Corrosion-resistant Alloy Seamless Products for Use as Casing, Tubing, Coupling Stock, and Accessory Material

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API Foreword

This American National Standard is under the jurisdiction of the API Subcommittee on Tubular Goods (SC 5). This standard is modified from the English version of ISO 13680:2020. ISO 13680:2020 was prepared by Technical Committee ISO/TC 67 (Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries), SC 5 (Casing, tubing and drill pipe).

In this American National Standard, certain technical modifications have been made. These technical modifications from the ISO Standard have been incorporated directly into this API (US) national adoption. The modifications are detailed in Annex J (Identification/explanation of modifications).

In this American National Standard, the following editorial deviations have been made throughout the document:

— Omitting “tubular” in the API title as compared to the ISO title

— Change spelling of words common to the US (e.g. color, not colour)

— Addition of a “—” into empty table cells.

— Addition of a period at the end of abbreviation for inch (e.g. in., not in)

— Substitution of a decimal point for a decimal comma (e.g. 4.5, not 4,5)

— Substitution of a comma for a space in numbers ≥ 10,000 (e.g. 12,547, not 12 547)

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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 documents 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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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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, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 5, *Casing, tubing and drill pipe*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 12, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This fourth edition cancels and replaces the third edition (ISO 13680:2010), which has been technically revised. The main changes compared to the previous edition are as follows:

— change of title and scope so that it includes accessory material and group 5;

— deletion of Annex F;

— addition of new Annex F, Annex H and Annex I;

— update of warning statement;

— complete revision of the technical content.

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.

Information marked as “NOTE” is for guidance in understanding or clarifying the associated requirement. “Notes to entry” used in Clause 3 provide additional information that supplements the terminological data and can contain provisions relating to the use of a term.

Contents

Corrosion-resistant Alloy Seamless Products for Use as Casing, Tubing, Coupling Stock, and Accessory Material

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 15156:2020 series should be considered when making specific requirements for H_2S-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 H_2S-containing environments, which are not addressed by the ISO 15156:2020 series.

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 15156:2020 series.

At the option of the manufacturer, PSL-2 products can be provided in lieu of PSL-1.

NOTE 1 The corrosion-resistant alloys included in this document are special alloys in accordance with ISO 4948-1 and ISO 4948-2.

NOTE 2 For the purpose of this document, NACE MR0175 is equivalent to the ISO 15156:2020 series.

NOTE 3 Accessory products can be manufactured from coupling stock and tubular material, or from solid bar stock or from bored and heat heat-treated bar stock as covered in Annex F.

This document contains no provisions relating to the connection of individual lengths of pipe.

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.

NOTE 4 Not all PSL-1 categories and grades can be made cracking resistant in accordance with the ISO 15156:2020 series and are, therefore, not included in PSL-2.

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 4287, *Geometrical Product Specifications (GPS)—Surface texture: Profile method—Terms, definitions and surface texture parameters*

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 Christmas 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 15156:2020 (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 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 E10, *Standard Test Method for Brinell Hardness of Metallic Materials*

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*

3 Terms and 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 terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://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

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) based on criteria defined in this standard

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 millimeters (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 millimeters (inches)
d	inside diameter of the product, expressed in millimeters (inches)

e minimum elongation in 50 mm (2.0 in.) gauge length for strip specimens or in 4*D* or 5*D* for round bar specimens, expressed in percent

m mass

Ra average surface roughness as defined in ISO 4287

R_m tensile strength, expressed in megapascals (thousand pounds per square inch)

$R_{p0.2}$ yield strength (0.2 % non-proportional elongation), expressed in megapascals (thousand pounds per square inch)

t wall thickness of the product, expressed in millimeters (inches)

w_x percent mass fraction of element *x*

$Y_{S,min}$ 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) or other system of units. 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 or other units 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.

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 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 millimeters (inches)	As specified in purchase agreement
g)	Length requirements	8.2; Table A.17 or Table C.17 or as specified in purchase agreement
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

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 84 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
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 color for marking the area of defect	9.17.14 b)

Requirement		Reference
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 color code identification	11.2
hh)	Color 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 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 purchaser and manufacturer. Maximum deformation, validation method and acceptance criteria for cold end sizing shall be by agreement between purchaser and 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 fiber 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 fiber 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 fiber 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, 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 the entry of new alloys and/or grades shall be made to ISO/TC 67/SC 5. Applications for new entries or alteration to existing entries shall be accompanied by supporting evidence as per Annex H.

For PSL-2, process of update of alloys and/or grades shall be as per 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 purchaser and 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 purchaser and 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 °C (14 °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 ±1 °C (±2 °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 millimeters (inches).

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 millimeters (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	$Y_{S,max} \times (0.00118t + 0.01259)$ or 40 J, whichever is greater; see Table A.9	$Y_{S,max} \times (0.00118t + 0.01259)$ or 40 J, whichever is greater; see Table A.10
	Groups 2, 3 and 4	$Y_{S,max} \times (0.00118t + 0.01259)$ or 27 J, whichever is greater; see Table A.11	NA [a]
USC units of foot-pounds	Group 1	$Y_{S,max} \times (0.152t + 0.064)$ or 29 ft-lb, whichever is greater; see Table C.9	$Y_{S,max} \times (0.152t + 0.064)$ or 29 ft-lb, whichever is greater; see Table C.10
	Groups 2, 3 and 4	$Y_{S,max} \times (0.152t + 0.064)$ 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.

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	$Y_{S,min} \times (0.00118t + 0.01259)$ or 40 J, whichever is greater; see Table A.12	$Y_{S,min} \times (0.00118t + 0.01259)$ or 40 J, whichever is greater; see Table A.13
	Groups 2, 3 and 4	$Y_{S,min} \times (0.00118t + 0.01259)$ or 27 J, whichever is greater; see Table A.14	NA [a]
USC units of foot-pounds	Group 1	$Y_{S,min} \times (0.152t + 0.064)$ or 29 ft-lb, whichever is greater; see Table C.12	$Y_{S,min} \times (0.152t + 0.064)$ or 29 ft-lb, whichever is greater; see Table C.13
	Groups 2, 3 and 4	$Y_{S,min} \times (0.152t + 0.064)$ 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 ½ size or larger.

By agreement between the purchaser and manufacturer for groups 3 and 4, flattening tests may be performed in addition to the impact tests that are required when ½ 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 percent, of the specified outside diameter, D, as calculated by Formula (1) for SI units and by Formula (2) for USC units:

$$S = 100 - \left\{\left[3.8458 \ln\left(Y_{S,max}\right) - 24.344\right] \times D/t\right\} \quad (1)$$

$$S = 100 - \left\{\left[3.8458 \ln\left(Y_{S,max}\right) - 16.919\right] \times D/t\right\} \quad (2)$$

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 millimeters (inches);

t is the specified wall thickness of the product, expressed in millimeters (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 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 ±1 °C (±2 °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 mandatory and is not normally 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 ±1 °C (±2 °F). Higher test temperatures are acceptable. The test exposure time shall be at least 24 hours.

No pitting shall be detected and weight loss shall be less than 1.0 g/m^2 (0.2 lb/1000 ft^2).

7.10 Microstructure properties

7.10.1 Group 1

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

For category 13-1-0, the ferrite content may exceed 2 % by agreement between purchaser and 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 mm^2 (0.40 $in.^2$);

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 ⅝. An accuracy of one decimal place shall be used for sizes larger than label 1:6 ⅝. 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 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 purchaser and 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 purchaser and 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 (½ in.) long.

The surfaces of the test piece that contact the anvil and the indenter shall be machined parallel within 0.5° and smooth with an average surface roughness of 0.6 µm (25 µin.) or finer, as defined by *Ra* value in ISO 4287. 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 center to the edge of the specimen or three diameters from another indentation measured center to center.

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 center 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, etc.) 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 ±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 ±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 ±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 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 ±1.0 % of the maximum value and the deflection measurement shall be accurate to ±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 $cm \cdot min^{-1}$ (0.4 $in. \cdot min^{-1}$) 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 (¼ 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 purchaser and 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 % HNO_3 + 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 purchaser and 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 content 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 content determination—Group 2

The ferrite content 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 content 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 micrometer 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, micrometer or with a calibrated non-destructive examination device of appropriate accuracy. When mechanical callipers or micrometers 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 ⅝ in.) and larger, a maximum radius D/4 for products less than 168.28 mm (6 ⅝ 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 an established written procedure. 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 (according to 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, or

b) subjected to a manual/semi-automatic test achieving, as a minimum, the same degree of inspection as the automatic NDE, or

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, or

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 mm^2 (0.4 $in.^2$). 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.

In addition, the manufacturer shall maintain documentation relating to

— NDE system operating procedures,

— NDE equipment description,

— NDE personnel qualification information, and

— dynamic test data demonstrating the NDE system/operation capabilities under production test conditions.

9.17.9 All product group 1

All lengths shall be inspected for the detection of

— longitudinal and transverse imperfections on the outside and inside surfaces to acceptance level U2 by ultrasonic testing in accordance with ISO 10893-10 or ASTM E213, and

— laminar imperfections with an area not greater than 260 mm^2 (0.4 $in.^2$) when outlined on the outside surface by ultrasonic testing in accordance with ISO 10893-8.

The signal-to-noise ratio shall not be less than 3 to 1, unless agreed in advance between the purchaser and the manufacturer.

In addition, when specified in the purchaser agreement, all lengths shall be inspected for the detection of longitudinal and transverse imperfections on the outside surface by one of the following methods:

a) flux leakage testing to acceptance level F2 in accordance with ISO 10893-3 or ASTM E570; or

b) eddy-current testing to acceptance level E2 in accordance with ISO 10893-2 or ASTM E309; or

c) magnetic-particle inspection in accordance with ISO 10893-5 or ASTM E3024.

9.17.10 Full-body NDE of product—Groups 2, 3 and 4

All lengths shall be inspected for the detection of

a) longitudinal and transverse imperfections on the outside and inside surfaces to acceptance level U2 by ultrasonic testing in accordance with ISO 10893-10 or ASTM E213;

b) laminar imperfections with an area not greater than 260 mm^2 (0.4 $in.^2$) when outlined on the outside surface by ultrasonic testing in accordance with ISO 10893-8.

All PSL-2 product lengths shall be inspected for the detection of internal and external oblique notches to acceptance level U2 by ultrasonic testing, in addition to longitudinal and transverse imperfections. The angle of the notches shall be validated and documented by manufacturer according to the imperfection orientation of their typical manufacturing process.

The signal-to-noise ratio shall not be less than 3 to 1, unless agreed in advance between the purchaser and the manufacturer.

NOTE For alloys, such as UNS N10276, a lower signal-to-noise ratio can be necessary.

9.17.11 Pipe, coupling stock and accessory material requiring further evaluation

In all cases, indications producing a threshold alarm condition as a result of the specified NDE operation(s) shall have the indications evaluated in accordance with 9.17.12, unless it can be demonstrated that the imperfection causing the indication is not a defect as described in 7.12.

9.17.12 Evaluation of indications (prove-up)

For an indication that is greater than or equal to the reject threshold, the manufacturer shall either evaluate it in accordance with this subclause or dispose of the indication as a defect in accordance with 9.17.13 or 9.17.14, as applicable. Evaluation of indications shall be performed by NDE level 1 qualified inspectors under the supervision of NDE level 2 qualified or level 3 certified inspectors, or by NDE level 2 qualified or level 3 certified inspectors. Evaluation of indications shall be performed in accordance with documented procedures.

When no imperfection is found in the area of the original indication and there is no explanation for the indication, then the length shall be rejected or, at the manufacturer's option, reinspected full-length either using the same inspection method or using ultrasonic inspection methods. At the manufacturer's option, the inspection equipment shall be adjusted either to the same sensitivity level as that used to perform the original inspection or to a reduced sensitivity that meets the specified requirements.

For the evaluation of an indicated imperfection, the depth shall be measured by one of the following methods:

a) Using a mechanical measuring device (e.g. pit gauge, callipers). Removal of material by grinding or other means to facilitate measurement shall not, for pipe, reduce the remaining wall thickness below the requirement specified in 7.12.1 b) or, for coupling stock and accessory material, reduce the remaining outside diameter or wall thickness below the minimum specified on the purchase agreement. Abrupt changes in wall thickness caused by material removal during prove-up shall be smoothed.

b) Using (an) ultrasonic technique(s) (time- and/or amplitude-based), or other comparable techniques. Verification of the ultrasonic technique(s) shall be documented, and shall show capability to differentiate imperfection sizes larger and smaller than the appropriate defect size stated in 7.12.

If the purchaser and manufacturer do not agree on the evaluation test results, either party may require destructive evaluation of the material, after which, disposition shall be as described in Annex D.

Imperfections that have been evaluated and found to be defects shall be given a disposition in accordance with 9.17.13 and 9.17.14, as applicable.

9.17.13 Disposition of pipe containing defects

Imperfections that satisfy the material requirements and are less than the defect size stated in 7.12 are allowed to remain in the pipe.

Repair by welding is not permitted.

Pipe containing defects shall be treated in one of the following ways:

a) grinding or machining: Grinding or machining of quench cracks or arc burns is not permitted.

   Other defects shall be completely removed by grinding or machining, provided the remaining wall thickness is within the limits specified in Table A.18 or Table C.18. Generous radii shall be made to prevent abrupt changes in wall thickness. The surface roughness after all local grinding or machining shall be equal or smoother than that obtainable with a number 36 abrasive disk according to ISO 525. The remaining wall thickness shall be verified in accordance with 9.11.3 and shall be within the specified limits. The manufacturer's documented prove-up procedures shall address the possibility that there can be coincident defects in the affected area. After removal of the defect, the affected area shall be reinspected by

   1) the same inspection unit at the same sensitivity that performed the initial inspection, or

   2) liquid-penetrant inspection according to ISO 10893-4 or ASTM E165 or for group 1, magnetic-particle inspection according to ISO 10893-5 or ASTM E3024, or

   3) another NDE method, or combination of methods, that demonstrates equal or greater sensitivity than the original NDE.

When method 3) is used, the NDE method (or combination of methods) shall be documented and shall demonstrate equal or greater sensitivity than the original NDE. In addition, method 3) shall address the possibility that there can be other coincident defects in the affected area.

b) cut off: The part of pipe containing the defect shall be cut off within the limits of requirements on length of the product.

c) rejection: The pipe shall be rejected. All pipes containing quench cracks shall be rejected.

9.17.14 Disposition of coupling stock and accessory material containing defects

Imperfections that satisfy the material requirements and are less than the defect size stated in 7.12 are allowed to remain in the coupling stock or accessory material. Repair welding is not permitted. Coupling stock and accessory material containing defects shall be given one of the following dispositions:

a) grinding or machining: Grinding or machining of quench cracks or arc burns is not permitted.

Other defects shall be completely removed by grinding or machining, provided the remaining outside diameter and wall thickness are within specified limits at the time of enquiry and agreed on the purchaser agreement. Grinding or machining shall be carried out in such a way that the dressed area blends smoothly into the contour of the coupling stock or accessory material. After removal of the defect, the outside diameter and wall thickness shall be measured in the dressed area for conformance to specified limits. The affected area shall also be reinspected by

1) the same inspection unit at the same sensitivity that performed the initial inspection, or

2) liquid-penetrant inspection according to ISO 10893-4 or ASTM E165 or for group 1, magnetic particle inspection according to ISO 10893-5 or ASTM E3024, or

3) another NDE method, or combination of methods, that demonstrates sensitivity equal to or greater than the original NDE.

When method 3) is used, the NDE method (or combination of methods) shall be documented and shall demonstrate sensitivity equal to or greater than the original NDE. In addition, method 3) shall address the possibility that there can be other coincident defects in the affected area.

b) marking the area of defect: If a defect is not removed from coupling stock or accessory material within acceptable limits, then the area shall be marked to indicate the presence of a defect.

The marking shall consist of a paint band encircling the coupling stock or accessory material that covers the entire defect area if this area is equal to or less than 50 mm (2 in.) in axial length, or bands in a cross-hatched pattern if this area is greater than 50 mm (2 in.) in length. The band color shall be as agreed between the purchaser and manufacturer.

c) cut off: The section of coupling stock and accessory material containing the defect shall be cut off within the limits of requirements on length of the product.

d) rejection: The coupling stock and accessory material shall be rejected. All coupling stock and accessory material containing quench cracks shall be rejected.

9.18 Positive material identification

All lengths of groups 2, 3 and 4 shall be inspected by PMI. For group 1, PMI can be performed by agreement between purchaser and manufacturer. PMI shall be performed using a method in accordance with ASTM E1476 or API RP 578 to validate that the inspected lengths correspond to the specified material category. PMI shall be based as a minimum on the detection of Cr, Ni and Mo.

PMI testing shall be performed after final marking. Alternatively, PMI testing may be performed prior to final marking provided a validated and documented procedure that demonstrates traceability shall be maintained between PMI testing through final marking.

In case of dispute, a new product chemical analysis in accordance with 9.3 shall govern.

The manufacturer shall establish and follow a documented procedure for the PMI test. This procedure shall describe, as a minimum:

a) production step in which PMI testing is performed and how traceability is maintained between PMI testing and final marking;

b) method used for PMI testing and identification of the instrument used;

c) capability analysis of the method and instrument to differentiate different material categories manufactured to this document and produced within the same mill, based as a minimum on the detection of Cr, Ni and Mo, individually or collectively;

d) surface preparation if any; in case the PMI test generates arc burn or other types of mark, these shall be considered as defects and managed in accordance with 7.12;

e) instrument verification method and frequency: the PMI equipment verification shall be performed on reference standard(s) with at least two readings once every shift;

f) methodology used for the verification of the composition of the reference standard, in which identification and recording of the serial number of each reference standard is required for each verification. Reference standards traceability to international, national or manufacturer-developed reference standards used for calibration or verification shall be documented;

g) records of training and qualification of personnel per test method and material category. A record of training shall be made available to the purchaser upon request.

10 Surface treatment

10.1 Group 1

All pipes shall be delivered with their internal surface pickled or grit blasted. Grit blasting shall be carried out using stainless steel or aluminum oxide grit.

The grit blasting level shall be in accordance with ISO 8501-1, Sa 2 ½.

10.2 Groups 2, 3 and 4

All pipes shall be delivered with clean external and internal surfaces.

Cleaning should include, but should not be restricted to, the following sequence:

— degreasing (for cold-hardened product);

— washing in water;

— pickling;

— final washing in clean water with chloride ion concentration of less than 200 mg/l.

NOTE At low concentrations, “mg/l” is approximately equivalent to the deprecated term “ppm”.

At the end of the cycle, the pipe shall be completely dry.

11 Marking

11.1 General

Marking shall consist of color coding and paint or ink stencilling. Die stamping shall be applied only if specified on the purchase agreement. Additional marking is permitted if agreed between purchaser and manufacturer. Markings shall not overlap and shall be applied in such a manner as not to damage the product surface. The detectable composition of the paint or ink shall not be detrimental to the product.

11.2 Color-code identification

Each length shall be color-coded as specified below:

— two bands for the identification of the material category, as given in Table A.26 or Table C.26;

— one band for the identification of the grade of the material, as given in Table A.27 or Table C.27.

Bands location, sequence and size are indicated in Figure B.7.

Color code identification may be modified or eliminated if so specified on the purchase order.

11.3 Marking content and sequence

The paint or ink stencilling and/or die stamping (see 11.1 for die stamping only applying when specified on the purchase agreement) shall be placed on the surface of each length starting after the color coding. Repeated marking along the product length is acceptable. The height of marking shall be as given in Table A.25 or Table C.25.

Each length shall be marked in the following sequence:

a) manufacturer's name or trademark;

b) reference to this document;

c) date of manufacture;

d) material category and grade;

e) if agreed (see 7.2), the letters “TY” followed by the value agreed to replace 34 MPa (5 ksi);

f) for PSL-2 product, mark L2 and the UNS number; for product as specified in G.2, mark L2A as specified in G.3 and G.4;

g) heat number;

h) outside diameter and wall thickness or labels 1 and 2 of Table A.16 or Table C.16;

i) unique length identification;

j) length, expressed in millimeters to the nearest millimeter, or meters, to two decimal places (expressed in feet, to one decimal place);

k) test lot number for mechanical and other tests;

l) additional marking, as agreed between the purchaser and the manufacturer.

Low-stress die-stamping or vibro-etching or equivalent are acceptable. When die stamping is specified in the purchase agreement (see 11.1), die stamping shall contain as a minimum the unique length identification.

The date of manufacture is defined for marking purposes as the first two digits representing the month and the last two digits representing the year with a hyphen (dash) or slash in between (e.g., 04-21 or 04/21 for April 2021).

Products manufactured in accordance with this edition of the specification during the period of overlap of application with the previous edition shall be identified by including the edition number after the manufacture date separated by a hyphen (dash) or slash (e.g., 2nd Edition during 1st Edition applicability,

04-21-2ED or 04/21/2ED for 2nd Edition). Once the new edition is effective, marking of the edition is at the manufacturer's discretion.

11.4 Marking informative for couplings, pup joints and accessories after threading

In order to keep marking consistency with this document, the following recommendations should be considered for marking couplings, pup joints and accessories.

Copper plating on the outer surface may reduce the paint adherence creating peeling problems. Couplings and accessories should not be painted with color bands unless specified in the purchase order. In case that color banding in couplings or accessories is specified, color bands width should be reduced to a maximum of 12.7 mm (0.5 in.). Pup joints should not be painted on the entire surface, and color banding should be consistent with plain end color banding, but with color bands reduced to a maximum width of 12.7 mm (0.5 in.).

Paint or ink stencilling and/or die stamping (see 11.1 for die stamping only applying when specified on the purchase agreement) should be consistent with the marking on plain end pipe, coupling stock or accessory material and should include the following information:

a) manufacturer's name or trademark;

b) reference to this document;

c) date of manufacture;

d) material category and grade;

e) if agreed (see 7.2), the letters "TY" followed by the value agreed to replace 34 MPa (5 ksi);

f) for PSL-2 product, mark L2 and the UNS number; for product as specified in G.2, mark L2A as specified in G.3 and G.4;

g) heat number;

h) finished nominal size and weight (Label 1 and 2 of Table A.16 or Table C.16);

i) connection identification, if applicable;

j) length number (consistent with plain end, coupling stock or accessory material unique length number);

k) test lot number for mechanical and other tests;

l) additional marking, as agreed between the purchaser and the manufacturer.

12 Surface protection—Group 1

12.1 Mill varnish shall be applied on the outside surface of the product to provide protection during transportation.

The following points should be noted:

a) There should be no need for removal of the protective coating before installing the pipe in the well.

b) Correct application of the coating is essential; the following parameters should be assessed:

   1) cleanliness of the pipe,

   2) temperature at application,

   3) thickness of the coating.

