mechanical characteristics

9.4.1 Test lot

The number of lengths per test lot shall conform to the requirements of [Table A.22](#) or [Table C.22](#).

9.4.2 Selection and preparation of samples and test pieces

Samples and test pieces shall be taken at the pipe ends and shall be in accordance with the requirements of ISO 377.

9.5 Tensile test

9.5.1 Orientation and size of test pieces

The test pieces shall be taken longitudinally to the pipe axis in accordance with the requirements of ISO 6892-1 or ASTM A370.

In case round-bar specimens are used, the largest gauge diameter compatible with the wall thickness of the product shall be used.

9.5.2 Test method

A tensile test shall be carried out at room temperature in accordance with ISO 6892-1 or ASTM A370.

The tensile strength, R_m , the yield strength, $R_{p0,2}$, and the percentage elongation after fracture, e , shall be determined during the tensile test.

The results of the tensile test shall conform to the requirement of [7.2](#) and with the values for the material category and grade specified in [Table A.3](#) or [Table C.3](#) for PSL-1 products or in [Table A.28](#) or [Table C.28](#) for PSL-2 products.

If agreed at the time of ordering, a tensile test at elevated temperature shall be carried out in accordance with ISO 6892-2 or ASTM E21. The yield strength, $R_{p0,2}$, shall be determined during the tensile test at the temperature agreed at the time of enquiry and order. The result of the tensile test shall conform to the value agreed at the time of enquiry and order.

9.5.3 Invalidation of test

Any test specimen that shows defective preparation or material imperfections unrelated to the intent of the test, whether observed before or after testing, may be discarded and be replaced by another specimen from the same length. Specimens shall not be judged defective for the sole reason that they fail to meet the required properties.

9.5.4 Retest

If a tensile test representing a lot fails to conform to the specified requirements, the manufacturer may elect to carry out retests on three additional lengths from the same lot. In the case of test lots with three or fewer lengths, each length shall be tested. If all of the retests conform to the requirements, the lot shall be accepted, excepting the failed length.

If one or more of the retest specimens fails to conform to the specified requirements, the manufacturer may elect to test each of the remaining lengths in the lot. Any length that fails shall be rejected. Specimens for retests shall be taken in the same manner as specified in [9.4.2](#).

Rejected lots may be re-heat-treated and tested as new lots, as applicable.

9.6 Hardness test

9.6.1 Test pieces

The test piece for the hardness test shall be a ring or product test block cut from one end of the sample pipe. The test ring or product test block shall be a minimum of 12,7 mm ($\frac{1}{2}$ in) long.

The surfaces of the test piece that contact the anvil and the indenter shall be machined parallel within $0,5^\circ$ and smooth with an average surface roughness of $0,6 \mu\text{m}$ ($25 \mu\text{in}$) or finer, as defined by Ra value in ISO 21920-2. They shall be visually inspected and shall be free of visible foreign matter, lubricants and burrs.

When product test blocks or rings are prepared using consistent machining processes that ensure this requirement is met, verification of parallelism and roughness is not required. Otherwise, the parallelism and the roughness shall be verified on each test piece.

9.6.2 Test method

A test block shall be tested in one quadrant. A row of three hardness indentations shall be made at required locations (outer, midwall, inner as applicable) and the hardness numbers shall be averaged to give one mean hardness number for each location. An illustration is given in [Figure B.4](#), key item 4.

The minimum number of rows shall be determined by the wall thickness of the product, see detail *a* in [Figure B.4](#). For wall thickness lower or equal to 7,62 mm (0.300 in), one row shall be used. For wall thickness higher than 7,62 mm (0.300 in) and lower or equal to 11,43 mm (0.450 in), two rows shall be used. For wall thickness higher than 11,43 mm (0.450 in) three rows shall be used. The outer and inner locations shall be taken between 2,54 mm (0.100 in) and 3,81 mm (0.150 in) from the applicable surface.

An indentation shall not be spaced closer than two and a half diameters from its centre to the edge of the specimen or three diameters from another indentation measured centre to centre.

The mean hardness number is the average of three Rockwell hardness numbers in the same location as it is shown in detail *b* of [Figure B.4](#). Rockwell hardness indentation data are called Rockwell hardness numbers; see detail *c* of [Figure B.4](#).