After drying the pipe, the ends shall be capped or the internal surface otherwise protected; however, the caps shall include a vent hole to avoid condensation inside the product.

12.2 Internal and external protective coatings and end caps for long-term storage shall be by agreement between the purchaser and the manufacturer.

13 Documents

13.1 Electronic media

A material test report, certificate of conformance or similar document printed from or used in electronic form from an electronic data interchange transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI-transmitted document shall be agreed between purchaser and manufacturer and shall meet the requirements of this document.

13.2 Retention of records

Tests and inspections requiring retention of records are given in Table A.21 or Table C.21. Test certificates record retention is required (see 13.3). Calibration record retention is required. Such records shall be retained by the manufacturer and shall be available to the purchaser on request for a period of five years after the date of purchase from the manufacturer.

13.3 Test certificates

The manufacturer's certificate shall cite this document, the revision date thereof, and the PSL to which the product was manufactured. The manufacturer shall provide the following data, as applicable, for each item that is specified on the purchase agreement:

a) specified label 1 and label 2 or specified outside diameter and specified wall thickness, group, category, grade, UNS number (as applicable), melting practice and type of heat-treatment or cold-hardened condition and the number of lengths per heat and per test lot;

b) minimum tempering temperature allowed by the documented heat-treatment procedure for each lot of quenched and tempered product;

c) heat number and test lot number;

d) chemical analyses (heat and product analysis) showing the mass fraction, expressed as a percent, of all elements whose limits or reporting requirements are set in this document;

e) test data for all tensile tests required by this document, including yield strength, tensile strength and elongation, together with the orientation of specimens.

   The report shall show the nominal width of the test specimen when strip specimens are used, the diameter and gauge length when round-bar specimens are used, or it shall state when full-section specimens are used.

f) impact test results (including the sampling frequency, the test criteria, the size, location and orientation of the test specimen, the nominal test temperature, the absorbed energy measured for each test specimen and the average absorbed energy for each set of tests), where such testing is required by this document;

g) hardness test results (including Rockwell hardness numbers and mean hardness numbers, criteria and specimen location);

h) flattening test results;

i) statement of conformance of microstructure, delta ferrite content, ferrite volume fraction, grain size, representative photo micrographs, as applicable. For Group 2, report carbide or nitride precipitates when observed;

j) pitting corrosion test results, where such testing is required by this document;

k) statement of conformance to visual inspection;

l) non-destructive examination results, the method of inspection employed (ultrasonic, electromagnetic, or magnetic particle) and the type (orientation, oblique angle(s) if applicable and internal or external) and size of the artificial reference indicators used;

m) statement of conformance to each of the dimensional requirements, which includes diameter, wall thickness, drift, length, straightness, mass and product ends (plain end out-of-squareness);

n) statement of conformance to PMI testing, the method used and the applicable internal procedure (as applicable);

o) results of any testing or inspection required at the purchaser's option;

p) statement of conformance with the metallurgical and manufacturing requirements of the ISO 15156:2020 series for PSL-2.

NOTE For the purpose of this provision NACE MR0175 is equivalent to the ISO 15156:2020 series.

14 Handling, packaging and storage

14.1 General

Handling, packaging and storage shall be suitable for the grade and consistent with the transportation and storage requirements, and shall be specified in the purchase agreement.

14.2 Handling

The handling system shall be designed to avoid any type of damage to the pipes during transit. The use of hooks or similar lifting equipment in the ends of pipes, and for materials in groups 2 to 4, contact with ferrous metallic materials, shall be prohibited.

14.3 Packaging

14.3.1 General

Products shall be packaged in suitable boxes or, by agreement, using another suitable transportation system. Contact between products should be avoided by the use of plastic or other separators, while contact between products and wood should be avoided by the use of plastic film not less than 0.2 mm (0.008 in.) thick. Precautions shall be taken in order to avoid the trapping of humidity under the plastic film.

Material used for packaging shall not cause iron contamination to the product.

14.3.2 Identification

Packaging shall include the following minimum identification data:

a) manufacturer's name or mark;

b) type of product and reference to this document;

c) material category and grade;

d) PSL indication;

e) dimensions;

f) number of lengths;

g) gross mass;

h) purchase agreement number;

i) purchaser's name and address.

14.4 Storage

Products awaiting final delivery or machining should be stored in a covered and dry place, away from pollution sources such as metallic powder, sea spray and standing water.

Products shall be free of corrosion and corrosion products when delivered to the purchaser.

Boxes or other transportation systems shall be placed at least 100 mm (4 in.) above the ground. Care shall be taken during handling in order to avoid damage to packages and protection.

NOTE Group 1 materials are particularly prone to corrosion damage during storage and additional precautions can be necessary, such as avoiding water-absorbent materials (e.g. wood) in contact with the products.

Annex A
(normative)

Tables in SI units

NOTE The numbers in italics in the table headers indicate column numbers.

Table A.1—Products manufacturing process, starting material, products forming and heat-treatment conditions

Starting material	Products forming conditions	Heat-treatment or cold-hardened conditions	Symbol
1	*2*	*3*	*4*
Ingot/billet or rolled/forged bar	Hot finished — Hot-rolled/forged or — Hot-extruded	Quenched and tempered	QT
		Solution-annealed	SA
Ingot/billet or rolled/forged/machined bar	Cold-hardened [a] — Cold drawing or — Cold pilgering	Cold-hardened	CH
		Solution-annealed	SA
Hot finished hollow	Cold-hardened [a] — Cold drawing or — Cold pilgering	Cold-hardened	CH
		Solution-annealed	SA

[a] For cold-hardened products, the minimum total hot work reduction ratio shall be 3:1. Total hot work reduction ratio is defined as the product of the individual reduction ratios achieved at each step in the hot work operation from ingot or bloom cross-section to final hot work cross-section.

Table A.2—Nominal analysis of corrosion-resistant alloy and material categories

Material			Nominal analysis % mass fraction					Grade						PREN [b] min number
Group	Structure	Category [a]	C	Cr	Ni	Mo	N	65	80	95	110	125	140	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
1	Martensitic	13-5-2	0.02	13	5	2	—	N	Y	Y	Y	N	N	NA
	Martensitic/ ferritic	13-1-0	0.03	13	0.5	—	0.01	N	Y	Y	Y	N	N	NA
2	Duplex austenitic/ ferritic	22-5-3	0.02	22	5	3	0.18	Y	N	N	Y	Y	Y	35
		25-7-3	0.02	25	7	3	0.18	Y	N [c]	N	Y	Y	Y	37.5
	Super-duplex austenitic/ ferritic	25-7-4	0.02	25	7	3.8	0.27	N	Y	N [d]	Y	Y	Y	40
		26-6-3	0.04	25.5	4.75	2.5	1.17	N	Y	Y	Y	Y	Y	40
3	Austenitic Fe base	27-31-4	0.02	27	31	3.5	—	N	N	N	Y	Y	Y	NA
		25-32-3	0.02	25	32	3	—	N	N	N	Y	Y	Y	NA
		22-35-4	0.03	22	35.5	4.5	—	N	N	N	Y	Y	N	NA
4	Austenitic Ni base	21-42-3	0.02	21	42	3	—	N	N	N	Y	Y	N	NA
		22-50-7	0.02	22	50	7	—	N	N	N	Y	Y	Y	NA
		25-50-6	0.03	25	50	6	—	N	N	N	Y	Y	Y	NA
		20-54-9	0.01	20	54	9	Fe = 17	N	N	N	Y	Y	Y	NA
		22-52-11	0.02	21.5	52	11	—	N	N	N	Y	Y	N	NA
		15-60-16	0.01	15	60	16	W = 4	N	N	N	Y	Y	Y	NA

[a] Designation of categories:
- — 1st digit: nominal chromium content;
- — 2nd digit: nominal nickel content;
- — 3rd digit: nominal molybdenum content.

[b] PREN = % Cr + 3.3 (% Mo + 0.5 % W) + 16 % N
- — Group 2 may contain tungsten.

[c] A 75 grade is available.

[d] A 90 grade is available.

Y: generally available

N: generally not available

NA: not applicable

Table A.3—Mechanical properties at room temperature

Material			Delivery condition	Yield strength [a] $R_{p0.2}$ MPa		Tensile strength [a] R_m MPa	Elongation e [b] %	Mean hardness number HRC
Group	Category	Grade		min.	max.	min.	min.	max.
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
1	13-5-2	80	HF or QT	552	655	621	[c]	27
		95	HF or QT	655	758	724	[c]	28
		110	HF or QT	758	965	793	[c]	32
	13-1-0	80	HF or QT	552	655	655	[c]	23
		95	HF or QT	655	758	724	[c]	26
		110	HF or QT	758	965	827	[c]	32
2	22-5-3	65	SA	448	621	621	25	26
		110	CH	758	965	862	11	36
		125	CH	862	1034	896	10	37
		140	CH	965	1103	1000	9	38
	25-7-3	75	SA	517	689	621	25	26
		110	CH	758	965	862	11	36
		125	CH	862	1034	896	10	37
		140	CH	965	1103	1000	9	38
	25-7-4	80	SA	552	724	758	20	28
		90	SA	621	724	793	20	30
		110	CH	758	965	862	12	36
		125	CH	862	1034	896	10	37
		140	CH	965	1103	1000	9	38
	26-6-3	80	SA	552	724	758	20	28
		90	SA	621	724	793	20	30
		110	CH	758	965	862	12	36
		125	CH	862	1034	896	10	37
		140	CH	965	1103	1000	9	38
3	27-31-4	110	CH	758	965	793	11	35
		125	CH	862	1034	896	10	37
		140	CH	965	1103	1000	9	38
	25-32-3	110	CH	758	965	793	11	35
		125	CH	862	1034	896	10	37
		140	CH	965	1103	1000	9	38
	22-35-4	110	CH	758	965	793	11	35
		125	CH	862	1034	896	10	37
		140	CH	965	1103	1000	9	38

Table A.3—Mechanical properties at room temperature (continued)

Material			Delivery condition	Yield strength [a] $R_{p0.2}$ MPa		Tensile strength [a] R_m MPa	Elongation e [b] %	Mean hardness number HRC
Group	Category	Grade		min.	max.	min.	min.	max.
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
4	21-42-3	110	CH	758	965	793	11	35
		125	CH	862	1034	896	10	37
	22-50-7	110	CH	758	965	793	11	35
		125	CH	862	1034	896	10	37
		140	CH	965	1103	1000	9	38
	25-50-6	110	CH	758	965	793	11	35
		125	CH	862	1034	896	10	37
		140	CH	965	1103	1000	9	38
	20-54-9	110	CH	758	965	793	11	35
		125	CH	862	1034	896	10	37
		140	CH	965	1103	1000	9	38
	22-52-11	110	CH	758	965	793	11	35
		125	CH	862	1034	896	10	37
		140	CH	965	1103	1000	9	38
	15-60-16	110	CH	758	965	793	11	35
		125	CH	862	1034	896	10	37
		140	CH	965	1103	1000	9	38

[a] See requirement in 7.2 for relationship between tensile and yield strength.

[b] e is the minimum elongation in 50 mm gauge length for strip specimens or in 4D or 5D for round bar specimens, expressed in percent.

[c] $$e = 1944 \frac{A^{0.2}}{R_m^{0.9}}$$

where

A is the cross-sectional area of the tensile test specimen, expressed in square millimeters, based on the specified outside diameter or nominal specimen width and the specified wall thickness, rounded to the nearest 10 mm^2, or 490 mm^2, whichever is smaller;

R_m is the specified minimum tensile strength, expressed in megapascals.

Table A.4—Allowable mean hardness number variation—All categories

Wall thickness t mm		Allowable mean hardness number variation expressed as HRC	
≥	<	Cold-hardened by pilger	All others
1	*2*	*3*	*4*
—	9.0	3	3
9.0	12.7	4	3
12.7	19.05	5	4
19.05	25.4	6	5
25.4	—	6	6

Table A.5—Acceptable size-impact specimens and absorbed-energy reduction factor

Test specimen size	Specimen dimensions mm	Absorbed energy reduction factor
1	*2*	*3*
Full size	10.0 × 10.0	1.00
¾-size	10.0 × 7.5	0.80
½-size	10.0 × 5.0	0.55

Table A.6—Hierarchy of test specimen orientation and size

Choice	Orientation	Size
1	*2*	*3*
1st	Transverse	Full size
2nd	Transverse	¾-size
3rd	Transverse	½-size
4th	Longitudinal	Full size [a]
5th	Longitudinal	¾-size [a]
6th	Longitudinal	½-size [a]

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

Table A.7—Transverse impact specimen size required

Label 1	Calculated wall thickness required to machine transverse Charpy impact specimens mm		
	Full size	¾-size	½-size
1	*2*	*3*	*4*
3-½	20.53	18.03	15.53
4	19.09	16.59	14.09
4-½	18.05	15.55	13.05
5	17.26	14.76	12.26
5-½	16.64	14.14	11.64
6-⅝	15.62	13.12	10.62
7	15.36	12.86	10.36
7-⅝	14.99	12.49	9.99
7-¾	14.92	12.42	9.92
8-⅝	14.51	12.01	9.51
9-⅝	14.13	11.63	9.13
10-¾	13.80	11.30	8.80
11-¾	13.56	11.06	8.56
13-⅜	13.24	10.74	8.24

NOTE The above provides a 0.50 mm ID and a 0.50 mm OD machining allowance.

Table A.8—Longitudinal impact specimen size required

Label 1	Calculated wall thickness required to machine longitudinal Charpy impact specimens, mm		
	Full size	¾-size	½-size
1	*2*	*3*	*4*
1.050	11.97	9.47	6.97
1.315	11.77	9.27	6.77
1.66	11.60	9.10	6.60
1.9	11.52	9.02	6.52
2.063	11.48	8.98	6.48
2-⅜	11.42	8.92	6.42
2-⅞	11.34	8.84	6.34
3-½	11.28	8.78	6.28
4	11.25	8.75	6.25
4-½	11.22	8.72	6.22
5	11.20	8.70	6.20
5-½	11.18	8.68	6.18
6-⅝	11.15	8.65	6.15
7	11.14	8.64	6.14
7-⅝	11.13	8.63	6.13
7-¾	11.13	8.63	6.13
8-⅝	11.11	8.61	6.11
9-⅝	11.10	8.60	6.10
10-¾	11.09	8.59	6.09
11-¾	11.08	8.58	6.08
13-⅜	11.07	8.57	6.07

NOTE The above provides a 0.50 mm ID and a 0.50 mm OD machining allowance.

Table A.9—Transverse Charpy absorbed-energy requirements with full-size test specimens for coupling stock and accessory material, group 1

Maximum critical thickness for various grades [a], mm			Minimum transverse absorbed energy, J
80	95	110	
1	*2*	*3*	*4*
41.73	34.61	24.89	40
—	—	25.77	41

[a] For wall thickness greater than shown above, the requirements shall be according to the formula for the critical thickness and grade.

Table A.10—Longitudinal Charpy absorbed-energy requirements with full-size test specimens for coupling stock and accessory material, group 1

Maximum critical thickness for various grades [a], mm			Minimum longitudinal absorbed energy, J
80	**95**	**110**	
1	*2*	*3*	*4*
41.73	34.61	24.89	40
—	—	25.77	41

[a] For wall thickness greater than shown above, the requirements shall be according to the formula for the wall thickness and grade.

Table A.11—Transverse Charpy absorbed-energy requirements with full-size test specimens for coupling stock and accessory material, groups 2, 3 and 4

Maximum critical thickness for various grades [a] mm						Minimum transverse absorbed energy J
65	**75**	**80 and 90**	**110**	**125**	**140**	
1	*2*	*3*	*4*	*5*	*6*	*7*
26.85	23.15	21.51	13.48	11.86	10.45	27
	24.38	22.69	14.35	12.68	11.22	28
	25.61	23.86	15.23	13.50	11.99	29
		25.03	16.11	14.32	12.76	30
		26.20	16.99	15.14	13.53	31
			17.87	15.96	14.30	32
			18.75	16.78	15.06	33
			19.62	17.60	15.83	34
			20.50	18.42	16.60	35
			21.38	19.24	17.37	36
			22.26	20.06	18.14	37
			23.14	20.88	18.91	38
			24.01	21.70	19.67	39
			24.89	22.52	20.44	40
			25.77	23.34	21.21	41
				24.16	21.98	42
				24.98	22.75	43
				25.80	23.52	44
					24.28	45
					25.05	46
					25.82	47

[a] For wall thickness greater than shown above, the requirements shall be in accordance with the formula for the wall thickness and grade.

Table A.12—Transverse Charpy absorbed-energy requirements with full-size test specimens for pipe, group 1

Maximum specified wall thickness for various grades [a] mm			Minimum transverse absorbed energy J
80	**95**	**110**	
1	*2*	*3*	*4*
51.50	41.73	34.61	40

[a] Wall thicknesses greater than standard pipe are shown here for information for special applications. For wall thicknesses greater than shown above, the requirements shall be according to the formula for the wall thickness and grade.

Table A.13—Longitudinal Charpy absorbed-energy requirements with full-size test specimens for pipe, group 1

Maximum specified wall thickness for various grades [a] mm			Minimum longitudinal absorbed energy J
80	**95**	**110**	
1	*2*	*3*	*4*
51.50	41.73	34.61	40

[a] Wall thicknesses greater than standard pipe are shown here for information for special applications. For wall thicknesses greater than shown above, the requirements shall be according to the formula for the wall thickness and grade.

Table A.14—Transverse Charpy absorbed-energy requirements with full-size test specimens for pipe, groups 2, 3 and 4

Maximum specified wall thickness for various grades [a] mm							Minimum transverse absorbed energy J
65	**75**	**80**	**90**	**110**	**125**	**140**	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
41.35	34.40	31.54	26.85	20.07	16.36	13.48	27
				21.19	17.34	14.35	28
				22.31	18.33	15.23	29
				23.43	19.31	16.11	30
				24.54	20.29	16.99	31
				25.66	21.28	17.87	32
					22.26	18.75	33
					23.24	19.62	34
—	—	—	—		24.23	20.50	35
					25.21	21.38	36
				—	26.19	22.26	37
						23.14	38
					—	24.01	39
						24.89	40
						25.77	41

[a] Wall thicknesses greater than standard pipe are shown here for information for special applications. For wall thicknesses greater than shown above, the requirements shall be according to the formula for the wall thickness and grade.

Table A.15—Charpy absorbed-energy requirements at low temperature with full-size test specimens for group 2

Test temperature °C	Longitudinal absorbed energy J		Transverse absorbed energy J	
	Average min.	Individual min.	Average min.	Individual min.
1	*2*	*3*	*4*	*5*
−46	65	50	45	35

Table A.16—Specified dimensions and masses of pipe

Label 1	Label 2	Outside diameter *D* mm	Wall thickness *t* mm	Inside diameter [a] *d* mm	Drift diameter [b] mm	Alternative drift diameter mm	Linear mass [c] plain end *m* kg/m
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1.050	1.14	26.67	2.87	20.93	18.55	—	1.68
1.050	1.48	26.67	3.91	18.85	16.47	—	2.19
1.315	1.70	33.40	3.38	26.64	24.26	—	2.50
1.315	2.19	33.40	4.55	24.30	21.92	—	3.24
1.660	2.09	42.16	3.18	35.80	33.42	—	3.06
1.660	2.30	42.16	3.56	35.04	32.66	—	3.39
1.660	3.03	42.16	4.85	32.46	30.08	—	4.46
1.900	2.40	48.26	3.18	41.90	39.52	—	3.54
1.900	2.75	48.26	3.68	40.90	38.52	—	4.05
1.900	3.65	48.26	5.08	38.10	35.72	—	5.41
1.900	4.42	48.26	6.35	35.56	33.18	—	6.56
1.900	5.15	48.26	7.62	33.02	30.64	—	7.64
2.063	3.24	52.40	3.96	44.48	42.10	—	4.73
2.063	4.50	52.40	5.72	40.96	38.58	—	6.58
2-⅜	4.00	60.32	4.24	51.84	49.46	—	5.86
2-⅜	4.60	60.32	4.83	50.66	48.28	—	6.61
2-⅜	5.80	60.32	6.45	47.42	45.04	—	8.57
2-⅜	6.60	60.32	7.49	45.34	42.96	—	9.76
2-⅜	7.35	60.32	8.53	43.26	40.88	—	10.89
2-⅞	6.40	73.02	5.51	62.00	59.62	—	9.17
2-⅞	7.80	73.02	7.01	59.00	56.62	—	11.41
2-⅞	8.60	73.02	7.82	57.38	55.00	—	12.57
2-⅞	9.35	73.02	8.64	55.74	53.36	—	13.72

Table A.16—Specified dimensions and masses of pipe (continued)

Label 1	Label 2	Outside diameter *D* mm	Wall thickness *t* mm	Inside diameter [a] *d* mm	Drift diameter [b] mm	Alternative drift diameter mm	Linear mass [c] plain end *m* kg/m
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
2-⅞	10.50	73.02	9.96	53.10	50.72	—	15.49
2-⅞	11.50	73.02	11.18	50.66	48.28	—	17.05
3-½	7.70	88.90	5.49	77.92	74.74	—	11.29
3-½	9.20	88.90	6.45	76.00	72.82	—	13.12
3-½	10.20	88.90	7.34	74.22	71.04	—	14.76
3-½	12.70	88.90	9.52	69.86	66.68	—	18.64
3-½	14.30	88.90	10.92	67.06	63.88	—	21.00
3-½	15.50	88.90	12.09	64.72	61.54	—	22.90
3-½	17.00	88.90	13.46	61.98	58.80	—	25.04
4	9.50	101.60	5.74	90.12	86.94	—	13.57
4	10.70	101.60	6.65	88.30	85.12	—	15.57
4	13.20	101.60	8.38	84.84	81.66	—	19.27
4	16.10	101.60	10.54	80.52	77.34	—	23.67
4	18.90	101.60	12.70	76.20	73.02	—	27.84
4	22.20	101.60	15.49	70.62	67.44	—	32.89
4-½	9.50	114.30	5.21	103.88	100.70	—	14.02
4-½	10.50	114.30	5.69	102.92	99.74	—	15.24
4-½	11.60	114.30	6.35	101.60	98.42	—	16.91
4-½	12.60	114.30	6.88	100.54	97.36	—	18.23
4-½	13.50	114.30	7.37	99.56	96.38	—	19.44
4-½	15.10	114.30	8.56	97.18	94.00	—	22.32
4-½	17.00	114.30	9.65	95.00	91.82	—	24.90
4-½	18.90	114.30	10.92	92.46	89.28	—	27.84
4-½	21.50	114.30	12.70	88.90	85.72	—	31.82
4-½	23.70	114.30	14.22	85.86	82.68	—	35.10
4-½	26.10	114.30	16.00	82.30	79.12	—	38.79
5	11.50	127.00	5.59	115.82	112.64	—	16.74
5	13.00	127.00	6.43	114.14	110.96	—	19.12
5	15.00	127.00	7.52	111.96	108.78	—	22.16
5	18.00	127.00	9.19	108.62	105.44	—	26.70