A Rockwell hardness test shall be carried out in accordance with ISO 6508-1 or ASTM E18. Hardness tests shall be made using the Rockwell C scale. The mean Rockwell hardness numbers shall conform to the requirements of [7.3](#), [Table A.4](#) or [Table C.4](#), and with the hardness requirements for the material category and grade specified in [Table A.3](#) or [Table C.3](#) for PSL-1 products or in [Table A.28](#) or [Table C.28](#) for PSL-2 products.

The first indentation on a hardness test specimen shall be made near the centre of the test block specimen to help seat the test specimen and reduce the possibility of errors. The result of this first indentation shall be ignored and it is not necessary to record it.

Overhang of product test blocks or rings beyond the anvil support of less than or equal to 40 % of the surface area of the product test block or ring is acceptable. The overhang may exceed 40 % of the surface area of the product test block or ring when the testing equipment is designed and validated to yield consistently accurate results for such use. External support is not permitted.

The anvil and anvil seat shall not have protrusions or indentations that adversely affect the hardness result.

When standardized test blocks are used for the verification of a hardness machine, the same anvil shall be used for the verification as will be used for acceptance testing following the verification.

Hardness tests shall only be made using hardness testers with digital readout with one or more decimal places.

Only indenters that have been calibrated (verified) for use with the specific test machine to be used, such as during an indirect verification, shall be used. When other indenters are used, they shall be verified using an indirect verification with respect to a more accurate indenter (e.g. reference indenter with less error).

The polished portion of the HRC indenter shall be visually inspected periodically for damage (e.g. cracks, chips, pits) with the aid of adequate magnification (e.g. 20× or higher).

If the difference between the highest and lowest indentations at a location (same outside-wall, mid-wall or inside-wall in a quadrant) is greater than 2,5 HRC, then three additional indentations in the same location shall be taken. In such case, the mean hardness number shall be based on the three additional indentations. The test report shall indicate that additional indentations were made and the original test data shall be available upon request.

9.6.3 Invalidation of tests

Any test specimen that shows defective preparation or material imperfections unrelated to the intent of the test, whether observed before or after testing, may be discarded and be replaced by another specimen from the same length. Specimens shall not be judged defective for the sole reason that they fail to meet the required properties.

9.6.4 Periodic checks of hardness-testing machines

Periodic checks of testing machines shall be made using the procedures in ISO 6508-1 or ASTM E18 for Rockwell hardness test machines.

The standardized test block shall have a maximum non-uniformity of 0,4 HRC. The non-uniformity of the standardized test block shall be determined by the difference between the highest and lowest indentation number stated in the standardized test block certificate.

At least two preliminary indentations on each standardized test block should be disregarded in order to reduce the possibility of errors. After the preliminary indentations, at least three hardness indentations shall be made on the standardized test block. The error shall not exceed $\pm 0,5$ HRC. The error shall be determined by the certified mean hardness number of the standardized test block minus the mean hardness number determined during the periodic check.

The testing machine shall be checked at the beginning and end of a continuous run of testing and at such times as are required to assure the operator of the equipment and the purchaser (or his representative) that the machine is satisfactory. In any event, checks should be made at least every 8 h of a continuous run of testing. The standardized test blocks chosen shall have a certified mean hardness number within 5 HRC of the maximum mean hardness number specified for the product being tested.

If the checks indicate that the testing machine results are unsatisfactory, the machine shall be verified by indirect verification using standardized test blocks according to the procedures in ISO 6508-2 or ASTM E18 for Rockwell hardness test machines.

The results obtained from the periodic checks shall be recorded and should be analysed using accepted statistical process control techniques, such as, but not limited to, X-bar (measurement averages) and R-charts (measurement ranges) and histograms.

9.6.5 Verification of hardness-testing machines and indenters

Indirect verification of hardness testing machines shall be performed at least once every 13 months and after a direct verification has been performed, in accordance with the procedures in ISO 6508-2 or ASTM E18 for Rockwell hardness test machines.

The HRC standardized test blocks shall be within 20 HRC to 50 HRC to confirm accuracy and linearity using a two-block verification. The standardized test blocks used shall bracket the HRC range for acceptance testing. The standardized test blocks shall have a maximum non-uniformity of 0,4 HRC (difference between the highest and lowest indentation number stated in the standardized test block certificate). The error shall not exceed $\pm 0,5$ HRC (determined by the certified mean hardness number of the standardized test block minus the mean hardness number determined during the indirect verification).

The indenter should be directly verified at least every 2 years. HRC indenters shall be certified by the manufacturer for performance error (deviation) with respect to a more accurate indenter (e.g. reference indenter with less error) and standardized test blocks in the range being tested. HRC indenters shall have a maximum performance error of $\pm 0,4$ HRC.

The calibration laboratory that conducts verifications of hardness testing machines and HRC indenters calibration and that issues certificate (verification report) for the hardness tester should meet the requirements of ISO/IEC 17025. As a minimum, the calibration certificate shall identify:

- a) the reference standard (ISO 6508-2 and/or ASTM E18);
- b) method of verification (direct and/or indirect);
- c) means of verification (reference blocks, elastic proving devices, etc.);
- d) temperature;
- e) hardness scale(s) verified;
- f) date of the verification;
- g) standardized test blocks references (mean hardness number, scale, serial number, manufacturer and non-uniformity);
- h) results obtained;
- i) identification of the hardness test machine (manufacturer, model number and serial number);
- j) serial number of indenter;
- k) certifying agency;
- l) name of their representative performing the verification.

9.6.6 Retests

If any mean hardness number fails to conform to specified requirements but does not exceed the specified requirements by more than 2,0 HRC units, three additional indentations shall be made in the immediate area to determine a new mean hardness number.

If the new mean hardness number conforms to the requirements, the length shall be accepted.

If the new mean hardness number fails to conform to the requirements, the length shall be rejected.

If a length is rejected due to exceeding maximum mean hardness or exceeding the maximum hardness variation, the manufacturer may elect to carry out retests on three additional lengths from the same lot from the same end as the original test specimen. If all the retests conform to the requirements, the lot shall be accepted. If one or more of the retest specimens fails to conform to the specified requirements, the manufacturer may elect to test each of the remaining lengths in the lot or reject the lot.

Rejected lots may be re-heat-treated and tested as new lots, as applicable.

9.7 Impact or flattening test

9.7.1 Test pieces

- a) Impact test pieces shall be taken in accordance with ASTM E23 and [7.4](#), [7.5](#) and [7.6](#) (see [Figure B.5](#)).

For the transverse test piece, the surface of the finished machined test piece may contain the curvature of the original tubular product, provided that the requirements of [Figure B.6](#) are met.

For group 1 and solution-annealed group 2, impact test pieces shall not be machined from flattened material.

For groups 2, 3 and 4 materials that have been cold hardened, transverse test pieces may be machined from flattened material by agreement between the purchaser and the manufacturer.

- b) Flattening test specimens shall be rings or crop ends not less than 50,8 mm (2 in) long. Specimens may be deburred prior to flattening.

9.7.2 Frequency of testing

The frequency of testing is as follows.

- a) Casing and tubing, group 1: Both ends of two lengths from each heat shall be tested.
- b) Casing and tubing, groups 2, 3 and 4:
- 1) Both ends of two lengths from each ingot or continuous cast strand shall be tested, as shall the top length of each ingot or continuous cast strand and the bottom length of each ingot or continuous cast strand.
 - 2) As an alternative, at the manufacturer's option, impact or flattening tests shall be made on both ends of two lengths taken at random from each test lot, provided the manufacturer has a documented procedure for cut-back of the end of the ingot or continuous-cast strand and for demonstration of the metal cleanliness that ensures that all delivered material conforms to the requirements of [Annex E](#). Testing for material cleanliness shall be done periodically to demonstrate that the cleanliness criteria are under control. Relevant data shall be provided on request.
- c) Coupling stock and accessory material:
- 1) Both ends of each length of coupling stock or accessory material shall be tested.

- 2) As an alternative, at the manufacturer's option, impact or flattening tests shall be made on both ends of two lengths taken at random from each test lot, provided the manufacturer can:
 - i) either demonstrate by traceability that all coupling stock and accessory material in the test lot has been made from bars that are not issued from either the top or the bottom length of the ingot or continuous cast strand, or
 - ii) provide a documented procedure for the cut-back of the end of the ingot or continuous-cast strand and for demonstration of the metal cleanliness that ensures that all delivered material conforms to the requirements of [Annex E](#). Testing for material cleanliness shall be done periodically to demonstrate that the cleanliness criteria are under control. Relevant data shall be provided on request.