Table A.16—Specified dimensions and masses of pipe (continued)

Label 1	Label 2	Outside diameter *D* mm	Wall thickness *t* mm	Inside diameter [a] *d* mm	Drift diameter [b] mm	Alternative drift diameter mm	Linear mass [c] plain end *m* kg/m
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
5	21.40	127.00	11.10	104.80	101.62	—	31.73
5	23.30	127.00	12.14	102.72	99.54	—	34.39
5	24.10	127.00	12.70	101.60	98.42	—	35.80
5-½	14.00	139.70	6.20	127.30	124.12	—	20.41
5-½	15.50	139.70	6.98	125.74	122.56	—	22.85
5-½	17.00	139.70	7.72	124.26	121.08	—	25.13
5-½	20.00	139.70	9.17	121.36	118.18	—	29.52
5-½	23.00	139.70	10.54	118.62	115.44	—	33.57
5-½	26.80	139.70	12.70	114.30	111.12	—	39.78
5-½	29.70	139.70	14.27	111.16	107.98	—	44.14
5-½	32.60	139.70	15.88	107.94	104.76	—	48.49
5-½	35.30	139.70	17.45	104.80	101.62	—	52.61
5-½	38.00	139.70	19.05	101.60	98.42	—	56.68
5-½	40.50	139.70	20.62	96.46	95.28	—	60.55
5-½	43.10	139.70	22.22	95.26	92.08	—	64.38
6-⅝	20.00	168.28	7.32	153.64	150.46	—	29.06
6-⅝	24.00	168.28	8.94	150.40	147.22	—	35.13
6-⅝	28.00	168.28	10.59	147.10	143.92	—	41.18
6-⅝	32.00	168.28	12.06	144.16	140.98	—	46.46
7	17.00	177.80	5.87	166.06	162.88	—	24.89
7	20.00	177.80	6.91	163.98	160.80	—	29.12
7	23.00	177.80	8.05	161.70	158.52	158.75	33.70
7	26.00	177.80	9.19	159.42	156.24	—	38.21
7	29.00	177.80	10.36	157.08	153.90	—	42.78
7	32.00	177.80	11.51	154.78	151.60	152.40	47.20
7	35.00	177.80	12.65	152.50	149.32	—	51.52
7	38.00	177.80	13.72	150.36	147.18	—	55.52
7	42.70	177.80	15.88	146.04	142.86	—	63.41
7	46.40	177.80	17.45	142.90	139.72	—	69.01
7	50.10	177.80	19.05	139.70	136.52	—	74.58

Table A.16—Specified dimensions and masses of pipe (continued)

Label 1	Label 2	Outside diameter *D* mm	Wall thickness *t* mm	Inside diameter [a] *d* mm	Drift diameter [b] mm	Alternative drift diameter mm	Linear mass [c] plain-end *m* kg/m
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
7	53.60	177.80	20.62	136.56	133.38	—	79.93
7	57.10	177.80	22.22	133.36	130.18	—	85.25
7-⅝	24.00	193.68	7.62	178.44	175.26	—	34.96
7-⅝	26.40	193.68	8.33	177.02	173.84	—	38.08
7-⅝	29.70	193.68	9.52	174.64	171.46	—	43.24
7-⅝	33.70	193.68	10.92	171.84	168.66	—	49.22
7-⅝	39.00	193.68	12.70	168.28	165.10	—	56.68
7-⅝	42.80	193.68	14.27	165.14	161.96	—	63.14
7-⅝	45.30	193.68	15.11	163.46	160.28	—	66.54
7-⅝	47.10	193.68	15.88	161.92	158.74	—	69.63
7-⅝	51.20	193.68	17.45	158.78	155.60	—	75.84
7-⅝	55.30	193.68	19.05	155.58	152.40	—	82.04
7-¾	46.10	196.85	15.11	166.63	163.45	165.10	67.72
8-⅝	24.00	219.08	6.71	205.66	202.48	—	35.14
8-⅝	28.00	219.08	7.72	203.64	200.46	—	40.24
8-⅝	32.00	219.08	8.94	201.20	198.02	200.02	46.33
8-⅝	36.00	219.08	10.16	198.76	195.58	—	52.35
8-⅝	40.00	219.08	11.43	196.22	193.04	193.68	58.53
8-⅝	44.00	219.08	12.70	193.68	190.50	—	64.64
8-⅝	49.00	219.08	14.15	190.78	187.60	—	71.51
9-⅝	32.30	244.48	7.92	228.64	224.67	—	46.20
9-⅝	36.00	244.48	8.94	226.60	222.63	—	51.93
9-⅝	40.00	244.48	10.03	224.42	220.45	222.25	57.99
9-⅝	43.50	244.48	11.05	222.38	218.41	—	63.61
9-⅝	47.00	244.48	11.99	220.50	216.53	—	68.75
9-⅝	53.50	244.48	13.84	216.80	212.83	215.90	78.72
9-⅝	58.40	244.48	15.11	214.26	210.29	212.72	85.47
9-⅝	59.40	244.48	15.47	213.54	209.57	—	87.37
9-⅝	64.90	244.48	17.07	210.34	206.37	—	95.73
9-⅝	70.30	244.48	18.64	207.20	203.23	—	103.82

Table A.16—Specified dimensions and masses of pipe (continued)

Label 1	Label 2	Outside diameter *D* mm	Wall thickness *t* mm	Inside diameter [a] *d* mm	Drift diameter [b] mm	Alternative drift diameter mm	Linear mass [c] plain end *m* kg/m
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
9-⅝	75.60	244.48	20.24	204.00	200.03	—	111.93
10-¾	32.75	273.05	7.09	258.87	254.90	—	46.50
10-¾	40.50	273.05	8.89	255.27	251.30	—	57.91
10-¾	45.50	273.05	10.16	252.73	248.76	250.82	65.87
10-¾	51.10	273.05	11.43	250.19	246.22	—	73.75
10-¾	55.50	273.05	12.57	247.91	243.94	244.48	80.75
10-¾	60.70	273.05	13.84	245.37	241.40	—	88.47
10-¾	65.70	273.05	15.11	242.83	238.86	—	96.12
10-¾	73.20	273.05	17.07	238.91	234.94	—	107.76
10-¾	79.20	273.05	18.64	235.77	231.80	—	116.95
10-¾	85.30	273.05	20.24	232.57	228.60	—	126.19
11-¾	42.00	298.45	8.46	281.53	277.56	279.40	60.50
11-¾	47.00	298.45	9.52	279.41	275.44	—	67.83
11-¾	54.00	298.45	11.05	276.35	272.38	—	78.32
11-¾	60.00	298.45	12.42	273.61	269.64	269.88	87.61
11-¾	65.00	298.45	13.56	271.33	267.36	269.88	95.27
11-¾	71.00	298.45	14.78	268.89	264.92	—	103.40
13-⅜	48.00	339.72	8.38	322.96	318.99	—	68.48
13-⅜	54.50	339.72	9.65	320.42	316.45	—	78.55
13-⅜	61.00	339.72	10.92	317.88	313.91	—	88.55
13-⅜	68.00	339.72	12.19	315.34	311.37	—	98.46
13-⅜	72.00	339.72	13.06	313.60	309.63	311.15	105.21

[a] $d = D - 2t$.

[b] The drift diameter is equal to *d* minus a constant (see Table A.19).

[c] $m = 0.0246615 \times (D - t) \times t$; see 8.1.1 for the multiplication factors with regard to the groups.

Table A.17—Length requirements

Dimensions in meters

Pipes for		Range 1 [b] (R1)	Range 2 [b] (R2)	Range 3 [b] (R3)
1		*2*	*3*	*4*
Casing and tubing	Total range length, inclusive	4.88 to 7.62	7.62 to 10.36	10.36 to 14.63
	Maximum permissible variation on 100 % of each order item of 18,144 kg or more	1.52		
Pup joints	Length [a,b]	0.61; 0.91; 1.22; 1.83; 2.44; 3.05; 3.66		
	Tolerance	±0.076		
Coupling stock and accessory material		By agreement		

[a] 0.61 m pup joints may be furnished up to 0.91 m long by agreement between manufacturer and purchaser.

[b] Lengths other than those listed may be furnished by agreement between manufacturer and purchaser.

Table A.18—Tolerances on dimensions and mass

Outside diameter *D* mm	Tolerance for supply condition					
	Outside diameter [a]		Wall thickness		Mass [b]	
	QT — SA	CH	QT — SA	CH	QT — SA	CH
1	*2*	*3*	*4*	*5*	*6*	*7*
< 114.3	±0.79 mm	±0.79 mm	$^{+}_{-12.5}$ %	$^{+}_{-10}$ %	$^{+6.5}_{-3.5}$ %	$^{+6.5}_{-3.5}$ %
≥ 114.3	$^{+1}_{-0.5}$ %	$^{+1}_{-0.5}$ %	$^{+}_{-12.5}$ %	$^{+}_{-10}$ %	$^{+6.5}_{-3.5}$ %	$^{+6.5}_{-3.5}$ %

[a] Out-of-roundness is included in the *D* tolerance.

[b] The tolerance is quoted for a single length. On each order item of 18,144 kg or more, the tolerance is −1.75 %.

Table A.19—Standard drift mandrel dimensions

Dimensions in millimeters

Pipes for	Outside diameter *D*		Drift mandrel size minimum	
	>	≤	Length	Diameter
1	*2*	*3*	*4*	*5*
Casing	—	219.08	152	*d* − 3.18
	219.08	—	305	*d* − 3.97
Tubing	—	73.03	1067	*d* − 2.38
	73.03	—	1067	*d* − 3.18

NOTE *d* is given in Table A.16.

Table A.20—Alternative drift mandrel dimensions

Label 1	Label 2	Outside diameter *D* mm	Wall thickness *t* mm	Drift mandrel size minimum		Linear mass plain end *m* kg/m
				Length [a] mm	Diameter mm	
1	*2*	*3*	*4*	*5*	*6*	*7*
7	23.00	177.80	8.05	152	158.75	33.70
7	32.00	177.80	11.51	152	152.40	47.20
7-¾	46.10	196.85	15.11	152	165.10	67.72
8-⅝	32.00	219.08	8.94	152	200.02	46.33
8-⅝	40.00	219.08	11.43	152	193.68	58.53
9-⅝	40.00	244.48	10.03	305	222.25	57.99
9-⅝	53.50	244.48	13.84	305	215.90	78.72
9-⅝	58.40	244.48	15.11	305	212.72	85.47
10-¾	45.50	273.05	10.16	305	250.82	65.87
10-¾	55.50	273.05	12.57	305	244.48	80.75
11-¾	42.00	298.45	8.46	305	279.40	60.50
11-¾	60.00	298.45	12.42	305	269.88	87.61
11-¾	65.00	298.45	13.56	305	269.88	95.27
13-⅜	72.00	339.72	13.06	305	311.15	105.21

[a] For tubing, minimum drift mandrel length shall be 1067 mm.

Table A.21—Type and frequency of tests for non-upset and upset product

Type of test or requirements		Test requirements	Frequency of testing [b]	Test methods	Requirements
1		*2*	*3*	*4*	*5*
Heat analysis		m [d]	1 per heat	9.3.2	7.1
Product analysis	Non-remelted alloy	m [d]	2 per heat	9.3.2	7.1
	Remelted alloy	m [d]	1 per ingot	9.3.2	7.1
Chromium depletion test		o [d,e]	1 per test lot [c]	9.3.3	9.3.3
Room-temperature tensile test		m [d]	1 per test lot [c]	9.5.2	7.2
Elevated-temperature tensile test		o [d]	1 per test lot [c]	9.5.2	7.2
Hardness test		m [d]	1 series/test lot [c]	9.6.2	7.3
Impact or flattening test		m [d]	9.7.2	9.7.3 or 9.7.4.1	7.4, 7.5, 7.6, 7.7
Impact test at low temperature		o [h]	1 per test lot	9.8	7.8
Pitting corrosion test		o [h]	1 per test lot	9.9	7.9.2
Microstructure examination		m [d]	1 per test lot [c]	9.10.2	7.10
Visual inspection		m	Each length	9.16	7.11, 7.12, 8.4
PMI		m (o [f])	Each length	9.18	9.18

Table A.21—Type and frequency of tests for non-upset and upset product (continued)

Type of test or requirements	Test requirements	Frequency of testing [b]	Test methods	Requirements
Dimensional testing:				
— Outside diameter	m	Each end of each length	9.11.2	Table A.16 and Table A.18
— Wall thickness	m	Each end of each length	9.11.3	Table A.16 and Table A.18
— Drift test	m	Each pipe	9.12	Table A.16 and Table A.19 or Table A.20
— Length	m [d]	Each length	9.13	Table A.17
— Straightness	m	Each pipe	9.14	8.3.3
— Mass	m	Each pipe	9.15	Table A.16 and Table A.18
Non-destructive examination:				
— UT for longitudinal defects	m [d]	Each length	9.17.9, 9.17.10	7.12
— UT for transverse defects	m [d]	Each length	9.17.9, 9.17.10	7.12
— UT for laminar defects	m [d]	Each length	9.17.9, 9.17.10	7.12
— UT for oblique defects	m [a]	Each length	9.17.10	7.12
— UT for wall thickness	m [d]	Each length	9.11.4; 9.17	7.12; 8.1; 8.3.1
— EMI	o [d,f]	Each length	9.17.9	7.12
— MT	o [f]	Each length	9.17.9	7.12
— NDE of untested ends	m [g]	Each length	9.17.5	7.12
— NDE of upset ends	m	Each upset length	9.17.6	7.12
— Disposition of defects	m	Each length containing defects	9.17.13, 9.17.14	7.12

[a] Mandatory for groups 2, 3 and 4 PSL-2 only.

[b] For definition of “test lot”, see 3.1.22. See Table A.22 for the maximum number of lengths in a test lot.

[c] Minimum 1 per heat.

[d] It is required that data records be retained.

[e] Option for groups 2, 3 and 4 only.

[f] Option for group 1 only.

[g] When NDE on untested end is applied in lieu of cropping untested end.

[h] Option for group 2 only.

m: mandatory

o: optional (an agreement is required)

Table A.22—Maximum number of lengths per test lot

Group	Number [a] of lengths for	
	Pipe	Coupling stock and accessory material
1	*2*	*3*
1	100	20
2, 3, 4	50	10

NOTE For the pup joints, see 9.2.

[a] Residual quantities of less than 20 % of the maximum number of lengths per test lot may be added to one test lot per heat.

Table A.23—Artificial reference indicator

Acceptance inspection level	Notch depth [a] max.	Notch length (max. at full depth)	Width max.	Radially drilled hole diameter [b]
1	*2*	*3*	*4*	*5*
U2/F2/E2	5 %	50 mm	1 mm	1.6 mm

NOTE See Figure B.8.

[a] Depth as a percent of specified wall thickness. The depth tolerance shall be ±15 % of the calculated notch depth with a minimum notch depth of 0.3 mm ±0.05 mm.

[b] Drilled hole diameter (through the pipe wall) shall be based on the drill bit size.

Table A.24—Acceptance level

Group	NDT method	External imperfection			Internal imperfection		
		Longitudinal	Transverse	Oblique	Longitudinal	Transverse	Oblique
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1	UT	U2	U2	—	U2	U2	—
	Second method [b]	F2 or E2	F2 or E2	—	—	—	—
2, 3, 4	UT	U2	U2	U2 [a]	U2	U2	U2 [a]

[a] For PSL-2 product only.

[b] For optional second method, see 9.17.9.

Table A.25—Marking height

Dimensions in millimeters

D	Minimum height of marking	
	Die stamping	Paint or ink stencilling
1	*2*	*3*
≤ 101.60	4	≥ 8
> 101.60	6	≥ 12

Table A.26—Color coding for material category

Material category	Color coding
1	*2*
13-5-2	white and green
13-1-0	white and red
22-5-3	red and red
25-7-3	red and orange
25-7-4	red and yellow
26-6-3	green and green
27-31-4	green and brown
25-32-3	green and orange
22-35-4	white and blue
21-42-3	yellow and yellow
22-50-7	yellow and orange
25-50-6	yellow and green
20-54-9	yellow and blue
22-52-11	white and brown
15-60-16	yellow and brown

Table A.27—Color coding for material grade

Material grade	Color coding
1	*2*
65	yellow
75	blue
80	red
90	brown
95	silver
110	white
125	orange
140	green

Table A.28—PSL-2 product mechanical properties at room temperature

Material identity		UNS number	Grade	Delivery condition	Yield strength [a,d] $R_{p0.2}$ MPa		Tensile strength [a] R_m MPa	Elongation e [b] %	Mean hardness number [d] HRC
Group	Category				min.	max.	min.	min.	max.
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1	13-5-2	S41426	80	QT	552	655	621	[c]	27
			95	QT	655	724	724	[c]	27
2	22-5-3	S31803	65	SA	448	621	621	25	26
			110	CH	758	965	862	11	36
			125	CH	862	1000	896	10	36
	25-7-3	S31260	75	SA	517	689	621	25	26
			110	CH	758	965	862	11	36
			125	CH	862	1000	896	10	36
	25-7-4	S32750	80	SA	552	724	758	20	28
			90	SA	621	724	793	20	30
			110	CH	758	965	862	12	36
			125	CH	862	1000	896	10	36
		S32760	80	SA	552	724	758	20	28
			90	SA	621	724	793	20	30
			110	CH	758	965	862	12	36
			125	CH	862	1000	896	10	36
		S39274	80	SA	552	724	758	20	28
			90	SA	621	724	793	20	30
			110	CH	758	965	862	12	36
			125	CH	862	1000	896	10	36
3	27-31-4	N08028	110	CH	758	965	793	11	33
			125	CH	862	1000	896	10	35
	25-32-3	N08535	110	CH	758	965	793	11	33
			125	CH	862	1000	896	10	35
	22-35-4	N08135	110	CH	758	965	793	11	33
4	21-42-3	N08825	110	CH	758	965	793	11	35
			125	CH	862	1000	896	10	35
	22-50-7	N06985	110	CH	758	965	793	11	35
			125	CH	862	1034	896	10	37
	25-50-6	N06255	110	CH	758	965	793	11	35
			125	CH	862	1034	896	10	37
		N06975	110	CH	758	965	793	11	35
			125	CH	862	1034	896	10	37
	20-54-9	N06950	110	CH	758	965	793	11	35
			125	CH	862	1034	896	10	37
	15-60-16	N10276	110	CH	758	965	793	11	35
			125	CH	862	1034	896	10	37
			140	CH	965	1103	1000	9	38

[a] See requirement in 7.2 for relation between tensile and yield strength.

[b] e is the minimum elongation in 50 mm gauge length for strip specimens or in 4D or 5D for round bar specimens, expressed in percent.

[c] $$e = 1944 \frac{A^{0.2}}{R_m^{0.9}}$$

where

A is the cross-sectional area of the tensile test specimen, expressed in square millimeters, based on specified outside diameter or nominal specimen width and specified wall thickness, rounded to the nearest 10 mm^2, or 490 mm^2, whichever is smaller;

R_m is the specified minimum tensile strength, expressed in megapascals.

[d] Other values may be agreed between purchaser and manufacturer, subject to the requirements in G.2.

Table A.29—PSL-2 chemical composition of corrosion-resistant alloy seamless material categories

Material identity			UNS number	Chemical composition maximum % mass fraction or range, unless otherwise indicated																PREN [b] range no.
Group	Structure	Category [a]		C	Cr	Ni [c]	Fe [c]	Mn	Si	Mo	Co	Cu	P	S	Ti	Nb + Ta	V	W	N	Al	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*
1	Martensitic	13-5-2	S41426	0.03	11.5 to 13.5	4.5 to 6.5	bal.	0.50	0.50	1.5 to 3.0	—	—	0.02	0.005	0.01 to 0.50	—	0.50	—	—	—	NA
2	Duplex austenitic/ ferritic	22-5-3	S31803	0.030	21.0 to 23.0	4.50 to 6.50	bal.	2.00	1.00	2.50 to 3.50	—	—	0.030	0.020	—	—	—	—	0.08 to 0.20	—	35 to 40.0
		25-7-3	S31260	0.03	24.0 to 26.0	5.50 to 7.50	bal.	1.00	0.75	2.50 to 3.50	—	0.20 to 0.80	0.030	0.030	—	—	—	0.10 to 0.50	0.10 to 0.30	—	37.5 to 40.0
	Super-duplex austenitic/ ferritic	25-7-4	S32750	0.030	24.0 to 26.0	6.0 to 8.0	bal.	1.20	0.8	3.0 to 5.0	—	—	0.035	0.020	—	—	—		0.24 to 0.32	—	> 40.0 to ≤ 45
			S32760	0.03	24.0 to 26.0	6.0 to 8.0	bal.	1.0	1.0	3.0 to 4.0	—	0.5 to 1.0	0.03	0.01	—	—	—	0.5 to 1.0	0.2 to 0.3	—	> 40.0 to ≤ 45
			S39274	0.030	24.0 to 26.0	6.0 to 8.0	bal.	1.0	0.80	2.50 to 3.50	—	0.20 to 0.80	0.030	0.020	—	—	—	1.50 to 2.50	0.24 to 0.32	—	> 40.0 to ≤ 45
3	Austenitic Fe base	27-31-4	N08028	0.03	26.0 to 28.0	30.0 to 32.5	bal.	2.50	1.00	3.0 to 4.0	—	0.6 to 1.4	0.030	0.030	—	—	—	—	—	—	NA
		25-32-3	N08535	0.030	24.0 to 27.0	29.0 to 36.5 [d]	bal.	1.00	0.50	2.5 to 4.0	[d]	1.50	0.03	0.03	—	—	—	—	—	—	NA
		22-35-4	N08135	0.03	20.5 to 23.5	33.0 to 38.0	bal.	1.00	0.75	4.0 to 5.0	—	0.70	0.03	0.03	—	—	—	0.20 to 0.80	—	—	NA

Table A.29—PSL-2 chemical composition of corrosion-resistant alloy and material categories (continued)

Material identity			UNS number	Chemical composition maximum % mass fraction or range, unless otherwise indicated																	PREN [b] range no.
Group	Structure	Category [a]		C	Cr	Ni [c]	Fe [c]	Mn	Si	Mo	Co	Cu	P	S	Ti	Nb + Ta	V	W	N	Al	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*
4	Austenitic Ni base	21-42-3	N08825	0.05	19.5 to 23.5	38.0 to 46.0	bal.	1.00	0.5	2.5 to 3.5	—	1.5 to 3.0	0.03	0.03	0.6 to 1.2	—	—	—	—	0.2	NA
		22-50-7	N06985	0.015	21.0 to 23.5	bal.	18.0 to 21.0	1.00	1.00	6.0 to 8.0	5.0	1.5 to 2.5	0.04	0.03	—	0.50	—	1.5	—	—	NA
		25-50-6	N06255	0.03	23.0 to 26.0	47.0 to 52.0	bal.	1.00	1.00	6.0 to 9.0	—	1.20	0.03	0.03	0.69	—	—	3.0	—	—	NA
			N06975	0.03	23.0 to 26.0	47.0 to 52.0	bal.	1.00	1.00	5.0 to 7.0 [e]	—	0.70 to 1.20	0.03	0.03	0.70 to 1.50	—	—	[e]	—	—	NA
		20-54-9	N06950	0.015	19.0 to 21.0	50.0 min	15.0 to 20.0	1.00	1.00	8.0 to 10.0	2.5	0.5	0.04	0.015	—	0.50 [g]	0.04	1.0	—	—	NA
		15-60-16	N10276	0.02	14.5 to 16.5	bal. [f]	4.0 to 7.0	1.00	0.08	15.0 to 17.0	2.5 [f]	—	0.030	0.030	—	—	0.35	3.0 to 4.5	—	—	NA

[a] Designation of categories: 1st digit: nominal chromium content; 2nd digit: nominal nickel content; 3rd digit: nominal molybdenum content.