9.7.3 Impact test method

Impact test on V-notched test pieces shall be carried out in accordance with ASTM A370 and ASTM E23. The evaluation of the results shall be in accordance with [7.4.1](#).

9.7.4 Flattening test method

9.7.4.1 Test method

Test specimens shall be flattened between parallel plates. A load versus deflection record shall be made for each flattening test. All records shall be identified with respect to the end of the pipe tested.

Rings shall be flattened until the distance between plates is as specified in [7.7](#).

The load measurement shall be accurate to $\pm 1,0$ % of the maximum value and the deflection measurement shall be accurate to $\pm 1,0$ % of the initial ring specified diameter. The test record shall include the required load and deflection accuracy. The crosshead speed shall not exceed $1 \text{ cm} \cdot \text{min}^{-1}$ ($0.4 \text{ in} \cdot \text{min}^{-1}$) during the test.

9.7.4.2 Acceptance/rejection criteria

Product shall meet the requirements of [7.7](#).

9.7.5 Impact test retest

For group 1, if either end of a length fails to meet the specified requirements, the manufacturer may elect to test three additional specimens taken from the same end of the length. The length may be cut back prior to taking retest samples. The impact energy from each of the retest specimens shall be equal to or exceed the specified minimum absorbed energy requirement or the length shall be rejected.

If the results of the retest do not meet the specified requirements of this document, then a test shall be made on both ends of an additional three lengths of product from the same test lot. If all of the additional tests conform to the specified requirements, then the test lot shall be qualified except for the length that was originally rejected. If one or more of the additional lengths tested fails to conform to the specified requirements, the manufacturer may elect either to test individually the remaining lengths in the test lot or to reject the lot. Rejected lots may be re-heat-treated and tested as new lots.

For groups 2, 3 and 4, when testing the end of the strand or ingot, if either test representing a single length fails to meet the specified requirements, the manufacturer may elect to test three additional specimens taken from the same end of the length. The length may be cut back prior to taking retest samples. If any retest specimen fails to meet the specified requirements, the manufacturer may elect either to cut back and retest the length or to reject the length and test both ends of the remaining lengths from the ingot or continuous cast strand. For solution-annealed materials, the manufacturer may elect to re-heat-treat all lengths from the ingot or continuous-cast strand and test as a new lot.

For groups 2, 3 and 4, when the lengths tested are selected at random, if either test representing a single length fails to meet the specified requirements, the manufacturer may elect to test three additional specimens taken from the same end of the length; however, no cut-back is allowed. The impact energy from

each of the retest specimens shall be equal to or exceed the specified minimum absorbed energy requirement or the length shall be rejected. The manufacturer may elect to test both ends of the remaining lengths from the ingot or continuous-cast strand. For solution-annealed materials, the manufacturer may elect to re-heat-treat all lengths from the ingot or continuous-cast strand and test as a new lot.

9.7.6 Flattening test retest

When testing the end of the strand or ingot, if either test specimen representing a single length fails to meet the specified requirements, the manufacturer may elect to conduct two retests of specimens from the same end of the same length. The length may be cut back prior to taking retest samples. If either retest fails to meet the specified requirements, the manufacturer may elect either to cut back and retest the length or to reject the length and test both ends of the remaining lengths from the ingot or continuous-cast strand.

When the length tested is selected at random, if either test specimen representing a single length fails to meet the specified requirements, the manufacturer may elect to conduct two retests of specimens from the same end of the same length; however, no cut-back is allowed. If either retest fails to meet the requirements specified, the manufacturer may elect to reject the length that failed and to test both ends of the remaining lengths from the ingot or continuous-cast strand. For solution-annealed materials, the manufacturer may elect to re-heat-treat all lengths from the ingot or continuous-cast strand and test as a new lot.

9.7.7 Invalidation of tests

Any test specimen that shows defective preparation or material imperfections unrelated to the intent of the test, whether observed before or after testing, may be discarded and replaced by another specimen from the same length. Specimens shall not be judged defective for the sole reason that they fail to meet the required properties.

9.8 Impact test at low temperature for group 2

When required for group 2, impact test at low temperature shall be conducted on one length per lot. The test pieces shall be taken at mid-wall either

- after the final heat treatment for solution-annealed group 2 materials, or
- after the heat treatment immediately preceding final cold finishing steps for cold hardened material.

Impact test pieces shall be taken in accordance with ASTM E23 and 7.8 (see [Figure B.5](#)). For the transverse test piece, the surface of the finished machined test piece may contain the curvature of the original tubular product, provided that the requirements of [Figure B.6](#) are met. Impact test pieces shall not be machined from flattened material.

Impact test on V-notched test pieces shall be carried out in accordance with ASTM A370 and ASTM E23. The evaluation of the results shall be in accordance with [7.8.2](#).

If either test fails to meet the specified requirements, the manufacturer may elect to test three additional specimens taken from the same end of the length; however, no cut-back is allowed. The impact energy from each of the retest specimens shall be equal to or exceed the specified minimum absorbed energy requirement or the length shall be rejected. The manufacturer may elect to test both ends of the remaining lengths from the lot. The manufacturer may elect to re-heat-treat all lengths from the lot and test as a new lot.

9.9 Pitting corrosion test for group 2

When required for group 2, pitting corrosion test shall be conducted using full-thickness test pieces. For products with large sections, the corrosion test specimen shall be taken transverse to the longitudinal axis with dimensions of approximately 6 mm × 25 mm (1/4 in × 1 in) by thickness. For very large sections, the thickness dimension of the specimen can be cut so that one-half to two-thirds of the product thickness is tested.

The test frequency shall be one test per lot.

The test pieces shall be taken either

- after the final heat treatment for solution-annealed group 2 materials, or
- after the heat treatment immediately preceding final cold finishing steps for cold hardened material.

The test pieces and test method shall be in accordance with ASTM G48, Method A. The complete specimen may be ground/polished/pickled before weighing and testing in accordance with a documented procedure by agreement between the purchaser and the manufacturer.

NOTE Guidance on pickling procedure can be found in ASTM A380. An example for such a procedure is for 5 min at 60 °C (140 °F) in a solution of 20 % HNO₃ + 5 % HF (volume fraction).

The presence of pitting shall be determined using a magnification of 20×. The results shall conform to the requirement of [7.9.2](#).

Any test specimen that shows defective preparation or material imperfections unrelated to the intent of the test, whether observed before or after testing, may be discarded and replaced by another specimen from the same length. Specimens shall not be judged defective for the sole reason that they fail to meet the required properties.

Retesting is by agreement between the purchaser and the manufacturer.

9.10 Microstructural examination

9.10.1 Test pieces

Test specimens shall be full radial wall thickness by minimum length of 6 mm (0.236 in).

The test pieces shall be taken:

- after the final heat treatment for group 1 and solution annealed group 2 materials;
- after the heat treatment immediately preceding final cold finishing steps for cold hardened material.

9.10.2 Test method

9.10.2.1 Ferrite volume fraction determination — Group 1

The examination of alloy structure and the determination of ferrite volume fraction shall be carried out in the longitudinal direction, in accordance with ASTM E562 with a minimum of 30 fields measured, using a minimum magnification of 400×. ASTM E1245 can be used as an alternative provided the manufacturer has a documented validation of the method.

9.10.2.2 Ferrite volume fraction determination — Group 2

The ferrite volume fraction shall be determined by either point counting according to ASTM E562 or by image analysis according to ASTM E1245. A minimum of 30 fields shall be measured. The ferrite volume fraction measurement shall be performed on a longitudinal or transverse section at the discretion of the manufacturer and cover the full wall thickness. The relative accuracy shall be 15 % maximum.

9.10.2.3 Microstructural examination — Groups 2, 3 and 4

The microstructure shall be examined by optical microscopy on the longitudinal section over the entire metallographic specimen, starting at low magnification and followed by progressively higher magnifications up to a minimum of 500×.

The used etchant or combination of etchants shall be suitable to identify all the constituents of the microstructure including intermetallic phases, nitride and carbide precipitates. For group 2, ISO 17781:2017,

Annex B can be used as a guidance on the effect of different etching solutions. Examples of correctly etched specimens are provided in [Annex I](#).

The presence and location of intermetallic phases shall be noted and reported with one micrograph representative of the microstructure at a location with the highest concentration. If intermetallic phases are not observed, a representative micrograph at or near mid-wall thickness shall be reported.

The presence and location of nitride/carbide precipitates shall be noted and reported with one micrograph representative of the microstructure at a location with the highest concentration.