[b] PREN = % Cr + 3.3 (% Mo + 0.5 % W) + 16 % N.

[c] Bal. is the balance of composition up to 100 %, determined arithmetically by difference.

[d] Ni + Co = 29.5 % minimum.

[e] When specified, Mo + W = 6 % minimum.

[f] Ni + Co = 52 % minimum.

[g] Nb = 0.50 % minimum. Analysis of Ta is not required.

NA: not applicable

Table A.30—Chemical composition of corrosion-resistant alloy and material categories for bar or drilled bar, groups 1 and 2

Material identity			UNS number	Chemical composition[d] maximum % mass fraction or range, unless otherwise indicated														PREN [b,d] range no.
Group	Structure	Category [a]		C	Cr	Ni	Fe [c]	Mn	Si	Mo	Cu	P	S	Ti	V	W	N	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*
1	Martensitic	13-5-2	S41425	0.050	12.00 to 15.00	4.0 to 7.0	bal.	0.30 to 1.00	0.5	1.50 to 2.00	0.30	0.020	0.005	—	—	—	0.06 to 0.12	NA
			S41426	0.03	11.5 to 13.5	4.5 to 6.5	bal.	0.50	0.50	1.5 to 3.0	—	0.02	0.005	0.01 to 0.50	0.50	—	—	NA
			S41427	0.03	11.5 to 13.5	4.5 to 6.0	bal.	1.0	0.50	1.5 to 2.5	—	0.02	0.005	0.01	0.10 to 0.50	—	—	NA
2	Duplex austenitic/ ferritic	22-5-3	S31803	0.030	21.0 to 23.0	4.50 to 6.50	bal.	2.00	1.00	2.50 to 3.50	—	0.030	0.020	—	—	—	0.08 to 0.20	35 to 40.0
			S32205	0.030	22.0 to 23.0	4.50 to 6.50	bal.	2.00	1.00	3.00 to 3.50	—	0.030	0.020	—	—	—	0.14 to 0.20	35 to 40.0
	Super-duplex austenitic/ ferritic	25-7-4	S32550	0.04	24.0 to 27.0	4.50 to 6.50	bal.	1.5	1.00	2.9 to 3.9	1.50 to 2.50	0.04	0.030	—	—		0.10 to 0.25	> 40.0 to ≤ 45
			S32750	0.030	24.0 to 26.0	6.0 to 8.0	bal.	1.20	0.8	3.0 to 5.0	—	0.035	0.020	—	—		0.24 to 0.32	> 40.0 to ≤ 45
			S32760	0.03	24.0 to 26.0	6.0 to 8.0	bal.	1.0	1.0	3.0 to 4.0	0.5 to 1.0	0.03	0.01	—	—	0.5 to 1.0	0.2 to 0.3	> 40.0 to ≤ 45
			S39277	0.025	24.0 to 26.0	6.5 to 8.0	bal.	0.80	0.80	3.0 to 4.0	1.2 to 2.0	0.025	0.002	—	—	0.80 to 1.20	0.23 to 0.33	> 40.0 to ≤ 45

[a] Designation of categories: 1st digit: nominal chromium content; 2nd digit: nominal nickel content; 3rd digit: nominal molybdenum content.
[b] PREN = % Cr + 3.3 (% Mo + 0.5 % W) + 16 % N.
[c] Bal. is the balance of composition up to 100 %, determined arithmetically by difference.
[d] Chemical composition and PREN meet both PSL-1 and PSL-2.
NA: not applicable

Table A.31—Product mechanical properties at room temperature for bar or drilled bar, groups 1 and 2

Material identity		UNS number	Grade	Delivery condition	Yield strength $R_{p0.2}$ MPa		Tensile strength R_m MPa	Elongation e %	Reduction of area [a] Z %	Mean hardness number [b] HRC	PSL
Group	Category				min.	max.	min.	min.	min.	max.	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
1	13-5-2	S41425	95	QT	655	793	724	20	40	29	1
			95	QT	655	772	724	20	40	28	2
			110	QT	758	896	862	15	40	32	1
		S41426	95	QT	655	793	724	20	40	29	1
			110	QT	758	896	862	15	40	32	1
		S41427	95	QT	655	793	724	20	40	29	1
			95	QT	655	772	724	20	40	29	2
			110	QT	758	896	862	15	40	32	1
2	22-5-3	S31803	65	SA	448	621	621	25	45	26	2
		S32205	65	SA	448	621	655	25	45	26	2
	25-7-4	S32550	80	SA	552	724	750	25	45	28	2
		S32750	80	SA	552	724	750	25	45	28	2
		S32760	80	SA	552	724	750	25	45	28	2
		S39277 [c]	80	SA	552	724	750	25	45	28	2
			85	SA	586	724	793	25	45	28	2

[a] Reduction of area requirement may be waived for use of strip tensile or product tested in full section.

[b] The conversion of hardness readings to or from other scales is material-dependent. Equivalent HBW hardness acceptance criteria can be by agreement between manufacturer and purchaser developed based on data available for the specific grade. In case of a dispute, HRC method shall be used as the acceptance of a material. When a conversion is utilized, the conversion method shall be documented and traceable to test results (see F.3.4). For reporting converted hardness numbers, see F.7.3.

[c] S39277 grade 85 also meets the requirements of grade 80.

Table A.32—Longitudinal Charpy absorbed-energy requirements with full-size test specimens for bar or drilled bar, groups 1 and 2

Material identity		UNS number	Grade	Delivery condition	Test temperature °C	Longitudinal absorbed energy J	
Group	Category					Average min.	Individual min.
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1	13-5-2	S41425	95	QT	−10	60	40
			110	QT	−10	60	40
		S41426	95	QT	−10	60	40
			110	QT	−10	60	40
		S41427	95	QT	−10	60	40
			110	QT	−10	60	40
2	22-5-3	S31803	65	SA	−46	41	30
		S32205	65	SA	−46	41	30
	25-7-4	S32550	80	SA	−46	41	30
		S32750	80	SA	−46	41	30
		S32760	80	SA	−46	41	30
		S39277 [e]	80 [a]	SA	−46	41	30
			85 [b]	SA	−46	41	30
			85 [c]	SA	−46	27	20
			85 [d]	SA	−46	30	20

[a] For bar diameters up to 165.1 mm, inclusive. Requirements for bar diameters greater than 165.1 mm are by agreement between purchaser and manufacturer.
[b] For bar diameters up to 165.1 mm, inclusive.
[c] For bar diameters greater than 165.1 mm up to 203.2 mm, inclusive.
[d] For bar diameters greater than 203.2 mm. Test location shall be 38.1 mm below surface.
[e] S39277 grade 85 also meets the requirements of grade 80 for bar diameters up to 165.1 mm, inclusive.

Table A.33—Microscopic cleanliness acceptance limits for bar or drilled bar, group 1

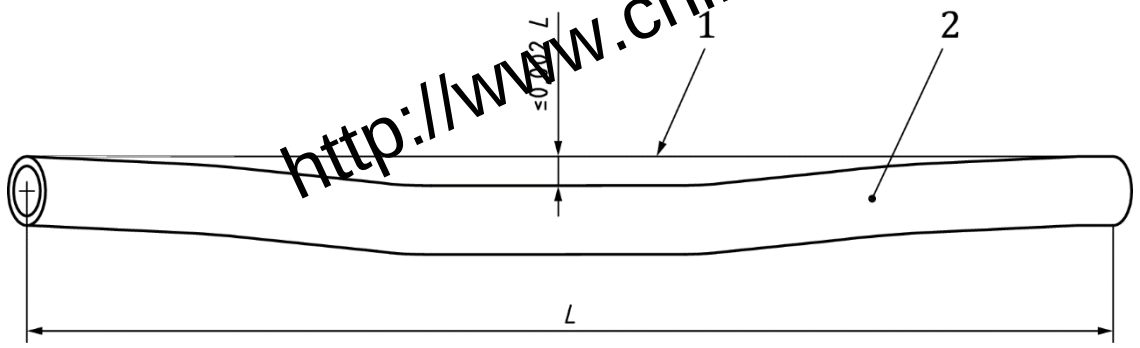
Inclusions [a]	Severity (maximum)	
	Heavy	Thin
Type A (sulphide)	1.0	1.0
Type B (aluminium)	2.5	3.0
Type C (silicate)	2.0	2.0
Type D (globular)	2.0	2.0

[a] Other features, anomalies or gross defects noted by the inspector/metallurgist while reviewing the microetched material either shall result in rejection, or shall be allowed a retest, or shall be brought to the attention of the purchaser for resolution.

Annex B
(normative)

Figures in SI (USC) units

Dimensions in millimeters



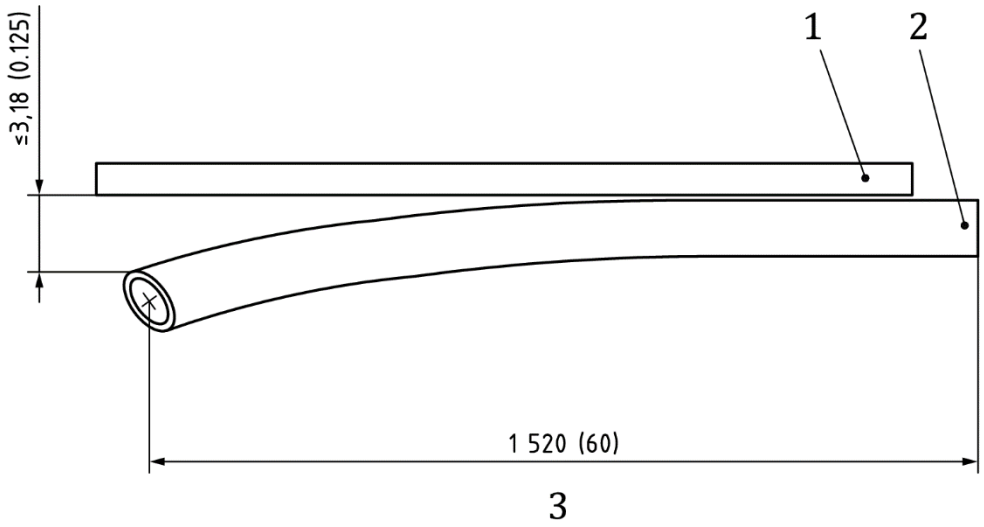
Key

1 taut string or wire

2 pipe

Figure B.1—Measuring full-length straightness

Dimensions in millimeters (inches)



Key

1 straightedge used for measuring

2 pipe

3 hooked end

Figure B.2—Measuring end straightness

Dimensions in millimeters (inches)

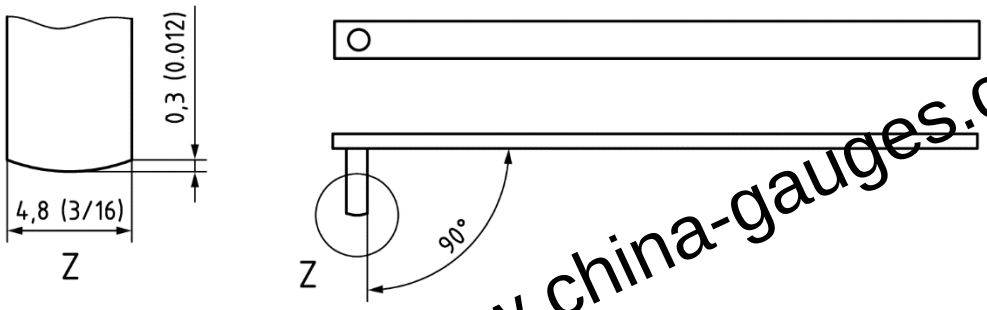
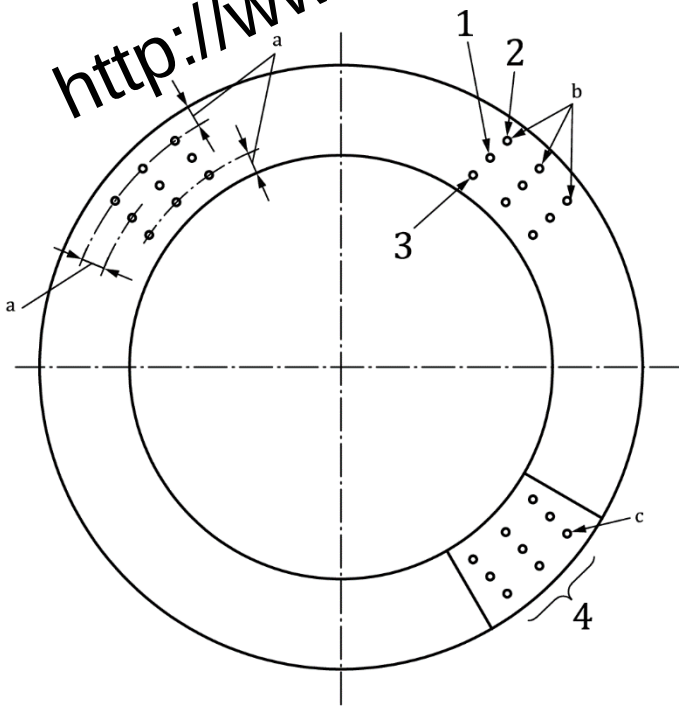


Figure B.3—Example of a typical 90° hook-type tool



Key

1 indentation at mid-wall location

2 indentation at OD location

3 indentation at ID location

4 hardness indentation test block

Testing is required in only one quadrant. In the above figure, hardness indents are shown in more than one quadrant only to illustrate details.

[a] The outer and inner tests shall be taken between 2.54 mm (0.100 in.) and 3.81 mm (0.150 in.) from the applicable surface, as follows:

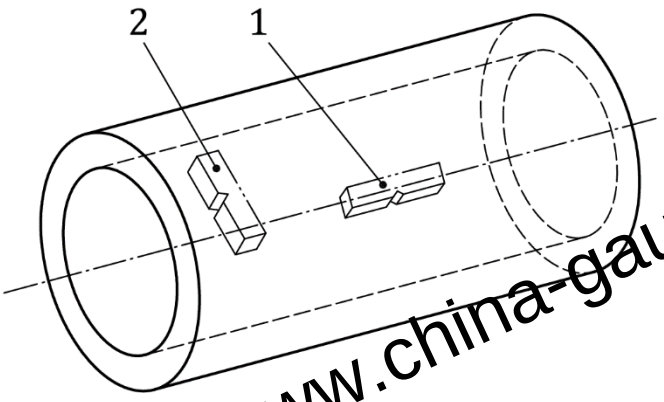
- for $t \leq 7.62$ mm (0.300 in.), one row shall be used;
- for 7.62 mm (0.300 in.) < $t \leq 11.43$ mm (0.450 in.), two rows shall be used;
- for $t > 11.43$ mm (0.450 in.), three rows shall be used.

An error can result if an indentation is spaced closer than 2 ½ diameters from its center to the edge of the specimen or three diameters from another indentation measured center-to-center.

[b] The mean hardness number is the average of three Rockwell hardness numbers in the same location.

[c] Rockwell hardness indentation data are called Rockwell hardness numbers.

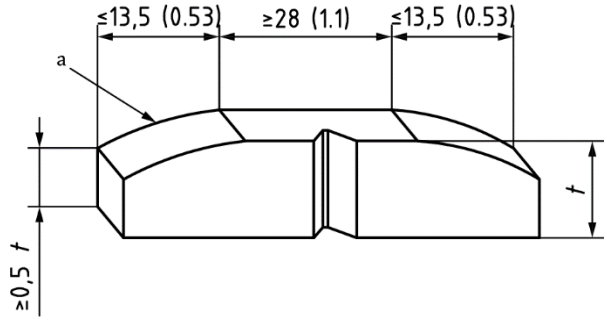
Figure B.4—Hardness test



Key
1 longitudinal test piece
2 transverse test piece

Figure B.5—Orientation of impact test pieces

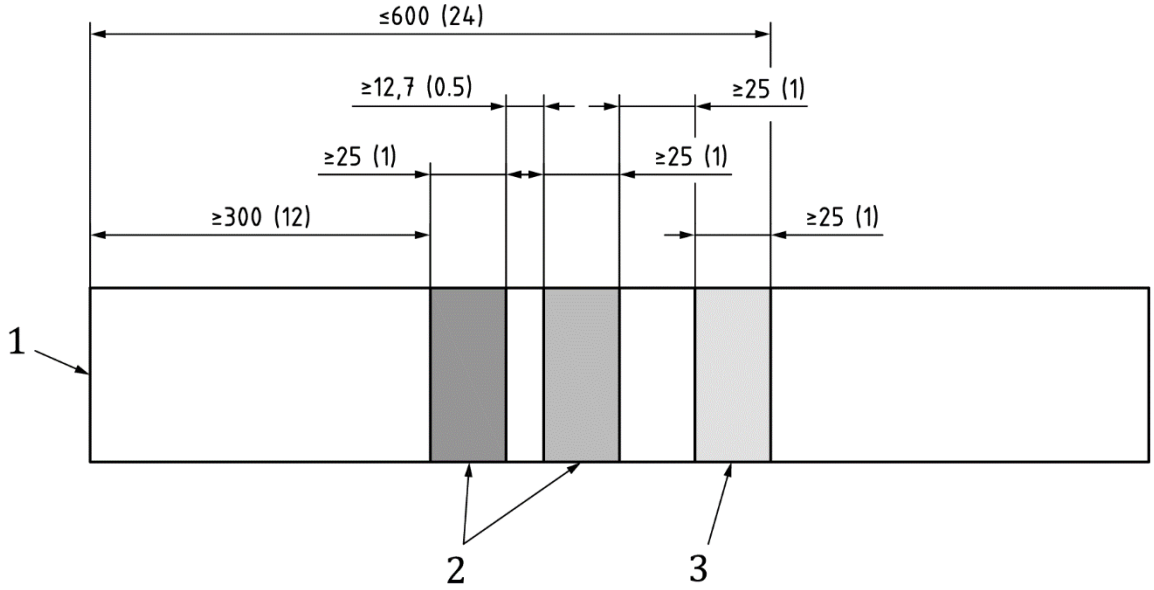
Dimensions in millimeters (inches)



[a] Outside diameter curvature.

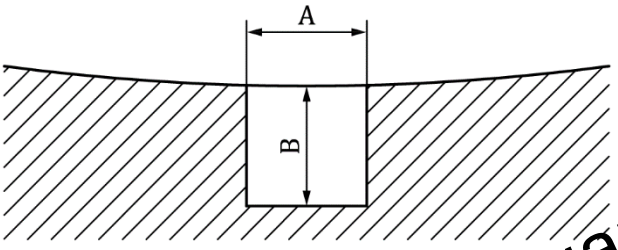
Figure B.6—*D* curvature allowance on impact test transverse test piece

Dimensions in millimeters (inches)

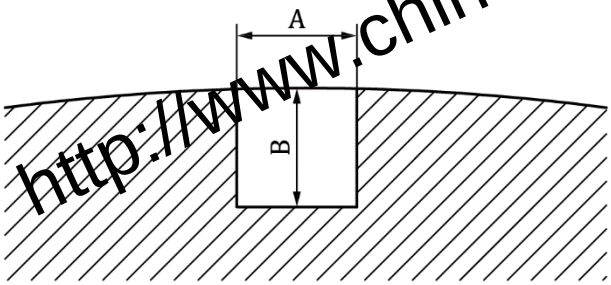


Key
1 pipe end
2 bands denoting material category
3 band denoting material grade

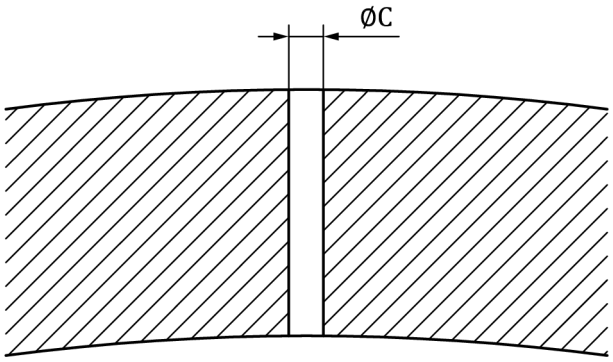
Figure B.7—Position of bands for color coding



a) Notch—Inner surface



b) Notch—Outer surface



c) Radially drilled hole

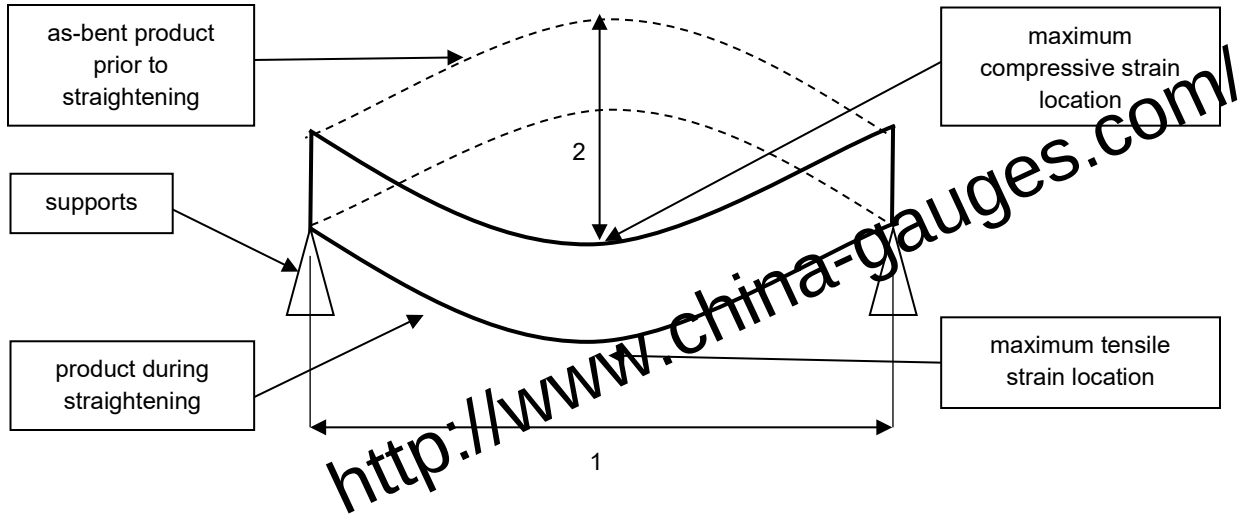
Key

A notch width

B notch depth

C hole diameter

Figure B.8—Non-destructive examination reference indicators



Key

1 distance between straightener product supports

2 maximum applied deflection distance during straightening

Figure B.9—Gag straightening

Annex C
(normative)

Tables in USC units

NOTE The numbers in italics in the table headers indicate column numbers.

Table C.1—Products manufacturing process, starting material, products forming and heat-treatment conditions

Starting material	Products forming conditions	Heat-treatment or cold-hardened conditions	Symbol
1	*2*	*3*	*4*
Ingot/billet or rolled/forged bar	Hot finished — Hot-rolled/forged or — Hot-extruded	Quenched and tempered	QT
		Solution-annealed	SA
Ingot/billet or rolled/forged/machined bar	Cold-hardened [a] — Cold drawing or — Cold pilgering	Cold-hardened	CH
		Solution-annealed	SA
Hot finished hollow	Cold-hardened [a] — Cold drawing or — Cold pilgering	Cold-hardened	CH
		Solution-annealed	SA

[a] For cold-hardened products, the minimum total hot work reduction ratio shall be 3:1. Total hot work reduction ratio is defined as the product of the individual reduction ratios achieved at each step in the hot work operation from ingot or bloom cross-section to final hot work cross-section.

Table C.2—Nominal analysis of corrosion-resistant alloy and material categories

Material			Nominal analysis % mass fraction					Grade						PREN [b] min. number
Group	Structure	Category [a]	C	Cr	Ni	Mo	N	65	80	95	110	125	140	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
1	Martensitic	13-5-2	0.02	13	5	2	—	N	Y	Y	Y	N	N	NA
	Martensitic / ferritic	13-1-0	0.03	13	0.5	—	0.01	N	Y	Y	Y	N	N	NA
2	Duplex austenitic/ ferritic	22-5-3	0.02	22	5	3	0.18	Y	N	N	Y	Y	Y	35
		25-7-3	0.02	25	7	3	0.18	Y	N [c]	N	Y	Y	Y	37.5
	Super-duplex austenitic/ ferritic	25-7-4	0.03	25	7	3.8	0.27	N	Y	N [d]	Y	Y	Y	40
		26-6-3	0.04	25.5	4.75	2.5	1.17	N	Y	Y	Y	Y	Y	40
3	Austenitic Fe base	27-31-4	0.02	27	31	3.5	—	N	N	N	Y	Y	Y	NA
		25-32-3	0.02	25	32	3	—	N	N	N	Y	Y	Y	NA
		22-35-4	0.03	22	35.5	4.5	—	N	N	N	Y	Y	N	NA
4	Austenitic Ni base	21-42-3	0.02	21	42	3	—	N	N	N	Y	Y	N	NA
		22-50-7	0.02	22	50	7	—	N	N	N	Y	Y	Y	NA
		25-50-6	0.03	25	50	6	—	N	N	N	Y	Y	Y	NA
		20-54-9	0.01	20	54	9	Fe = 17	N	N	N	Y	Y	Y	NA
		22-52-11	0.02	21.5	52	11	—	N	N	N	Y	Y	N	NA
		15-60-16	0.01	15	60	16	W = 4	N	N	N	Y	Y	Y	NA

[a] Designation of categories:
- — 1st digit: nominal chromium content;
- — 2nd digit: nominal nickel content;
- — 3rd digit: nominal molybdenum content.

[b] PREN = % Cr + 3.3 (% Mo + 0.5 % W) + 16 % N
Group 2 may contain tungsten.

[c] A 75 grade is available.

[d] A 90 grade is available.

Y: generally available

N: generally not available

NA: not applicable

Table C.3—Mechanical properties at room temperature

Material			Delivery condition	Yield strength [a] $R_{p0.2}$ ksi		Tensile strength [a] R_m ksi	Elongation e [b] %	Mean hardness number HRC
Group	Category	Grade		min.	max.	min.	min.	max.
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
1	13-5-2	80	HF or QT	80	95	95	[c]	27
		95	HF or QT	95	110	105	[c]	28
		110	HF or QT	110	140	115	[c]	32
	13-1-0	80	HF or QT	80	95	95	[c]	23
		95	HF or QT	95	110	105	[c]	26
		110	HF or QT	110	140	120	[c]	32
2	22-5-3	65	SA	65	90	90	25	26
		110	CH	110	140	125	11	36
		125	CH	125	150	130	10	37
		140	CH	140	160	145	9	38
	25-7-3	75	SA	75	100	90	25	26
		110	CH	110	140	125	11	36
		125	CH	125	150	130	10	37
		140	CH	140	160	145	9	38
	25-7-4	80	SA	80	105	110	20	28
		90	SA	90	105	115	20	30
		110	CH	110	140	125	12	36
		125	CH	125	150	130	10	37
		140	CH	140	160	145	9	38
	26-6-3	80	SA	80	105	110	20	28
		90	SA	90	105	115	20	30
		110	CH	110	140	125	12	36
		125	CH	125	150	130	10	37
		140	CH	140	160	145	9	38
3	27-31-4	110	CH	110	140	115	11	35
		125	CH	125	150	130	10	37
		140	CH	140	160	145	9	38
	25-32-3	110	CH	110	140	115	11	35
		125	CH	125	150	130	10	37
		140	CH	140	160	145	9	38
	22-35-4	110	CH	110	140	115	11	35
		125	CH	125	150	130	10	37
		140	CH	140	160	145	9	38

Table C.3—Mechanical properties at room temperature (continued)

Material			Delivery condition	Yield strength [a] $R_{p0.2}$ ksi		Tensile strength [a] R_m ksi	Elongation e [b] %	Mean hardness number HRC
Group	Category	Grade		min.	max.	min.	min.	max.
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
4	21-42-3	110	CH	110	140	115	11	35
		125	CH	125	150	130	10	37
	22-50-7	110	CH	110	140	115	11	35
		125	CH	125	150	130	10	37
		140	CH	140	160	145	9	38
	25-50-6	110	CH	110	140	115	11	35
		125	CH	125	150	130	10	37
		140	CH	140	160	145	9	38
	20-54-9	110	CH	110	140	115	11	35
		125	CH	125	150	130	10	37
		140	CH	140	160	145	9	38
	22-52-11	110	CH	110	140	115	11	35
		125	CH	125	150	130	10	37
		140	CH	140	160	145	9	38
	15-60-16	110	CH	110	140	115	11	35
		125	CH	125	150	130	10	37
		140	CH	140	160	145	9	38

[a] See requirement in 7.2 for relation between tensile and yield strength.

[b] e is the minimum elongation in 2.0 in. gauge length for strip specimens or in 4D or 5D for round bar specimens, expressed in percent.

[c] $e = 625{,}000 \frac{A^{0.2}}{R_m^{0.9}}$

where

A is the cross-sectional area of the tensile test specimen, expressed in square inches, based on the specified outside diameter or nominal specimen width and the specified wall thickness, rounded to the nearest 0.01 in.^{2}, or 0.75 in.^{2}, whichever is smaller;

R_m is the specified minimum tensile strength, expressed in thousand pounds per square inch.

Table C.4—Allowable mean hardness number variation—All categories

Wall thickness t in.		Allowable mean hardness number variation expressed as HRC	
≥	<	Cold-hardened by pilger	All others
1	*2*	*3*	*4*
—	0.354	3	3
0.354	0.500	4	3
0.500	0.750	5	4
0.750	1.000	6	5
1.000	—	6	6

Table C.5—Acceptable size impact specimens and absorbed-energy reduction factor

Test specimen size	Specimen dimensions mm	Absorbed energy reduction factor
1	*2*	*3*
Full size	10.0 × 10.0	1.00
¾-size	10.0 × 7.5	0.80
½-size	10.0 × 5.0	0.55

Table C.6—Hierarchy of test specimen orientation and size

Choice	Orientation	Size
1	*2*	*3*
1st	Transverse	Full size
2nd	Transverse	¾-size
3rd	Transverse	½-size
4th	Longitudinal	Full size [a]
5th	Longitudinal	¾-size [a]
6th	Longitudinal	½-size [a]

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

Table C.7—Transverse impact specimen size required

Label 1	Calculated wall thickness required to machine transverse Charpy impact specimens in.		
	Full size	¾-size	½-size
1	*2*	*3*	*4*
3-½	0.809	0.711	0.612
4	0.752	0.654	0.555
4-½	0.712	0.614	0.515
5	0.681	0.583	0.484
5-½	0.656	0.558	0.459
6-⅝	0.616	0.518	0.419
7	0.606	0.508	0.409
7-⅝	0.591	0.493	0.394
7-¾	0.588	0.490	0.391
8-⅝	0.572	0.474	0.375
9-⅝	0.557	0.459	0.360
10-¾	0.544	0.446	0.347
11-¾	0.535	0.437	0.338
13-⅜	0.522	0.424	0.325

NOTE The above provides a 0.02 in. ID and a 0.02 in. OD machining allowance.

Table C.8—Longitudinal impact specimen size required

Label 1	Calculated wall thickness required to machine longitudinal Charpy impact specimens in.		
	Full size	¾-size	½-size
1	*2*	*3*	*4*
1.050	0.472	0.374	0.275
1.315	0.464	0.366	0.267
1.66	0.458	0.360	0.261
1.9	0.455	0.357	0.258
2.063	0.453	0.355	0.256
2-⅜	0.450	0.352	0.253
2-⅞	0.448	0.350	0.251
3-½	0.445	0.347	0.248
4	0.444	0.346	0.247
4-½	0.443	0.345	0.246
5	0.442	0.344	0.245
5-½	0.441	0.343	0.244
6-⅝	0.440	0.342	0.243
7	0.440	0.342	0.243
7-⅝	0.439	0.341	0.242
7-¾	0.439	0.341	0.242
8-⅝	0.439	0.341	0.242
9-⅝	0.438	0.340	0.241
10-¾	0.438	0.340	0.241
11-¾	0.437	0.339	0.240
13-⅜	0.437	0.339	0.240

NOTE The above provides a 0.020 in. ID and a 0.020 in. OD machining allowance.

Table C.9—Transverse Charpy absorbed-energy requirements with full-size test specimens for coupling stock and accessory material, group 1

Maximum critical thickness for various grades [a] in.			Minimum transverse absorbed energy ft-lb
80	**95**	**110**	
1	*2*	*3*	*4*
1.621	1.343	0.965	29
—	—	1.012	30

[a] For wall thickness greater than shown above, the requirements shall be according to the formula for the critical thickness and grade.

Table C.10—Longitudinal Charpy absorbed-energy requirements with full-size test specimens for coupling stock and accessory material, group 1

Maximum critical thickness for various grades [a] in.			Minimum longitudinal absorbed energy ft-lb
80	**95**	**110**	
1	*2*	*3*	*4*
1.621	1.343	0.965	29
—	—	1.012	30

[a] For wall thickness greater than shown above, the requirements shall be according to the formula for the wall thickness and grade.

Table C.11—Transverse Charpy absorbed-energy requirements with full-size test specimens for coupling stock and accessory material, groups 2, 3 and 4

Maximum critical thickness for various grades [a] in.						Minimum transverse absorbed energy ft-lb
65	**75**	**80 and 90**	**110**	**125**	**140**	
1	*2*	*3*	*4*	*5*	*6*	*7*
1.077	0.927	0.863	0.542	0.478	0.421	20
	0.993	0.926	0.589	0.521	0.462	21
	1.059	0.988	0.636	0.565	0.504	22
		1.051	0.683	0.609	0.545	23
			0.730	0.653	0.586	24
			0.777	0.697	0.627	25
			0.824	0.741	0.668	26
			0.871	0.785	0.709	27
			0.918	0.828	0.750	28
—	—	—	0.965	0.872	0.791	29
			1.012	0.916	0.833	30
				0.960	0.874	31
				1.004	0.915	32
			—		0.956	33
				—	0.997	34
					1.038	35

[a] For wall thickness greater than shown above, the requirements shall be according to the formula for the wall thickness and grade.

Table C.12—Transverse Charpy absorbed-energy requirements with full-size test specimens for pipe, group 1

Maximum critical thickness for various grades [a] in.			Minimum transverse absorbed energy ft-lb
80	**95**	**110**	
1	*2*	*3*	*4*
2.004	1.621	1.343	29

[a] For wall thicknesses greater than shown above, the requirements shall be according to the formula for the wall thickness and grade.

Table C.13—Longitudinal Charpy absorbed-energy requirements with full-size test specimens for pipe, group 1

Maximum specified wall thickness for various grades [a] in.			Minimum longitudinal absorbed energy ft-lb
80	**95**	**110**	
1	*2*	*3*	*4*
2.004	1.621	1.343	29

[a] For wall thicknesses greater than shown above, the requirements shall be according to the formula for the wall thickness and grade.

Table C.14—Transverse Charpy absorbed-energy requirements with full-size test specimens for pipe, groups 2, 3 and 4

Maximum specified wall thickness for various grades [a] in							Minimum transverse absorbed energy ft-lb
65	**75**	**80**	**90**	**110**	**125**	**140**	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1.653	1.377	1.264	1.077	0.805	0.657	0.542	20
				0.864	0.710	0.589	21
				0.924	0.763	0.636	22
				0.984	0.815	0.683	23
				1.044	0.868	0.730	24
					0.921	0.777	25
					0.973	0.824	26
					1.026	0.871	27
—	—	—	—	—		0.918	28
					—	0.965	29
						1.012	30

[a] Wall thicknesses greater than standard pipe are shown here for information for special applications. For wall thickness greater than shown above, the requirements shall be according to the formula for the wall thickness and grade.

Table C.15—Charpy absorbed-energy requirements at low temperature with full-size test specimens for group 2

Test temperature °F	Longitudinal absorbed energy ft-lb		Transverse absorbed energy ft-lb	
	Average min.	Individual min.	Average min.	Individual min.
1	*2*	*3*	*4*	*5*
−50	48	37	33	26

Table C.16—Specified dimensions and masses of pipe

Label 1	Label 2	Outside diameter *D* in.	Wall thickness *t* in.	Inside diameter [a] *d* in.	Drift diameter [b] in.	Alternative drift diameter in.	Linear mass [c] plain end *m* lb/ft
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1.050	1.14	1.050	0.113	0.824	0.730	—	1.13
1.050	1.48	1.050	0.154	0.742	0.648	—	1.48
1.315	1.70	1.315	0.133	1.049	0.955	—	1.68
1.315	2.19	1.315	0.179	0.957	0.863	—	2.17
1.660	2.09	1.660	0.125	1.410	1.316	—	2.05
1.660	2.30	1.660	0.140	1.380	1.286	—	2.27
1.660	3.03	1.660	0.191	1.278	1.184	—	3.00
1.900	2.40	1.900	0.125	1.650	1.556	—	2.37
1.900	2.75	1.900	0.145	1.610	1.516	—	2.72
1.900	3.65	1.900	0.200	1.500	1.406	—	3.63
1.900	4.42	1.900	0.250	1.400	1.306	—	4.41
1.900	5.15	1.900	0.300	1.300	1.206	—	5.13
2.063	3.24	2.063	0.156	1.751	1.657	—	3.18
2.063	4.50	2.063	0.225	1.613	1.519	—	4.42
2-⅜	4.00	2.375	0.167	2.041	1.947	—	3.94
2-⅜	4.60	2.375	0.190	1.995	1.901	—	4.44
2-⅜	5.80	2.375	0.254	1.867	1.773	—	5.76
2-⅜	6.60	2.375	0.295	1.785	1.691	—	6.56
2-⅜	7.35	2.375	0.336	1.703	1.609	—	7.32
2-⅞	6.40	2.875	0.217	2.441	2.347	—	6.17
2-⅞	7.80	2.875	0.276	2.323	2.229	—	7.67
2-⅞	8.60	2.875	0.308	2.259	2.165	—	8.45

Table C.16—Specified dimensions and masses of pipe (continued)

Label 1	Label 2	Outside diameter *D* in.	Wall thickness *t* in.	Inside diameter [a] *d* in.	Drift diameter [b] in.	Alternative drift diameter in.	Linear mass [c] plain end *m* lb/ft
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
2-⅞	9.35	2.875	0.340	2.195	2.101	—	9.21
2-⅞	10.50	2.875	0.392	2.091	1.997	—	10.40
2-⅞	11.50	2.875	0.440	1.995	1.901	—	11.45
3-½	7.70	3.500	0.216	3.068	2.943	—	7.58
3-½	9.20	3.500	0.254	2.992	2.867	—	8.81
3-½	10.20	3.500	0.289	2.922	2.797	—	9.92
3-½	12.70	3.500	0.375	2.750	2.625	—	12.53
3-½	14.30	3.500	0.430	2.640	2.515	—	14.11
3-½	15.50	3.500	0.476	2.548	2.423	—	15.39
3-½	17.00	3.500	0.530	2.440	2.315	—	16.83
4	9.50	4.000	0.226	3.548	3.423	—	9.12
4	10.70	4.000	0.262	3.476	3.351	—	10.47
4	13.20	4.000	0.330	3.340	3.215	—	12.95
4	16.10	4.000	0.415	3.170	3.045	—	15.90
4	18.90	4.000	0.500	3.000	2.875	—	18.71
4	22.20	4.000	0.610	2.780	2.655	—	22.11
4-½	9.50	4.500	0.205	4.090	3.965	—	9.41
4-½	10.50	4.500	0.224	4.052	3.927	—	10.24
4-½	11.60	4.500	0.250	4.000	3.875	—	11.36
4-½	12.60	4.500	0.271	3.958	3.833	—	12.25
4-½	13.50	4.500	0.290	3.920	3.795	—	13.05
4-½	15.10	4.500	0.337	3.826	3.701	—	15.00
4-½	17.00	4.500	0.380	3.740	3.615	—	16.74
4-½	18.90	4.500	0.430	3.640	3.515	—	18.71
4-½	21.50	4.500	0.500	3.500	3.375	—	21.38
4-½	23.70	4.500	0.560	3.380	3.255	—	23.59
4-½	26.10	4.500	0.630	3.240	3.115	—	26.06
5	11.50	5.000	0.220	4.560	4.435	—	11.24
5	13.00	5.000	0.253	4.494	4.369	—	12.84
5	15.00	5.000	0.296	4.408	4.283	—	14.88

Table C.16—Specified dimensions and masses of pipe (continued)

Label 1	Label 2	Outside diameter *D* in.	Wall thickness *t* in.	Inside diameter [a] *d* in.	Drift diameter [b] in.	Alternative drift diameter in.	Linear mass, plain end *m* lb/ft
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
5	18.00	5.000	0.362	4.276	4.151	—	17.95
5	21.40	5.000	0.437	4.126	4.001	—	21.32
5	23.30	5.000	0.478	4.044	3.919	—	23.11
5	24.10	5.000	0.500	4.000	3.875	—	24.05
5-½	14.00	5.500	0.244	5.012	4.887	—	13.71
5-½	15.50	5.500	0.275	4.950	4.825	—	15.36
5-½	17.00	5.500	0.304	4.892	4.767	—	16.89
5-½	20.00	5.500	0.361	4.778	4.653	—	19.83
5-½	23.00	5.500	0.415	4.670	4.545	—	22.56
5-½	26.80	5.500	0.500	4.500	4.375	—	26.73
5-½	29.70	5.500	0.562	4.376	4.251	—	29.67
5-½	32.60	5.500	0.625	4.250	4.125	—	32.57
5-½	35.30	5.500	0.687	4.126	4.001	—	35.35
5-½	38.00	5.500	0.750	4.000	3.875	—	38.08
5-½	40.50	5.500	0.812	3.876	3.751	—	40.69
5-½	43.10	5.500	0.875	3.750	3.625	—	43.26
6-⅝	20.00	6.625	0.288	6.049	5.924	—	19.51
6-⅝	24.00	6.625	0.352	5.921	5.796	—	23.60
6-⅝	28.00	6.625	0.417	5.791	5.666	—	27.67
6-⅝	32.00	6.625	0.475	5.675	5.550	—	31.23
7	17.00	7.000	0.231	6.538	6.413	—	16.72
7	20.00	7.000	0.272	6.456	6.331	—	19.56
7	23.00	7.000	0.317	6.366	6.241	6.250	22.65
7	26.00	7.000	0.362	6.276	6.151	—	25.69
7	29.00	7.000	0.408	6.184	6.059	—	28.75
7	32.00	7.000	0.453	6.094	5.969	6.000	31.70
7	35.00	7.000	0.498	6.004	5.879	—	34.61
7	38.00	7.000	0.540	5.920	5.795	—	37.29
7	42.70	7.000	0.625	5.750	5.625	—	42.59
7	46.40	7.000	0.687	5.626	5.501	—	46.36

Table C.16—Specified dimensions and masses of pipe (continued)