Micrographs shall be reported at the actual magnification and shall include the scale bar.

9.10.2.4 Grain size evaluation — Groups 3 and 4

The average grain size shall be determined according to ISO 643 or ASTM E112 on the longitudinal section. Grain size evaluation shall be made at least in three locations covering the full section of the specimen.

9.10.3 Retest

If a microstructure test fails to conform to the specified requirements, the manufacturer may elect to retest three additional lengths randomly selected from the lot. In the case of a continuous process, these shall represent the start, the middle and the end of the heat treat cycle.

If all the retests conform to the requirements, the lot, except the failed length, shall be accepted.

If one or more of these retests fails to conform to the requirements, the lot shall be rejected. If the manufacturer can provide, to the satisfaction of the purchaser, evidence of the cause of the failed test, the manufacturer may be allowed to retest each length and qualify the non-failing lengths.

Rejected lots may be re-heat-treated and retested as new lots, as applicable.

9.11 Dimensional testing

9.11.1 General

Each length of product shall be inspected to verify conformance to the requirements of [Clause 8](#).

9.11.2 Outside diameter

The dimension shall be checked across the diameter by means of a mechanical calliper or micrometre at 0° and at 90° on each end of the length or by a continuous laser system or equivalent device with demonstrated capability at 0° and at 90° or one direction spirally along the full length of the product.

The frequency of measurement may be reduced, provided the manufacturer applies a process control plan that has demonstrated to the satisfaction of the purchaser that the requirements of this document are met.

9.11.3 Wall thickness at end of products

Wall thickness measurements shall be made with a mechanical calliper, micrometre or with a calibrated non-destructive examination device of appropriate accuracy. When mechanical callipers or micrometres are used, the shape of the contacts or anvil in contact with the inside diameter shall be either round, point or knife edge. In case of dispute, the measurement determined by use of the mechanical calliper shall govern. The mechanical calliper shall be fitted with contact pins having circular cross-sections of 6,35 mm (0.25 in) diameter. The end of the pin contacting the inside surface of the product shall be rounded to a maximum radius of 38,10 mm (1.50 in) for products 168,28 mm (6 5/8 in) and larger, a maximum radius D/4 for products less than 168,28 mm (6 5/8 in) and a minimum radius of 3,18 mm (0.125 in). The end of the pin contacting the outside surface of the product shall be either flat or rounded to a radius of not less than 38,10 mm (1.50 in).

9.11.4 Wall thickness of product body

Continuous wall thickness measurement shall be performed according to ISO 10893-12. The coverage shall not be less than 100 % of the product-body surface. Accessory material shall have the wall thickness verified if specified in the purchase agreement.

9.12 Drift test

9.12.1 Non-upset and external upset pipe

All drift testing shall be performed with a drift mandrel containing a cylindrical portion conforming to the standard drift requirements shown in [Table A.19](#) or [Table C.19](#) or the alternative drift requirement shown in [Table A.20](#) or [Table C.20](#), as specified in the purchase agreement. The ends of the drift mandrel extending beyond the specified cylindrical portion shall be shaped to permit easy entry into the pipe. The drift mandrel shall pass freely through the pipe by use of either a manual or power-drift procedure. In case of dispute, the manual-drift procedure shall be used. A pipe shall not be rejected until it has been drift-tested with the bore free from all foreign matter and the pipe properly supported to prevent sagging.

9.12.2 Internal upset pipe

For internally upset end tubing and casing, the pipe shall be full-length drift-tested either before or after upsetting at the manufacturer's option, using the drift mandrel dimensions given in [Table A.19](#) or [Table C.19](#) for standard drift mandrels or [Table A.20](#) or [Table C.20](#) for alternative drift mandrel dimensions or a drift mandrel having dimensions agreed at the time of enquiry and order. End drifting after upsetting is not required.

9.12.3 Drift mandrel coating

The drift mandrel shall be externally coated or manufactured from suitable non-ferrous material or in the same material as the pipe in order to avoid iron contamination. The mandrel's surface shall be free from extraneous ferrous material.

9.13 Length

The length of each finished length of product shall be measured using either a manual or an automatic device.

9.14 Straightness

All pipes shall be visually examined.