Label 1	Label 2	Outside diameter *D* in.	Wall thickness *t* in.	Inside diameter [a] *d* in.	Drift diameter [b] in.	Alternative drift diameter in.	Linear mass, plain end *m* lb/ft
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
7	50.10	7.000	0.750	5.500	5.375	—	50.11
7	53.60	7.000	0.812	5.376	5.251	—	53.71
7	57.10	7.000	0.875	5.250	5.125	—	57.29
7-⅝	24.00	7.625	0.300	7.025	6.900	—	23.49
7-⅝	26.40	7.625	0.328	6.969	6.844	—	25.59
7-⅝	29.70	7.625	0.375	6.875	6.750	—	29.06
7-⅝	33.70	7.625	0.430	6.765	6.640	—	33.07
7-⅝	39.00	7.625	0.500	6.625	6.500	—	38.08
7-⅝	42.80	7.625	0.562	6.501	6.376	—	42.43
7-⅝	45.30	7.625	0.595	6.435	6.310	—	44.71
7-⅝	47.10	7.625	0.625	6.375	6.250	—	46.77
7-⅝	51.20	7.625	0.687	6.251	6.126	—	50.95
7-⅝	55.30	7.625	0.750	6.125	6.000	—	55.12
7-¾	46.10	7.750	0.595	6.560	6.435	6.500	45.51
8-⅝	24.00	8.625	0.264	8.097	7.972	—	23.60
8-⅝	28.00	8.625	0.304	8.017	7.892	—	27.04
8-⅝	32.00	8.625	0.352	7.921	7.796	7.875	31.13
8-⅝	36.00	8.625	0.400	7.825	7.700	—	35.17
8-⅝	40.00	8.625	0.450	7.725	7.600	7.625	39.33
8-⅝	44.00	8.625	0.500	7.625	7.500	—	43.43
8-⅝	49.00	8.625	0.557	7.511	7.386	—	48.04
9-⅝	32.30	9.625	0.312	9.001	8.845	—	31.06
9-⅝	36.00	9.625	0.352	8.921	8.765	—	34.89
9-⅝	40.00	9.625	0.395	8.835	8.679	8.750	38.97
9-⅝	43.50	9.625	0.435	8.755	8.599	—	42.73
9-⅝	47.00	9.625	0.472	8.681	8.525	—	46.18
9-⅝	53.50	9.625	0.545	8.535	8.379	8.500	52.90
9-⅝	58.40	9.625	0.595	8.435	8.279	8.375	57.44
9-⅝	59.40	9.625	0.609	8.407	8.251	—	58.70
9-⅝	64.90	9.625	0.672	8.281	8.125	—	64.32

Table C.16—Specified dimensions and masses of pipe (continued)

Label 1	Label 2	Outside diameter *D* in.	Wall thickness *t* in.	Inside diameter [a] *d* in.	Drift diameter [b] in.	Alternative drift diameter in.	Linear mass [c] plain end *m* lb/ft
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
9-⅝	70.30	9.625	0.734	8.157	8.001	—	69.76
9-⅝	75.60	9.625	0.797	8.031	7.875	—	75.21
10-¾	32.75	10.750	0.279	10.192	10.036	—	31.23
10-¾	40.50	10.750	0.350	10.050	9.894	—	38.91
10-¾	45.50	10.750	0.400	9.950	9.794	9.875	44.26
10-¾	51.10	10.750	0.450	9.850	9.694	—	49.55
10-¾	55.50	10.750	0.495	9.760	9.604	9.625	54.26
10-¾	60.70	10.750	0.545	9.660	9.504	—	59.45
10-¾	65.70	10.750	0.595	9.560	9.404	—	64.59
10-¾	73.20	10.750	0.672	9.406	9.250	—	72.40
10-¾	79.20	10.750	0.734	9.282	9.126	—	78.59
10-¾	85.30	10.750	0.797	9.156	9.000	—	84.80
11-¾	42.00	11.750	0.333	11.084	10.928	11.000	40.64
11-¾	47.00	11.750	0.375	11.000	10.844	—	45.60
11-¾	54.00	11.750	0.435	10.880	10.724	—	52.62
11-¾	60.00	11.750	0.489	10.772	10.616	10.625	58.87
11-¾	65.00	11.750	0.534	10.682	10.526	10.625	64.03
11-¾	71.00	11.750	0.582	10.586	10.430	—	69.48
13-⅜	48.00	13.375	0.330	12.715	12.559	—	46.02
13-⅜	54.50	13.375	0.380	12.615	12.459	—	52.79
13-⅜	61.00	13.375	0.430	12.515	12.359	—	59.50
13-⅜	68.00	13.375	0.480	12.415	12.259	—	66.17
13-⅜	72.00	13.375	0.514	12.347	12.191	12.250	70.67

[a] $d = D - 2t$.

[b] The drift diameter is equal to *d* minus a constant (see Table C.19).

[c] $m = 10.690 \times (D - t) \times t$; see 8.1.1 for the multiplication factors with regard to the groups.

Table C.17—Length requirements

Dimensions in feet

Pipes for		Range 1 [b] (R1)	Range 2 [b] (R2)	Range 3 [b] (R3)
1		*2*	*3*	*4*
Casing and tubing	Total range length, inclusive	16.0 to 25.0	25.0 to 34.0	34.0 to 48.0
	Maximum permissible variation on 100 % of each order item of 40,000 lb or more	5.0		
Pup joints	Length [a,b]	2; 3; 4; 6; 8; 10; 12		
	Tolerance	±0.25		
Coupling stock and accessory material		By agreement		

[a] 2 ft pup joints may be furnished up to 3 ft long by agreement between manufacturer and purchaser.

[b] Lengths other than those listed may be furnished by agreement between manufacturer and purchaser.

Table C.18—Tolerances on dimensions and mass

Outside diameter *D* in.	Tolerance for supply condition					
	Outside diameter [a]		Wall thickness		Mass [b]	
	QT — SA	CH	QT — SA	CH	QT — SA	CH
1	*2*	*3*	*4*	*5*	*6*	*7*
< 4-½	±0.031 in.	±0.031 in.	$^{-}_{-12.5}$ %	$^{-}_{-10}$ %	$^{+6.5}_{-3.5}$ %	$^{+6.5}_{-3.5}$ %
≥ 4-½	$^{+1}_{-0.5}$ %	$^{+1}_{-0.5}$ %	$^{-}_{-12.5}$ %	$^{-}_{-10}$ %	$^{+6.5}_{-3.5}$ %	$^{+6.5}_{-3.5}$ %

[a] Out-of-roundness is included in the *D* tolerance.

[b] The tolerance is quoted for a single length. On each order item of 40,000 lb or more, the tolerance is −1.75 %.

Table C.19—Standard drift mandrel dimensions

Dimension in inches

Pipes for	Outside diameter *D*		Drift mandrel size minimum	
	>	≤	Length	Diameter
1	*2*	*3*	*4*	*5*
Casing	—	8-⅝	6	*d* − 0.125
	8-⅝	—	12	*d* − 0.156
Tubing	—	2-⅞	42	*d* − 0.094
	2-⅞	—	42	*d* − 0.125

NOTE *d* is given in Table C.16.

Table C.20—Alternative drift mandrel dimensions

Label 1	Label 2	Outside diameter *D* in.	Wall thickness *t* in.	Drift mandrel size minimum		Linear mass, plain end *m* lb/ft
				Length [a] in.	Diameter in.	
1	*2*	*3*	*4*	*5*	*6*	*7*
7	23.00	7.000	0.317	6	6.250	22.65
7	32.00	7.000	0.453	6	6.000	31.70
7-¾	46.10	7.750	0.595	6	6.500	45.51
8-⅝	32.00	8.625	0.352	6	7.875	31.13
8-⅝	40.00	8.625	0.450	6	7.625	39.33
9-⅝	40.00	9.625	0.395	12	8.750	38.97
9-⅝	53.50	9.625	0.545	12	8.500	52.90
9-⅝	58.40	9.625	0.595	12	8.375	57.44
10-¾	45.50	10.750	0.400	12	9.875	44.26
10-¾	55.50	10.750	0.495	12	9.625	54.26
11-¾	42.00	11.750	0.333	12	11.000	40.64
11-¾	60.00	11.750	0.489	12	10.625	58.87
11-¾	65.00	11.750	0.534	12	10.625	64.03
13-⅜	72.00	13.375	0.514	12	12.250	70.67

[a] For tubing, minimum drift mandrel length shall be 42 in.

Table C.21—Type and frequency of tests for non-upset and upset products

Type of test or requirements		Test requirements	Frequency of testing [b]	Test methods	Requirements
1		*2*	*3*	*4*	*5*
Heat analysis		m [d]	1 per heat	9.3.2	7.1
Product analysis	Non-remelted alloy	m [d]	2 per heat	9.3.2	7.1
	Remelted alloy	m [d]	1 per ingot	9.3.2	7.1
Chromium depletion test		o [d,e]	1 per test lot [c]	9.3.3	9.3.3
Room-temperature tensile test		m [d]	1 per test lot [c]	9.5.2	7.2
Elevated-temperature tensile test		o [d]	1 per test lot [c]	9.5.2	7.2
Hardness test		m [d]	1 series/test lot [c]	9.6.2	7.3
Impact or flattening test		m [d]	9.7.2	9.7.3 or 9.7.4.1	7.4, 7.5, 7.6, 7.7
Impact test at low temperature		o [h]	1 per test lot	9.8	7.8
Pitting corrosion test		o [h]	1 per test lot	9.9	7.9.2
Microstructure examination		m [d]	1 per test lot [c]	9.10.2	7.10
Visual inspection		m	Each length	9.16	7.11, 7.12, 8.4
PMI		m (o [f])	Each length	9.18	9.18
Dimensional testing:					
— Outside diameter		m	Each end of each length	9.11.2	Table C.16 and Table C.18
— Wall thickness		m	Each end of each length	9.11.3	Table C.16 and Table C.18
— Drift test		m	Each pipe	9.12	Tables C15 and Table C.19 or Table C.20
— Length		m [d]	Each length	9.13	Table C.17
— Straightness		m	Each pipe	9.14	8.3.3
— Mass		m	Each pipe	9.15	Table C.16 and Table C.18
Non-destructive examination:					
— UT for longitudinal defects		m [d]	Each length	9.17.9, 9.17.10	7.12
— UT for transverse defects		m [d]	Each length	9.17.9, 9.17.10	7.12
— UT for laminar defects		m [d]	Each length	9.17.9, 9.17.10	7.12
— UT for oblique defects		m [a]	Each length	9.17.10	7.12
— UT for wall thickness		m [d]	Each length	9.11.4; 9.17	7.12; 8.1; 8.3.1
— EMI		o [d,f]	Each length	9.17.9	7.12
— MT		o [f]	Each length	9.17.9	7.12
— NDE of untested ends		m [g]	Each length	9.17.5	7.12
— NDE of upset ends		m	Each upset length	9.17.6	7.12
— Disposition of defects		m	Each length containing defects	9.17.13, 9.17.14	7.12

[a] Mandatory for groups 2, 3 and 4 PSL-2 only.
[b] For definition of “test lot”, see 3.1.22. See Table C.22 for the maximum number of lengths in a test lot.
[c] Minimum 1 per heat.
[d] It is required that data records be retained.
[e] Option for groups 2, 3 and 4 only.
[f] Option for group 1 only.
[g] When NDE on untested end is applied in lieu of cropping untested end.
[h] Option for group 2 only.
m: mandatory
o: optional (an agreement is required)

Table C.22—Maximum number of lengths per test lot

Group	Number [a] of lengths for	
	Pipe	Coupling stock and accessory material
1	*2*	*3*
1	100	20
2, 3, 4	50	10

NOTE For the pup joints, see 9.2.

[a] Residual quantities of less than 20 % of the maximum number of lengths per test lot may be added to one test lot per heat.

Table C.23—Artificial reference indicator

Acceptance inspection level	Notch depth [a] max.	Notch length (max. at full depth)	Width max.	Radially drilled hole diameter [b]
1	*2*	*3*	*4*	*5*
U2/F2/E2	5 %	2.0 in.	0.040 in.	1/16 in.

NOTE See Figure B.8.

[a] Depth as a percent of specified wall thickness. The depth tolerance shall be ±15 % of the calculated notch depth with a minimum notch depth of 0.012 in. ±0.002 in.

[b] Drilled hole diameter (through the pipe wall) shall be based on the drill bit size.

Table C.24—Acceptance level

Group	NDT method	External imperfection			Internal imperfection		
		Longitudinal	Transverse	Oblique	Longitudinal	Transverse	Oblique
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1	UT	U2	U2	—	U2	U2	—
	Second method [b]	F2 or E2	F2 or E2	—	—	—	—
2, 3, 4	UT	U2	U2	U2 [a]	U2	U2	U2 [a]

[a] For PSL-2 product only.

[b] For optional second method, see 9.17.9.

Table C.25—Marking height

Dimensions in inches

D	Minimum height of marking	
	Die stamping	Paint or ink stencilling
1	*2*	*3*
≤ 4	0.157	≥ 0.315
> 4	0.236	≥ 0.472

Table C.26—Color coding for material category

Material category	Color coding
1	*2*
13-5-2	white and green
13-1-0	white and red
22-5-3	red and red
25-7-3	red and orange
25-7-4	red and yellow
26-6-3	green and green
27-31-4	green and brown
25-32-3	green and orange
22-35-4	white and blue
21-42-3	yellow and yellow
22-50-7	yellow and orange
25-50-6	yellow and green
20-54-9	yellow and blue
22-52-11	white and brown
15-60-16	yellow and brown

Table C.27—Color coding for material grade

Material grade	Color coding
1	*2*
65	yellow
75	blue
80	red
90	brown
95	silver
110	white
125	orange
140	green

Table C.28—PSL-2 product mechanical properties at room temperature

Material identity		UNS number	Grade	Delivery condition	Yield strength [a,d] $R_{p0.2}$ ksi		Tensile strength [a] R_m ksi	Elongation e [b] %	Mean hardness number [d] HRC
Group	Category				min.	max.	min.	min.	max.
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1	13-5-2	S41426	80	QT	80	95	90	[c]	27
			95	QT	95	105	105	[c]	27
2	22-5-3	S31803	65	SA	65	90	90	25	26
			110	CH	110	140	125	11	36
			125	CH	125	145	130	10	36
	25-7-3	S31260	75	SA	75	100	90	25	26
			110	CH	110	140	125	11	36
			125	CH	125	145	130	10	36
	25-7-4	S32750	80	SA	80	105	110	20	28
			90	SA	90	105	115	20	30
			110	CH	110	140	125	12	36
			125	CH	125	145	130	10	36
		S32760	80	SA	80	105	110	20	28
			90	SA	90	105	115	20	30
			110	CH	110	140	125	12	36
			125	CH	125	145	130	10	36
		S39274	80	SA	80	105	110	20	28
			90	SA	90	105	115	20	30
			110	CH	110	140	125	12	36
			125	CH	125	145	130	10	36
3	27-31-4	N08028	110	CH	110	140	115	11	33
			125	CH	125	145	130	10	35
	25-32-3	N08535	110	CH	110	140	115	11	33
			125	CH	125	145	130	10	35
	22-35-4	N08135	110	CH	110	140	115	11	33
4	21-42-3	N08825	110	CH	110	140	115	11	35
			125	CH	125	145	130	10	35
	22-50-7	N06985	110	CH	110	140	115	11	35
			125	CH	125	150	130	10	37
	25-50-6	N06255	110	CH	110	140	115	11	35
			125	CH	125	150	130	10	37
		N06975	110	CH	110	140	115	11	35
			125	CH	125	150	130	10	37
	20-54-9	N06950	110	CH	110	140	115	11	35
			125	CH	125	150	130	10	37
	15-60-16	N10276	110	CH	110	140	115	11	35
			125	CH	125	150	130	10	37
			140	CH	140	160	145	9	38

[a] See requirement in 7.2 for relation between tensile and yield strength.

[b] e is the minimum elongation in 2.0 in. gauge length for strip specimens or in 4D or 5D for round bar specimens, expressed in percent.

[c] $$e = 625{,}000\frac{A^{0.2}}{R_m^{0.9}}$$

where

A is the cross-sectional area of the tensile test specimen, expressed in square inches, based on specified outside diameter or nominal specimen width and specified wall thickness, rounded to the nearest 0.01 in.^{2}, or 0.75 in.^{2}, whichever is smaller;

R_m is the specified minimum tensile strength, expressed in thousand pounds per square inch

[d] Other values may be agreed between purchaser and manufacturer, subject to the requirements in G.2.

Table C.29—PSL-2 chemical composition of corrosion-resistant alloy and material categories

Material identity			UNS number	Chemical composition maximum % mass fraction or range, unless otherwise indicated																PREN [b] range no.
Group	Structure	Category [a]		C	Cr	Ni [c]	Fe [c]	Mn	Si	Mo	Co	Cu	P	S	Ti	Nb + Ta	V	W	N	Al	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*
1	Martensitic	13-5-2	S41426	0.03	11.5 to 13.5	4.5 to 6.5	bal.	0.50	0.50	1.5 to 3.0	—	—	0.02	0.005	0.01 to 0.50	—	0.50	—	—	—	NA
2	Duplex austenitic/ ferritic	22-5-3	S31803	0.030	21.0 to 23.0	4.50 to 6.50	bal.	2.00	1.00	2.50 to 3.50	—	—	0.030	0.020	—	—	—	—	0.08 to 0.20	—	35 to 40.0
		25-7-3	S31260	0.03	24.0 to 26.0	5.50 to 7.50	bal.	1.00	0.75	2.50 to 3.50	—	0.20 to 0.80	0.030	0.030	—	—	—	0.10 to 0.50	0.10 to 0.30	—	37.5 to 40.0
	Super-duplex austenitic/ ferritic	25-7-4	S32750	0.030	24.0 to 26.0	6.0 to 8.0	bal.	1.20	0.8	3.0 to 5.0	—	—	0.035	0.020	—	—	—	—	0.24 to 0.32	—	> 40.0 to ≤ 45
			S32760	0.03	24.0 to 26.0	6.0 to 8.0	bal.	1.0	1.0	3.0 to 4.0	—	0.5 to 1.0	0.03	0.01	—	—	—	0.5 to 1.0	0.2 to 0.3	—	> 40.0 to ≤ 45
			S39274	0.030	24.0 to 26.0	6.0 to 8.0	bal.	1.0	0.80	2.50 to 3.50	—	0.20 to 0.80	0.030	0.020	—	—	—	1.50 to 2.50	0.24 to 0.32	—	> 40.0 to ≤ 45
3	Austenitic Fe base	27-31-4	N08028	0.03	26.0 to 28.0	30.0 to 32.5	bal.	2.50	1.00	3.0 to 4.0	—	0.6 to 1.4	0.030	0.030	—	—	—	—	—	—	NA
		25-32-3	N08535	0.030	24.0 to 27.0	29.0 to 36.5 [d]	bal.	1.00	0.50	2.5 to 4.0	[d]	1.50	0.03	0.03	—	—	—	—	—	—	NA
		22-35-4	N08135	0.03	20.5 to 23.5	33.0 to 38.0	bal.	1.00	0.75	4.0 to 5.0	—	0.70	0.03	0.03	—	—	—	0.20 to 0.80	—	—	NA

Table C.29—PSL-2 chemical composition of corrosion-resistant alloy and material categories (continued)

Material identity			UNS number	Chemical composition maximum % mass fraction or range, unless otherwise indicated																	PREN [b] range no.
Group	Structure	Category [a]		C	Cr	Ni [c]	Fe [c]	Mn	Si	Mo	Co	Cu	P	S	Ti	Nb + Ta	V	W	N	Al	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*
4	Austenitic Ni base	21-42-3	N08825	0.05	19.5 to 23.5	38.0 to 46.0	bal.	1.00	0.5	2.5 to 3.5	—	1.5 to 3.0	0.03	0.03	0.6 to 1.2	—	—	—	—	0.2	NA
		22-50-7	N06985	0.015	21.0 to 23.5	bal.	18.0 to 21.0	1.00	1.00	6.0 to 8.0	5.0	1.5 to 2.5	0.04	0.03	—	0.50	—	1.5	—	—	NA
		25-50-6	N06255	0.03	23.0 to 26.0	47.0 to 52.0	bal.	1.00	1.00	6.0 to 9.0	—	1.20	0.03	0.03	0.69	—	—	3.0	—	—	NA
			N06975	0.03	23.0 to 26.0	47.0 to 52.0	bal.	1.00	1.00	5.0 to 7.0 [e]	—	0.70 to 1.20	0.03	0.03	0.70 to 1.50	—	—	[e]	—	—	NA
		20-54-9	N06950	0.015	19.0 to 21.0	50.0 min	15.0 to 20.0	1.00	1.00	8.0 to 10.0	2.5	0.5	0.04	0.015	—	0.50 [g]	0.04	1.0	—	—	NA
		15-60-16	N10276	0.02	14.5 to 16.5	bal. [f]	4.0 to 7.0	1.00	0.08	15.0 to 17.0	2.5 [f]	—	0.030	0.030	—	—	0.35	3.0 to 4.5	—	—	NA

[a] Designation of categories: 1st digit: nominal chromium content; 2nd digit: nominal nickel content; 3rd digit: nominal molybdenum content.

[b] PREN = % Cr + 3.3 (% Mo + 0.5 % W) + 16 % N.

[c] Bal. is the balance of composition up to 100 %, determined arithmetically by difference.

[d] Ni + Co = 29.5 % minimum.

[e] When specified, Mo + W = 6 % minimum.

[f] Ni + Co = 52 % minimum.

[g] Nb = 0.50 % minimum. Analysis of Ta is not required.

Table C.30—Chemical composition of corrosion-resistant alloy and material categories for bar or drilled bar, groups 1 and 2

Material identity			UNS number	Chemical composition [d] maximum % mass fraction or range, unless otherwise indicated														PREN [b,d] range no.
Group	Structure	Category [a]		C	Cr	Ni	Fe [c]	Mn	Si	Mo	Cu	P	S	Ti	V	W	N	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*
1	Martensitic	13-5-2	S41425	0.050	12.00 to 15.00	4.0 to 7.0	bal.	0.50 to 1.00	0.5	1.50 to 2.00	0.30	0.020	0.005	—	—	—	0.06 to 0.12	NA
			S41426	0.03	12.5 to 13.5	4.5 to 6.5	bal.	0.50	0.50	1.5 to 3.0	—	0.02	0.005	0.01 to 0.50	0.50	—	—	NA
			S41427	0.03	11.5 to 13.5	4.5 to 6.0	bal.	1.0	0.50	1.5 to 2.5	—	0.02	0.005	0.01	0.10 to 0.50	—	—	NA
2	Duplex austenitic/ ferritic	22-5-3	S31803	0.030	21.0 to 23.0	4.50 to 6.50	bal.	2.00	1.00	2.50 to 3.50	—	0.030	0.020	—	—	—	0.08 to 0.20	35 to 40.0
			S32205	0.030	22.0 to 23.0	4.50 to 6.50	bal.	2.00	1.00	3.00 to 3.50	—	0.030	0.020	—	—	—	0.14 to 0.20	35 to 40.0
	Super-duplex austenitic/ ferritic	25-7-4	S32550	0.04	24.0 to 27.0	4.50 to 6.50	bal.	1.5	1.00	2.9 to 3.9	1.50 to 2.50	0.04	0.030	—	—	—	0.10 to 0.25	> 40.0 to ≤ 45
			S32750	0.030	24.0 to 26.0	6.0 to 8.0	bal.	1.20	0.8	3.0 to 5.0	—	0.035	0.020	—	—	—	0.24 to 0.32	> 40.0 to ≤ 45
			S32760	0.03	24.0 to 26.0	6.0 to 8.0	bal.	1.0	1.0	3.0 to 4.0	0.5 to 1.0	0.03	0.01	—	—	0.5 to 1.0	0.2 to 0.3	> 40.0 to ≤ 45
			S39277	0.025	24.0 to 26.0	6.5 to 8.0	bal.	0.80	0.80	3.0 to 4.0	1.2 to 2.0	0.025	0.002	—	—	0.80 to 1.20	0.23 to 0.33	> 40.0 to ≤ 45

[a] Designation of categories: 1st digit: nominal chromium content; 2nd digit: nominal nickel content; 3rd digit: nominal molybdenum content.
[b] PREN = % Cr + 3.3 (% Mo + 0.5 % W) + 16 % N.
[c] Bal. is the balance of composition up to 100 %, determined arithmetically by difference.
[d] Chemical composition and PREN meet both PSL-1 and PSL-2.

Table C.31—Product mechanical properties at room temperature for bar or drilled bar, groups 1 and 2

Material identity		UNS number	Grade	Delivery condition	Yield strength $R_{p0.2}$ ksi		Tensile strength R_m ksi	Elongation e %	Reduction of area [a] Z %	Mean hardness number [b] HRC	PSL
Group	Category				min.	max.	min.	min.	min.	max.	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
1	13-5-2	S41425	95	QT	95	115	105	20	40	29	1
			95	QT	95	112	105	20	40	28	2
			110	QT	110	130	125	15	40	32	1
		S41426	95	QT	95	115	105	20	40	29	1
			110	QT	110	130	125	15	40	32	1
		S41427	95	QT	95	115	105	20	40	29	1
			95	QT	95	112	105	20	40	29	2
			110	QT	110	130	125	15	40	32	1
2	22-5-3	S31803	65	SA	65	90	90	25	45	26	2
		S32205	65	SA	65	90	95	25	45	26	2
	25-7-4	S32550	80	SA	80	105	109	25	45	28	2
		S32750	80	SA	80	105	109	25	45	28	2
		S32760	80	SA	80	105	109	25	45	28	2
		S39277 [c]	80	SA	80	105	109	25	45	28	2
			85	SA	85	105	115	25	45	28	2

[a] Reduction of area requirement may be waived for use of strip tensile or product tested in full section.

[b] The conversion of hardness readings to or from other scales is material-dependent. Equivalent HBW hardness acceptance criteria can be by agreement between manufacturer and purchaser developed based on data available for the specific grade. In case of a dispute, HRC method shall be used as the acceptance of a material. When a conversion is utilized, the conversion method shall be documented and traceable to test results (see F.3.4). For reporting converted hardness numbers, see F.7.3.

[c] S39277 grade 85 also meets the requirements of grade 80.

Table C.32—Longitudinal Charpy absorbed-energy requirements with full-size test specimens for bar or drilled bar, groups 1 and 2

Material identity		UNS number	Grade	Delivery condition	Test temperature	Longitudinal absorbed energy ft-lb	
Group	Category				°F	Average min.	Individual min.
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1	13-5-2	S41425	95	QT	14	44	29
			110	QT	14	44	29
		S41426	95	QT	14	44	29
			110	QT	14	44	29
		S41427	95	QT	14	44	29
			110	QT	14	44	29
2	22-5-3	S31803	65	SA	−50	30	22
		S32205	65	SA	−50	30	22
	25-7-4	S32550	80	SA	−50	30	22
		S32750	80	SA	−50	30	22
		S32760	80	SA	−50	30	22
		S39277[e]	80[a]	SA	−50	30	22
			85[b]	SA	−50	30	22
			85[c]	SA	−50	20	15
			85[d]	SA	−50	22	15

[a] For bar diameters up to 6.5 in., inclusive. Requirements for bar diameters greater than 6.5 in. are by agreement between purchaser and manufacturer.

[b] For bar diameters up to 6.5 in., inclusive.

[c] For bar diameters greater than 6.5 in. up to 8 in., inclusive.

[d] For bar diameters greater than 8 in. Test location shall be 1.5 in. below surface.

[e] S39277 grade 85 also meets the requirements of grade 80 for bar diameters up to 6.5 in., inclusive.

Table C.33—Microscopic cleanliness acceptance limits for bar or drilled bar, group 1

Inclusions [a]	Severity (maximum)	
	Heavy	Thin
Type A (sulphide)	1.0	1.0
Type B (aluminium)	2.5	3.0
Type C (silicate)	2.0	2.0
Type D (globular)	2.0	2.0

[a] Other features, anomalies or gross defects noted by the inspector/metallurgist while reviewing the microetched material either shall result in rejection, or shall be allowed a retest, or shall be brought to the attention of the purchaser for resolution.

Annex D
(normative)

Purchaser inspection

D.1 Inspection notice

Where the purchaser's inspector desires that the product be inspected or that the tests be witnessed, reasonable notice of the time shall be given by the manufacturer.

D.2 Plant access

All inspections should be made at the place of manufacture prior to shipment, unless otherwise specified on the purchase agreement, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

D.3 Conformance

The manufacturer is responsible for conforming to all of the provisions of this document. The purchaser may make any investigation necessary to ensure conformance by the manufacturer and may reject any material that does not conform to this document.

D.4 Rejection

Unless otherwise provided, material showing defects on inspection or reinspection subsequent to acceptance at the manufacturer's works may be rejected, and the manufacturer so notified. If tests that require the destruction of material are carried out, any length that is proven not to meet the requirements of this document shall be rejected. Treatment of rejected lengths shall be a matter of agreement between manufacturer and purchaser.

Annex E
(normative)

Cleanliness requirements

E.1 General

This annex specifies the periodical testing of cleanliness specific to meeting the requirements of 9.7.2 b.2) and c.2, ii), where cleanliness is used to reduce Charpy V-notch test frequency.

The manufacturer shall have a written procedure, including test frequency, for each material category.

E.2 Macroetch quality

The macroetch test shall be performed for two discs representing the casting sequence for ingot casting. If continuous casting is used, discs representing the first and last metal for the tested strand shall be sampled.

Discs shall be etched in accordance with ASTM E340 and the macroetch rating shall be in accordance with either ASTM E381 for conventionally melted materials or ASTM A604/A604M for remelted materials, and shall conform to the requirements specified in Tables E.1 and E.2.

Table E.1—Macroetch acceptance limits for conventionally melted materials

Type	**Severity** (maximum)
Class 1 (subsurface conditions)	S-3
Class 2 (random conditions)	R-3
Class 3 (center segregation)	C-3

Table E.2—Macroetch acceptance limits for remelted materials

Type	**Severity** (maximum)
Class 1 (freckles)	A
Class 2 (white spots)	A
Class 3 (radial segregation)	C
Class 4 (ring pattern)	D

Other features, anomalies or gross defects noted by the inspector/metallurgist while reviewing the macroetched material shall either result in rejection, allowable retest or shall be brought to the attention of the purchaser for resolution.

Ingots or strands exhibiting unacceptable characteristics shall be rejected or cut back and retested until the characteristics are within acceptable limits. In addition, other suspect ingots or strands from the heat shall be evaluated for acceptability. For continuous-cast steel, if the top of bottom bloom is rejected in total, then the material in the adjacent bloom shall be tested for acceptability. If the sequence of the blooms is not known or the ends (top or bottom) cannot be identified, then each end of each bloom shall be tested for acceptability.

E.3 Microetch quality—Cleanliness

The microetch test shall be performed on two samples representing the casting sequence for ingot casting. If continuous casting is used, samples representing the first and last metal for the tested strand shall be taken.

Microcleanliness evaluation shall be carried out in accordance with ASTM E45, method A, and performed on the longitudinal section of the forged or rolled bar. The acceptance limits, as defined in ASTM E45, method A, shall be as given in Table E.3.

Table E.3—Microscopic cleanliness acceptance limits

Inclusions[a]	**Severity** (maximum)	
	Heavy	**Thin**
Type A (sulphide)	2.5	2.5
Type B (aluminium)	2.5	3.0
Type C (silicate)	2.5	2.5
Type D (globular)	3.0	3.0

[a] Other features, anomalies or gross defects noted by the inspector/metallurgist while reviewing the microetched material either shall result in rejection, or shall be allowed a retest, or shall be brought to the attention of the purchaser for resolution.

If any sample fails to meet the requirements, the ingot or strands may be cut back and retested until it is within the specified limits. In addition, other suspect ingots or strands from the heat shall be evaluated for acceptability. For continuous-cast steel, if the top of bottom bloom is rejected in total, then the material in the adjacent bloom shall be tested for acceptability. If the sequence of the blooms is not known or the ends (top or bottom) cannot be identified, then each end of each bloom shall be tested for acceptability.

Annex F
(normative)

Coupling blanks and accessory material from bar

F.1 General

Coupling blanks and accessories are not covered by this document. However accessory products may be manufactured

— from coupling stock and tubular accessory material

— from solid bar stock or from bored and heat-treated bar stock when coupling stock or tubular accessory material is not available.

This annex provides the requirements necessary for the supply of bar stock applicable to the manufacture of coupling blanks and tubular accessories of the grades and sizes defined in this document.

In the case of conflict between a requirement of this annex and a more stringent requirement of the purchase agreement, the purchase agreement takes precedence.

The bar materials listed in this annex are classified under:

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 5, which is composed of age-hardened (AH) nickel-based alloys with austenitic structure.

This annex specifies the technical delivery conditions for corrosion-resistant alloy bar products for two product specification levels:

— PSL-1;

— PSL-2, which provides additional requirements for a product that is intended to be both corrosion resistant and cracking resistant for the environments and qualification method specified in Annex G and in the ISO 15156:2020 series.

NOTE 1 For the purpose of this document, NACE MR0175 is equivalent to the ISO 15156:2020 series.

For groups 1 and 2, PSL levels are listed in Table A.31 or Table C.31. All group 5 products are PSL-2.

NOTE 2 Group 1 bar stock is available at each strength grade listed in Table A.31 or Table C.31.

NOTE 3 Group 2 bar stock with larger diameters can be bored and re-heat treated to meet the impact properties.

NOTE 4 Groups 3 and 4 bar stock is not available in the size range required by accessories, so it is not included in this annex. Applications involving groups 3 and 4 are typically covered by group 5.

NOTE 5 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.

F.2 Information to be supplied by the purchaser

F.2.1 The purchaser shall state the minimum information as given in Table F.1, as applicable, in the enquiry and purchase agreement.

F.2.2 The purchaser shall also state on the purchase agreement the requirements, where applicable, concerning the stipulations listed in Table F.2, which are at the purchaser's option.

Table F.1 — Minimum information to be supplied by purchaser

Requirement		Reference
a)	Quantity of product	—
b)	Product designation: bar stock	—
c)	Reference to this document	—
d)	Material category/grade	Table A.30 or Table C.30
e)	PSL level for group 1 grade 95	Table A.31 or Table C.31
f)	Bar stock dimensions and tolerances, expressed in millimeters (inches)	As specified in purchase agreement
g)	Bar stock length and tolerance	As specified in purchase agreement
h)	Inspection by the purchaser	Annex D

Table F.2 — Additional requirements on purchase agreements

Requirement		Reference
a)	Alternative minimum total hot work ratio	F.3.2
b)	MPQT program	F.3.6 and Annex H
c)	Transverse tensile testing and acceptance criteria	F.4.2
d)	Alternative lower Charpy V-notch test temperature	F.4.4
e)	Transverse Charpy V-notch testing and acceptance criteria	F.4.4
f)	Surface NDE, acceptance criteria and inspection method	F.4.8; F.5.9.4
g)	Alternative test locations for tensile testing	F.5.3
h)	Alternative lower test frequency for surface hardness	F.5.4.2
i)	Alternative test locations for impact testing	F.5.5
j)	Alternative test locations for cleanliness evaluation	F.5.6.1
k)	Alternative test locations for microstructural examination	F.5.7.1
l)	Retesting provision for pitting corrosion for group 2	F.5.8
m)	Band color for marking the area of defect	F.5.9.6
n)	Content of the EDI-transmitted document	F.7.1
o)	Equivalent HBW hardness acceptance criteria	Table A.31 or Table C.31, footnote b
p)	Impact requirements for UNS S39277 grade 80 with bar diameter greater than 165.1 mm (6.5 in.)	Table A.32 or Table C.32, footnote a
q)	Alternative place for inspection	D.2
r)	Treatment of rejected lengths	D.4
s)	Minimum quantities, heats and lots to undergo MPQT Additional validation requirements Bar dimension representative of a range of sizes	H.3.1
t)	Statistical criteria for an in-control process	H.3.2
u)	Other test methods for MPQT	H.3.2

F.3 Manufacturing process

F.3.1 Melting practices

The alloys in group 1 shall be made by the basic oxygen process or the electric furnace process or blast furnace or the VIM process, followed by further refining operations. Refining operations shall be done using one or a combination of AOD, VOD, VAD or vacuum degassing processes.

The alloys in group 2 shall be made by the electric furnace process or the VIM process followed by further refining operations. Refining operations shall be done using one or a combination of AOD, VOD, VAD, VAR or ESR.

The alloys in group 5 shall be made as per API Standard 6ACRA.

F.3.2 Hot working processes

For groups 1 and 2, the minimum total hot work reduction ratio shall be 4:1. Total hot work reduction ratio is defined as the product of the individual reduction ratios achieved at each step in the hot work operation from ingot or bloom cross-section to final hot work cross-section. A different minimum total hot work ratio can be agreed between purchaser and manufacturer.

The alloys in group 5 shall be made as per API Standard 6ACRA.

F.3.3 Heat-treatment process

F.3.3.1 Heat treating equipment qualification and calibration

Groups 1 and 2 shall meet the following:

a) each furnace shall have been surveyed within one year prior to heat treating operations. Batch-type and continuous-type heat treating furnaces shall be calibrated in accordance with an internationally recognized standard at the discretion of the manufacturer;

   NOTE ISO 10423, AMS 2750E, API Spec 6A and API Standard 20H provide a list of available standards specifying methods for furnaces calibration, including information on their fields of application and accuracy.

b) temperature-controlling and temperature-recording instruments shall be calibrated at least once every three months until a documented calibration history can be established; calibration intervals shall then be established based on repeatability, degree of usage, and documented calibration history.

The heat-treating equipment qualification, calibration and temperature monitoring for group 5 shall be as per API Standard 6ACRA.

F.3.3.2 Heat treatment condition

Alloys in group 1 shall be in quenched and tempered (QT) condition. The austenitizing temperature, quench media and tempering temperature are to be suitably chosen by the manufacturer to ensure consistent properties through the lot and meeting the applicable property requirements.

For group 1 PSL-2, heat treatment requirements of the ISO 15156:2020 series shall apply.

Alloys in group 2 shall be in solution-annealed (SA) condition. The solution annealing temperature and cooling media are to be suitably chosen by the manufacturer to ensure consistent properties through the lot and meeting the applicable property requirements including avoiding deleterious microstructure.

Alloys in group 5 shall be in solution-annealed and age-hardened (AH) condition. The heat treatment requirements for group 5 alloys shall be as per API Standard 6ACRA.

F.3.4 Process requiring validation

Those processes requiring validation are

— non-destructive examination (see F.5.9.1);

— final heat treatment (excluding stress relieving) (see F.3.3.2);

— stress relieving, if applicable;

— hardness scale conversion, if applicable (see Tables A.30 or C.30).

Manufacturers shall document the method used for validation and extent of the validation, including but not limited to the range of products, size range and manufacturing facilities.

NOTE Evidence of validation can comprise a manufacturing procedure specification and associated manufacturer procedure qualification.

F.3.5 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 are performed and conformance with specification requirements has been shown.

F.3.6 Manufacturing procedure qualification test

If so specified in the purchase order, purchaser may request that an MPQT program shall 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 can be considered for the definition of the MPQT scope.

F.4 Material requirements

F.4.1 Chemical composition

For groups 1 and 2, chemical composition shall conform to the weight percent requirements for the applicable alloy as identified in Table A.30 or Table C.30. For group 2 alloys, a minimum and maximum pitting-resistance equivalent number (PREN) shall be met as per Table A.30 or Table C.30.

For group 5, the chemical composition shall be as per API Standard 6ACRA.

F.4.2 Tensile properties

Tensile test pieces shall be taken after final heat treatment.

For groups 1 and 2, tensile properties at room temperature in the longitudinal direction shall meet the requirements given in Table A.31 or Table C.31 for the relevant alloy, group, and grade combination.

Any transverse tensile testing requirements and/or acceptance criteria shall be as per agreement between manufacturer and purchaser.

For group 5, the tensile requirements shall be as per API Standard 6ACRA.

F.4.3 Hardness properties

Surface hardness tests shall be performed after final heat treatment. Cross-section hardness test pieces shall be taken after final heat treatment.

For groups 1 and 2, the hardness shall meet the requirements given in Table A.31 or Table C.31.

For group 5, the hardness requirements shall be as per API Standard 6ACRA.

F.4.4 Charpy V-notch test properties

Charpy V-notch test pieces shall be taken after final heat treatment. A test shall consist of a set of three specimens.

For groups 1 and 2, Charpy V-notch testing shall be done in the longitudinal direction. The test temperature and test results shall meet the requirements given in Table A.32 or Table C.32 for the relevant alloy, group, and grade combination. The tolerance on the test temperature shall be ±1 °C (±2 °F). The average energy value of three impact specimens shall equal or exceed the specified average. No more than one impact specimen shall exhibit an absorbed energy below the specified average and it shall not be below the specified single minimum.

When sub-size impact-test specimens are used, the minimum Charpy V-notch absorbed energy requirement shall be that specified for a full-size test specimen multiplied by the reduction factor in Table A.5 or Table C.5.

An alternative lower test temperature may be specified on the purchase agreement or selected by the manufacturer for any grade.

Any transverse Charpy V-notch testing requirements and/or acceptance criteria shall be as per agreement between manufacturer and purchaser.

For group 5, the Charpy V-notch requirements shall be as per API Standard 6ACRA.

F.4.5 Cleanliness requirements

For group 1, cleanliness requirements of Table A.33 or Table C.33 shall apply.

For group 5, macroetch requirements of API Standard 6ACRA shall apply.

F.4.6 Microstructure properties

The microstructure requirements for group 1 shall be in accordance with 7.10.1 while that of group 2 shall be in accordance with 7.10.2.

For group 5, the microstructure requirements shall be as per API Standard 6ACRA.

F.4.7 Pitting corrosion properties for group 2

Pitting corrosion resistance shall be evaluated in the longitudinal direction at 30 °C (86 °F) or higher for category 22-5-3 materials and at 50 °C (122 °F) or higher for category 25-7-3 materials. Test temperature tolerance shall be ±1 °C (±2 °F). The test exposure time shall be at least 24 hours.

No pitting shall be detected and weight loss shall be less than 1.0 g/m^2 (0.2 lb/1000 ft^2).

F.4.8 Defects

Bar stock shall be free from the following defects:

a) any quench crack or arc burn;

b) for defects by volumetric ultrasonic examination, the criteria shall be in accordance with ISO 10423 or API Spec 6A as described in the quality control requirements for materials for Bodies, PSL-3 for groups 1 and 2 and PSL-4 for group 5;

c) when surface NDE is agreed between purchaser and manufacturer, surface defects exceeding the agreed acceptance criteria.

The manufacturer, based on knowledge of the production process and the inspection and testing requirements shall apply a process control plan that ensures that the above requirements are fulfilled.

F.5 Inspection and testing

F.5.1 Test lot and rounding

For groups 1 and 2, maximum number of bars per test lot at the time of heat treatment shall be

— 50 for outside diameter less than 60 mm (2.36 in.);

— 25 for outside diameter 60 mm (2.36 in.) or greater.

For group 5, test frequency shall be as per API Standard 6ACRA.

Rounding of test results to determine conformance to specification shall be in accordance with ISO 80000-1 or ASTM E29.

F.5.2 Testing of chemical composition

F.5.2.1 Testing of chemical composition for groups 1 and 2

For groups 1 and 2, chemical analysis shall be done on each heat of material. 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.

An analysis of the product shall be made on one sample per heat.

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 of Table A.30 or Table C.30 and any other intentionally added element.

F.5.2.2 Testing of chemical composition for group 5

For group 5, the chemical composition shall be tested as per API Standard 6ACRA.

F.5.3 Tensile test

F.5.3.1 Tensile test for groups 1 and 2

For groups 1 and 2, tensile test shall be conducted on a prolongation or a sacrificial production part in the longitudinal direction. The test frequency shall be one tensile test per lot.

For material heat treated as solid (bar), the test specimen shall be removed from a location at mid-radius or deeper from the side or outer diameter. For material heat treated as hollow (drilled bar), the test specimen shall be removed from a mid-wall location.

Alternative test locations may be agreed between manufacturer and purchaser based on assessment of critical cross-section of the actual component to be manufactured from the heat-treated raw material.

The test pieces and test method shall be in accordance with ISO 6892-1 or ASTM A370.

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

The results of the tensile test shall conform to the requirement of F.4.2 and with the values for the material category and grade specified in Table A.31 or Table C.31.

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 bar. Specimens shall not be judged defective for the sole reason that they fail to meet the required properties.

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 bars from the same lot. In the case of test lots with three or fewer bars, each bar shall be tested. If all of the retests conform to the requirements, the lot shall be accepted, excepting the failed bar.

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 bars in the lot. Any bar that fails shall be rejected.

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

F.5.3.2 Tensile test for group 5

For group 5, tensile test shall be as per API Standard 6ACRA.

F.5.4 Hardness test

F.5.4.1 General

For groups 1 and 2, F.5.4.2 and F.5.4.3 shall apply.

For group 5, hardness test shall be as per API Standard 6ACRA.

F.5.4.2 Surface hardness for groups 1 and 2

The frequency of surface hardness shall be each bar in the test lot. Hardness tests shall be performed at alternating ends of bars, unless MPQT as per F.3.6 has been successfully performed in which case the alternating end requirement does not apply. An alternative lower surface hardness test frequency and/or end location sampling may be used by agreement between manufacturer and purchaser.

Hardness shall be tested on or near the surface in accordance with ISO 6508-1, ASTM E18 or ASTM E110 using the Rockwell C scale. For near-surface tests, indentations shall be 2.54 mm to 3.81 mm (0.100 in. to 0.150 in.) from the surface and shall be performed in accordance with ISO 6508-1 or ASTM E18 using the Rockwell C scale.

Alternatively, hardness testing can be done in accordance with ISO 6506-1, ASTM E10 or ASTM E110 using the Brinell method with ball diameter of 10 mm (0.394 in.) and test force of 29.42 kN (3 000 kgf). The surface may be prepared using light grinding. When light grinding is used it shall be to a maximum depth of 3.18 mm (0.125 in.).