The straightness of excessively bent pipes or hooked extremities shall be verified

- using a straightedge or taut string (wire) from one end of the pipe to the other end (see [Figure B.1](#)), and
- using a minimum 1,83 m (6 ft) straightedge shouldered on the pipe surface beyond the extent of the hooked extremity (see [8.3.3](#) and [Figure B.2](#)).

9.15 Mass determination

Each pipe for casing or tubing shall be weighed separately or in convenient quantities. The linear density shall be calculated to determine conformance to the requirements in [Table A.18](#) or [Table C.18](#).

9.16 Visual inspection

9.16.1 General

Each length of product shall be submitted to a visual inspection in order to ensure conformance with the requirements of [7.12](#) and [8.4](#). The visual inspection of the products shall be carried out in accordance with

a procedure written by the manufacturer. If another method is applied with demonstrated capability of detecting defects as defined in [7.12](#), physical visual inspection is not required.

All visual inspection shall be carried out by trained personnel with satisfactory visual acuity to detect surface imperfections. Documented lighting standards for visual inspection shall be established by the manufacturer. The minimum illumination level at the inspection surface shall be 500 lx (50 foot-candles).

Physical visual inspection may be replaced by a visual technique, other than those stated in [9.17.9](#) or [9.17.10](#), if the system has validated and documented capability of detecting surface defects, as defined in [7.12](#), and the manufacturer has documented capability records (per [9.17.8](#) as applicable), verification criteria and calibration procedures, including frequency.

The visual inspection shall be on the product in the final surface and mechanical processing condition, but before coating, if applicable.

9.16.2 Pipe body, coupling stock and accessory material

Each pipe, coupling stock or accessory material shall be visually inspected over the entire outside surface for the detection of imperfections.

9.16.3 Pipe ends

For non-upset products, pipe ends shall be visually inspected on the inside surface for a minimum distance of $2,5 D$ or 450 mm (18 in), whichever is the lesser.

For upset products, pipe ends shall be visually inspected on the inside surface for a minimum distance of the length of upset, including the run-out interval.

If end cropping is performed to remove defects, the end of the pipe revealed after cropping shall be subjected to a repeat internal surface inspection as previously performed.

9.16.4 Disposition

Surface imperfections disclosed by visual inspection shall be treated in accordance with [9.17.12](#) to [9.17.14](#).

9.17 Non-destructive examination

9.17.1 General

The NDE requirements and inspection levels for pipe, coupling stock and accessory material are specified in [9.17.2](#) to [9.17.14](#). A summary of the required NDE operations for pipe, coupling stock and accessory material is given in [Table A.21](#) or [Table C.21](#). All pipe, coupling stock and accessory material that require NDE (except visual inspection) shall be inspected full length (end-to-end) for defects.

The NDE standards for the inspection of pipe referenced in [9.17](#) are based on traditional, proven NDE methods and techniques practiced and adopted worldwide for the inspection of tubular products. However, other NDE methods/techniques that have demonstrated capability in detecting defects as defined in [7.12](#) may be used. Records in accordance with [9.17.8](#) shall be maintained.

At the discretion of the manufacturer, artificial reference indicators in addition to those in [Table A.23](#) or [Table C.23](#) may be oriented at an angle such that detection of defects typical of the manufacturing process is optimized. The technical justification for choice of the orientation shall be documented.

For PSL-2 products of groups 2, 3 and 4, in addition to longitudinal and transverse notches, internal and external oblique notch shall be utilized in accordance with [9.17.10](#). The angle of the notch shall be validated and documented by manufacturer according to the defect of their typical manufacturing process.

If the provisions for purchaser inspection of pipe and/or witnessing of NDE operations are stated on the purchase agreement, they shall be in accordance with [Annex D](#).

The inspections performed in accordance with [9.17](#), with the equipment calibrated to the artificial reference indicators in [Table A.23](#) or [Table C.23](#), should not be construed as assuring that the material requirements in [7.12](#) have been met.

For full-body, full-length NDE, the inspection equipment shall provide 100 % coverage for imperfections other than wall thickness (see [9.11.4](#)). For untested pipe ends, see [9.17.5](#).

9.17.2 NDE personnel

9.17.2.1 ISO 9712, ISO 11484, ASNT-SNT-TC-1A or equivalent recognized industry standard shall be the basis for the qualification of non-destructive inspection personnel (excluding visual inspection). Such personnel shall be requalified for any method previously qualified, if they have not performed non-destructive inspection in that method for a period exceeding 12 months. The manufacturer or inspection company shall have a training program to qualify or certify, or both, the NDE personnel for the method, technique, and equipment that are used for the inspection(s) specified in this document.

9.17.2.2 Non-destructive inspection shall be conducted by level 1, 2 or 3 personnel, using procedures approved by level 3 personnel.

9.17.2.3 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.

9.17.3 Products

Unless otherwise agreed, all required NDE operations shall be carried out after final heat treatment or, for CH products, after final cold hardening, and straightening operations, with the following exceptions:

- a) as described in [9.17.4](#) for pup joints;
- b) for group 1, when more than one NDE method is applied, one of these (other than ultrasonic inspection) may take place prior to heat treatment/rotary straightening.

9.17.4 Pup joints

For pup joints made from full-length casing and tubing, the required inspection for inside and outside defects shall take place either before or after cutting into final length, provided there is no subsequent upsetting or heat treatment.

9.17.5 Untested ends

In many of the automatic NDE operations specified in this document, there can be a short length at both ends which cannot be tested. In such cases, the untested ends shall be:

- a) cropped off;
- b) subjected to a manual/semi-automatic test achieving, as a minimum, the same degree of inspection as the automatic NDE;
- c) for group 1, subjected to magnetic particle inspection of the outside and inside surfaces around the full periphery and over the length of the untested ends; or
- d) for groups 2, 3 and 4, subjected to liquid-penetrant inspection of the outside and inside surfaces around the full periphery and over the length of the untested ends.

9.17.6 Upset ends

Forged upsets (including the upset run-out length) on all grades shall be subjected, after all heat-treatment operations, to NDE as outlined below for the detection of transverse and longitudinal imperfections on the outside and inside surfaces of the upset, using the acceptance criteria given in [7.12](#):

- a) subjected to a manual/semi-automatic test achieving, as a minimum, the same degree of inspection as the automatic NDE;
- b) for group 1, subjected to magnetic particle inspection of the outside and inside surfaces around the full periphery; or
- c) for groups 2, 3 and 4, subjected to liquid-penetrant inspection of the outside and inside surfaces around the full periphery.

9.17.7 Reference standards

Ultrasonic and electromagnetic inspection systems for other than laminar imperfection and wall-thickness verification shall use reference standards containing notches or holes as shown in [Figure B.8](#) and [Table A.23](#) or [Table C.23](#) to verify equipment response from artificial reference indicators.

The reference standard for laminar imperfections shall contain a flat-bottom recess machined into the inner surface with an area not greater than 260 mm² (0.4 in²). The shape of the artificial reference indicator shall be determined at the discretion of the manufacturer as that which provides detection of defects typical to the manufacturer's process.

The manufacturer may use any documented procedures to establish the reject threshold for ultrasonic or electromagnetic inspection, provided that the artificial reference indicators described in [Table A.23](#) or [Table C.23](#) can be detected dynamically under normal operating conditions. Such detection capability shall be demonstrated dynamically. At the option of the manufacturer, this may be performed either on-line or off-line.

[Table A.24](#) or [Table C.24](#) and [Table A.23](#) or [Table C.23](#) list the acceptance (inspection) levels and associated artificial reference indicators that manufacturers shall use in establishing reject thresholds for inspecting pipe that can contain the defects, except laminar imperfections, as defined in [7.12](#). The reference indicators used during automated ultrasonic or electromagnetic inspection shall not be construed as being the defect sizes defined in [7.12](#), or be used by those other than the manufacturer as the only basis for pipe rejection.

When calibrating eddy-current or flux-leakage testing equipment using drilled holes, the inspection system shall be capable of producing signals from both OD and ID notches that are equal to or greater than the reject threshold established using the drilled hole. Records in accordance with [9.17.8](#) shall be maintained.

9.17.8 NDE system capability records

The manufacturer shall maintain NDE 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), including wall thickness verification;
- b) capability for the intended wall thickness;
- c) repeatability;
- d) transducer orientation that provides detection of defects typical of the manufacturing process (see [9.17.1](#));
- e) documentation demonstrating that defects typical of the manufacturing process are detected using the NDE methods in [Table A.24](#) or [Table C.24](#);
- f) threshold-setting parameters.