For Rockwell C-scale testing, three adjacent indentations shall be made, averaged to calculate the mean, and the mean shall conform to the requirements of Table A.31 or Table C.31. No individual hardness number shall be greater than 2 HRC units above the maximum specified mean hardness number.

If any Rockwell C-scale mean hardness number fails to conform to specified requirements but does not exceed the specified requirements by more than 2 HRC units, three additional indentations shall be made in the immediate area to determine a new mean hardness number. If the new Rockwell C-scale mean hardness number conforms to the requirements, the bar shall be accepted. If the new Rockwell C-scale mean hardness number fails to conform to the requirements, the bar shall be rejected.

For Brinell testing, one indentation is sufficient. For equivalent Brinell hardness values, see Table A.31 or Table C.31, footnote b. In case of dispute, the Rockwell C scale shall be the referee method and shall take precedence.

If any Brinell hardness number fails to conform to specified requirements, two additional Brinell indentations shall be made in the immediate area. If the new Brinell hardness numbers conform to the requirements, the bar shall be accepted. If the new Brinell hardness numbers fail to conform to the requirements, the bar shall be rejected.

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

F.5.4.3 Cross-section hardness for groups 1 and 2

Cross-section hardness testing shall be performed at frequency of at least one test per test lot.

Hardness testing shall be performed in accordance with ISO 6508-1, ASTM E18 or ASTM E110 using the Rockwell C scale.

For material heat treated as solid (bar), near center, mid-radius and near surface locations shall be evaluated unless allowance is made depending on product size. For material heat treated as hollow (drilled bar), the mid-wall location and both near the inner and outer surfaces shall be evaluated unless allowance is made depending on product size.

At each location three adjacent indentations shall be performed, and the mean hardness number from each location shall conform to the requirements of F.4.3, Table A.31 or Table C.31. The hardness test location for the inner and outer surface tests shall be 2.54 mm to 3.81 mm (0.100 in. to 0.150 in.) from the surface. All hardness indentations shall be reported. No individual hardness indentation shall be greater than 2 HRC units above the maximum specified mean hardness number.

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 bar. Specimens shall not be judged defective for the sole reason that they fail to meet the required properties.

If any mean hardness number fails to conform to specified requirements but does not exceed the specified requirements by more than 2 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 bar shall be accepted.

If the new mean hardness number fails to conform to the requirements, the manufacturer may elect to carry out retests on three additional bars from the same lot. In the case of test lots with three or fewer bars, each bar shall be tested. If all of the retests conform to the requirements, the lot shall be accepted, excepting the failed bar. 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 bars in the lot. Any bar that fails shall be rejected.

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

F.5.5 Impact test

F.5.5.1 Impact test for groups 1 and 2

For groups 1 and 2, impact test shall be conducted on a prolongation or a sacrificial production part in the longitudinal direction. One set of Charpy V-notch impact tests shall be performed per test lot.

NOTE 1 For group 2, impact test and acceptance criteria have been defined to allow detection of deleterious phases. Values for individual grades have been selected on this basis and can differ from one another in Table A.32 or Table C.32. The presence or absence of an indication of deleterious phase in this test is not necessarily a measure of performance of the material in service with regard to any property other than that measured directly.

For material heat treated as solid (bar), the test specimen shall be removed from a location at mid-radius or deeper from the side or outer diameter. For material heat treated as hollow (drilled bar), the test specimen shall be removed from a mid-wall location.

For UNS S39277 with bar diameters greater than 203.2 mm (8 in.), the test specimens shall be removed from a location 38.1 mm (1.5 in.) below the surface (see Table A.32 or Table C.32, footnote d).

NOTE 2 At deeper locations than 38.1 mm (1.5 in.) below the surface, for UNS S39277 with bar diameters greater than 203.2 mm (8 in.), the impact properties might not be achieved.

Alternative test locations may be agreed between manufacturer and purchaser based on assessment of critical cross-section of the actual component to be manufactured from the heat-treated raw material.

The test pieces and test method shall be in accordance with ASTM A370 and ASTM E23.

The results of the impact test shall conform to the requirement of F.4.4 and with the values for the material category and grade specified in Table A.32 or Table C.32.

If a test fails, then a retest of three additional specimens removed from the same area of the same bar with no additional heat treatment may be made. If each retest specimen exhibits an impact value equal to or exceeding the specified average minimum, the lot shall be accepted.

If one or more of the retest specimens is below the specified average minimum, the manufacturer may elect to test each of the remaining bars in the lot. Any bar that fails shall be rejected.

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 bar. Specimens shall not be judged defective for the sole reason that they fail to meet the required properties.

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

F.5.5.2 Impact test for group 5

For group 5, impact test shall be as per API Standard 6ACRA.

F.5.6 Cleanliness evaluation

F.5.6.1 Cleanliness evaluation for group 1

For group 1, microetch shall be conducted on a prolongation or a sacrificial production part or on samples extracted as per ASTM E45. One microetch shall be performed per lot.

For material heat treated as solid (bar), the test specimen shall be removed from a location at mid-radius or deeper from the side or outer diameter. For material heat treated as hollow (drilled bar), the test specimen shall be removed from a mid-wall location.

Alternative test locations may be agreed between manufacturer and purchaser based on assessment of critical cross-section of the actual component to be manufactured from the heat treated raw material.

Microcleanliness evaluation shall be carried out in accordance with ASTM E45, method A, and performed on the longitudinal section of the forged or rolled bar. The acceptance limits, as defined in ASTM E45, method A, shall be as given in Table A.33 or Table C.33.

If any sample fails to meet the requirements, the ingot or strands may be cut back and retested until it is within the specified limits. In addition, other suspect ingots or strands from the heat shall be evaluated for acceptability. For continuous-cast steel, if the top of bottom bloom is rejected in total, then the material in the adjacent bloom shall be tested for acceptability. If the sequence of the blooms is not known or the ends (top or bottom) cannot be identified, then each end of each bloom shall be tested for acceptability.

F.5.6.2 Cleanliness evaluation for group 5

For group 5, macroetch requirements of API Standard 6ACRA shall apply.

F.5.7 Microstructural examination

F.5.7.1 Microstructural examination for groups 1 and 2

For groups 1 and 2, the microstructure examination shall be conducted on the same prolongation or sacrificial production part used to determine the tensile and Charpy V-notch impact properties, in the longitudinal direction. The test frequency shall be one test per lot.

For material heat treated as solid (bar), the test specimen shall be removed from a location at mid-radius or deeper from the side or outer diameter. For material heat treated as hollow (drilled bar), the test specimen shall be removed from a mid-wall location.

Alternative test locations maybe agreed between manufacturer and purchaser based on assessment of critical cross-section of the actual component to be manufactured from the heat-treated raw material.

The test method shall be in accordance with 9.10.2. The results of the microstructural examination shall conform to the requirement of F.4.6.

In case of failure, retest shall be in accordance with 9.10.3.

F.5.7.2 Microstructural examination for group 5

For group 5, the microstructural examination shall be as per API Standard 6ACRA.

F.5.8 Pitting corrosion test for group 2

For group 2, pitting corrosion test shall be conducted on a prolongation or sacrificial production part in the longitudinal direction. The test frequency shall be one test per lot.

For material heat treated as solid (bar), the test specimen shall be removed from a location at mid-radius or deeper from the side or outer diameter. For material heat treated as hollow (drilled bar), the test specimen shall be removed from a mid-wall location.

The test pieces and test method shall be in accordance with ASTM G48, Method A. The complete specimen may be pickled before weighing and testing in accordance with a documented procedure.

NOTE Guidance on pickling procedure can be found in ASTM A380. An example can be found in NORSOK M-630 MDS D57.

The presence of pitting shall be determined using a magnification of 20×. The results shall conform to the requirement of F.4.7.

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 bar. Specimens shall not be judged defective for the sole reason that they fail to meet the required properties.

Retesting is by agreement between purchaser and manufacturer.

F.5.9 Non-destructive examination

F.5.9.1 General

All NDE operations (except visual inspection) referred to in this document shall be conducted by NDE personnel qualified in accordance with ISO 11484, ISO 9712 or ASNT SNT-TC-1A, under the responsibility of level 3 certified personnel according to ASNT SNT-TC-1A or equivalent.

The NDE standards for the inspection of bar stock referenced in F.5.9 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 F.4.8 may be used.

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);

b) capability for the intended bar diameter;

c) repeatability;

d) transducer orientation that provides detection of defects typical of the manufacturing process;

e) documentation demonstrating that defects typical of the manufacturing process are detected using the NDE methods;

f) threshold-setting parameters.

In addition, the manufacturer shall maintain documentation relating to

— NDE system operating procedures,

— NDE equipment description,

— NDE personnel qualification information, and

— dynamic test data demonstrating the NDE system/operation capabilities under production test conditions.

F.5.9.2 Visual inspection

All bars shall be submitted to a visual inspection over the entire surface for the detection of imperfections in order to ensure conformance to the requirements of F.4.8. The visual inspection shall be carried out according to an established written procedure. If another method is applied with demonstrated capability of detecting defects as defined in F.4.8, 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). The visual inspection shall be on the product in the final surface and mechanical processing condition, but before coating, if applicable.

Physical visual inspection may be replaced by a visual technique, other than those stated in F.5.9.3 or F.5.9.4, if the system has validated and documented capability of detecting surface defects, as defined in F.4.8, and the manufacturer has documented capability records (per F.5.9.1 as applicable), verification criteria and calibration procedures, including frequency.

Surface imperfections disclosed by visual inspection shall be treated in accordance with F.5.9.5 and F.5.9.6.

F.5.9.3 Volumetric ultrasonic NDE

The volumetric ultrasonic NDE shall be conducted in accordance with ISO 10423 or API Spec 6A as described in the quality control requirements for materials for Bodies, PSL-3 for groups 1 and 2 and PSL-4 for group 5.

Defects shall be treated in accordance with F.5.9.5 and F.5.9.6.

F.5.9.4 Surface NDE

When specified, the inspection method shall be agreed between purchaser and manufacturer.

F.5.9.5 Evaluation of indications (prove-up)

In all cases, indications producing a threshold alarm condition as a result of the specified NDE operations shall have the indications evaluated unless it can be demonstrated that the imperfection causing the indication is not a defect as described in F.4.8.

For an indication that is greater than or equal to the reject threshold, the manufacturer shall either evaluate it in accordance with this clause or dispose of the indication as a defect in accordance with F.5.9.6. Evaluation of indications shall be performed by NDE level 1 qualified inspectors under the supervision of NDE level 2 qualified or level 3 certified inspectors, or by NDE level 2 qualified or 3 certified inspectors. Evaluation of indications shall be performed in accordance with documented procedures.

When no imperfection is found in the area of the original indication and there is no explanation for the indication, then the bar shall be rejected or, at the manufacturer's option, re-inspected full-length either using the same inspection method or using ultrasonic inspection methods. At the manufacturer´s option, the inspection equipment shall be adjusted either to the same sensitivity level as that used to perform the original inspection or to a reduced sensitivity that meets the specified requirements.

For the evaluation of an indicated imperfection, the depth shall be measured by one of the following methods:

a) Using a mechanical measuring device (for example, pit gauge, callipers, etc.). Removal of material by grinding or other means to facilitate measurement shall not reduce the outside diameter below the minimum specified. Abrupt changes in bar surface caused by material removal during prove-up shall be smoothed.

b) Using (an) ultrasonic technique(s) or other comparable techniques. Verification of the ultrasonic technique(s) shall be documented and shall show capability to differentiate imperfection sizes larger and smaller than the appropriate defect size stated in F.4.8.

If the purchaser and manufacturer do not agree on the evaluation test results, either party may require destructive evaluation of the material; after which, disposition shall be as described in Annex D.

Imperfections that have been evaluated and found to be defects shall be given a disposition in accordance with F.5.9.6.

F.5.9.6 Disposition of bar stock containing defects

Imperfections that satisfy the material requirements and are less than the defect size stated in F.4.8 are allowed to remain in the bar stock. Repair welding is not permitted. Bar stock containing defects shall be given one of the following dispositions:

a) grinding or machining: Grinding or machining of quench cracks is not permitted.

   Other defects shall be completely removed by grinding or machining, provided the remaining outside diameter is within specified limits. Grinding or machining shall be carried out in such a way that the dressed area blends smoothly into the contour of the bar stock. After removal of the defect, the outside diameter shall be measured in the dressed area for conformance to specified limits. The affected area shall also be re-inspected by

   1) the same inspection unit at the same sensitivity that performed the initial inspection, or

   2) liquid-penetrant inspection according to ISO 3452-1 or ASTM E165 or magnetic particle inspection according to ISO 9934-1 or ASTM E3024 for ferromagnetic materials, or

   3) another NDE method, or combination of methods, that demonstrates sensitivity equal to or greater than the original NDE. The method, or combination of methods, shall be documented. The possibility that there can be other coincident defects in the affected area shall be addressed.

b) marking the area of defect: If a defect is not removed from bar stock within acceptable limits, then the area shall be marked to indicate the presence of a defect.

The marking shall consist of a paint band encircling the bar stock that covers the entire defect area if this area is equal or less than 50 mm (2 in) in axial length, or bands in a cross-hatched pattern if this area is greater. The band color shall be as agreed between purchaser and manufacturer.

c) cut off: The section of bar stock containing the defect shall be cut off within the limits of requirements on length for the product.

d) rejection: The bar stock shall be rejected. All bar stock containing quench cracks shall be rejected.

F.5.10 Dimensional inspection

Each length shall be inspected to verify conformance with the requirements specified by the purchaser (Table F.1).

Outside diameter shall be inspected per 9.11.2 or by an alternative inspection method validated to be capable to ensure conformance with Table F.1 f).

Length shall be inspected per 9.11.3 or by an alternative inspection method validated to be capable to ensure conformance with Table F.1 g).

F.6 Marking

The material shall be marked or tagged with identification traceable to the certification for the heat and heat treat lot for groups 1 and 2.

Marking for group 5 shall be as per API Standard 6ACRA.

Additional marking is permitted.

F.7 Documents

F.7.1 Electronic media

A material test report, certificate of conformance or similar document printed from or used in electronic form from an EDI transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI-transmitted document shall be agreed between purchaser and manufacturer and shall meet the requirements of this document.

F.7.2 Retention of records

Tests and inspections as specified herein require retention of records. Test certificates record retention is required (see F.7.3). Such records shall be retained by the manufacturer and shall be available to the purchaser on request for a period of five years after the date of purchase from the manufacturer.

F.7.3 Test certificates

F.7.3.1 Test certificates for groups 1 and 2

The manufacturer's certificate shall cite this document and the publication date thereof (i.e. ISO 13680:2020), to which the product was manufactured. The manufacturer shall provide the following data, as applicable, for each item that is specified on the purchase agreement:

a) specified outside diameter, group, category, grade, UNS number and the number of bars per heat and per test lot;

b) name(s) of company and facility performing melting operations;

c) melting practice;

d) heat number and test lot number;

e) chemical analysis (heat and product analysis) showing the mass fraction, expressed as a percent, of all elements whose limits or reporting requirements are set in this document;

f) name(s) of company and facility performing the hot working operations;

g) total hot work reduction ratio;

h) name(s) of company and facility performing the heat treatment;

i) actual heat treatment times and temperatures and cooling media;

j) name(s) of company and facility performing testing;

k) statement describing the test sample (e.g. "coupon/longation" or "sacrificial production part");

l) test data for all tensile tests required by this document, including yield strength, tensile strength and elongation. The type, size, location and orientation of the specimens shall be reported. The report shall show the nominal width of the test specimen when strip specimens are used, or the diameter and gauge length when round-bar specimens are used;

m) impact test results (including the test criteria, the size, location and orientation of the test specimen, the nominal test temperature, the absorbed energy measured for each test specimen and the average absorbed energy for each set of tests);

n) hardness test results and hardness test scale (including hardness numbers and mean hardness numbers, criteria and specimen location). When reporting converted hardness numbers, the measured hardness and test scale shall be reported in parentheses [e.g. 20 HRC (228 HBW), where 20 HRC is the converted hardness value and 228 HBW is the original measurement value and test scale];

o) statement of conformance of microstructure, delta ferrite content, ferrite volume fraction, representative photo micrographs, as applicable;

p) cleanliness results (if applicable);

q) pitting corrosion test results (if applicable);

r) statement of conformance to visual inspection;

s) non-destructive examination results;

t) statement of conformance to each of the dimensional requirements, which includes diameter and length;

u) results of any testing or inspection required at the purchaser's option;

v) statement of conformance with the metallurgical and manufacturing requirements of the ISO 15156:2020 series for PSL-2.

F.7.3.2 Test certificates for group 5

For group 5, the certificate details shall per API Standard 6ACRA and results of any testing or inspection required at the purchaser's option.

Annex G
(normative)

Product specification level 2 (PSL-2)

G.1 General

This annex specifies requirements for product specification level 2 (PSL-2). PSL-2 may be specified by the purchaser or supplied at the option of the manufacturer. The requirements for PSL-2 are in addition to those for PSL-1, which form the basis of this document. PSL-2 product is intended to conform to the requirements of prequalified materials listed in the ISO 15156:2020 series to provide a product that is both corrosion resistant and cracking resistant for the environments and qualification method specified in these Standards.

For tubulars, PSL-2 may include any alloy in a category in Table A.2 or Table C.2, provided all requirements in the ISO 15156:2020 series are fulfilled in addition to the requirements of this document. For bars in groups 1 and 2, PSL-2 products are listed in Table A.31 or Table C.31. All group 5 products are PSL-2.

The marking and packaging requirements for PSL-2 are listed in G.3 and G.4.

NOTE For the purpose of this document, NACE MR0175 is equivalent to the ISO 15156 series.

WARNING 1—End sizing, connection manufacture or welding operations can influence the corrosion and cracking resistance of the materials specified in this annex. Demonstration of conformance to ISO 15156-3:2020 of material affected by these processes is outside the scope of this document.

WARNING 2—The corrosion-resistant alloys (CRAs) selected using the ISO 15156:2020 series are resistant to cracking in defined H_2S-containing environments in oil and gas production but are not necessarily immune to cracking under all service conditions. It is the equipment user's responsibility to select the CRAs suitable for the intended service. 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. Other variables which may contribute to hydrogen embrittlement should be considered. There are other sources of hydrogen besides H_2S-containing environments, which are not addressed by the ISO 15156:2020 series.

G.2 PSL-2 product

Material categories and grades listed in Table A.2 or Table C.2 can be assessed for conformance to the applicable requirements of the ISO 15156:2020 series. Documented information about deliveries (provided by manufacturers) and use as down hole tubular (provided by users) can also be taken into consideration. Some of the higher strength grades listed in Table A.2 or Table C.2 cannot be delivered as PSL-2 because of non-conformance to the requirements of the ISO 15156:2020 series.

Some requirements for PSL-2 can in some cases be more restrictive than the ones of the ISO 15156:2020 series.

PSL-2 products are specified in

— Table A.28 or Table C.28 and Table A.31 or Table C.31, which give specific tensile properties and hardness requirements, and

— Table A.29 or Table C.29 and Table A.30 or Table C.30, which give specific chemical compositions (identified by UNS numbers).

In taking into account experience based on successful laboratory testing and/or satisfactory field experience specific to special applications, values other than those listed in Table A.28 or Table C.28 may be used by agreement between purchaser and manufacturer. However, the agreement shall demonstrate that the relevant requirements in the ISO 15156:2020 series are fulfilled at that time. In some circumstances, this can require qualification according to ISO 15156-3:2020, Annex B. Such products may be designated as PSL-2 but shall be marked in accordance with the applicable requirements in G.3 and/or G.4. In addition, the agreed values and the corresponding test results shall be documented on the material certification.

G.3 Markings for tubulars

Product meeting the requirements of PSL-2 shall be paint or ink stencilled “L2” as specified in 11.3 f). Products subject to agreement between purchaser and manufacturer (see G.2) shall be marked “L2A” (agreement) instead of “L2”.

G.4 Package identification for tubulars

Product meeting the requirements of PSL-2 shall be identified “L2” as specified in 14.3.2 d). Products subject to agreement between purchaser and manufacturer (see G.2) shall be identified “L2A” (agreement) instead of “L2”.

G.5 Process for update of alloys and/or grades

Applications for the entry of new alloys and/or grades shall be made to ISO/TC 67/SC 5. Only alloys, grades or types of alloys which are already included in ISO 15156-3:2020 will be considered. Applications for new entries or alteration to existing entries shall be accompanied by supporting evidence as per H.4.

Annex H
(normative)

Standardized manufacturing procedure qualification test

H.1 General

This annex specifies the requirements for a Manufacturing Procedure Qualification Test (MPQT) program for a specific product. MPQT may be used for qualification of a new product or a change in the manufacturing process. Alternatives to MPQT are also described in this annex.

If so specified in the purchase order, purchaser may request that this program be conducted using the first lengths effectively produced for the agreed scope of the MPQT. The successful completion of the program will in such a case be part of the requirements for the order.

For groups 1, 2, 3 and 4, this annex also describes the minimum information needed to be supplied for the consideration of the introduction of a new alloy and/or grade into this document. API 6ACRA defines requirements for addition of a new alloy and/or grade for those alloys and grades included in group 5.

H.2 Manufacturing processes

The manufacturer shall provide a full description of the manufacturing process, following the same structure of Clause 6, including as a minimum:

a) starting material manufacturing process:

   — melting process and general equipment description;

   — secondary metallurgy process and general equipment description;

   — casting method (ingot, continuous cast or state other casting method);

   — starting material (e.g. ingot/billet or rolled/forged bar/machined bar, hot finished hollow or other).

b) product manufacturing process (only seamless manufacturing is allowed):

   — hot forming process and general equipment description (e.g. hot finished, hot-rolled/forged, or hot-extruded), including total hot working ratio;

   — cold forming process and general equipment description (e.g. cold-hardened by cold drawing, cold pilgering or other);

   — final heat treatment conditions (e.g. quenched and tempered, solution-annealed, solution annealed and age-hardened), requirements (e.g. temperature, time, quench media or other) and general equipment description;

   — final conditioning processes and general equipment description, including straightening and end sizing if applicable.

c) main process details, including demonstration that control variables and standard range of operation for those variables are defined;

d) surface finish and delivery condition.

Special attention should be taken on using the same terms and definitions as in Clause 6.

H.3 MPQT

H.3.1 General

In addition to the information to be specified by the purchaser in Clause 5 or F.2, for tubulars and bars respectively, the purchaser shall specify the minimum quantities, heats and lots to undergo MPQT either in a single run or in multiple runs. Only industrial manufacturing scale is acceptable. Laboratory manufacturing scale is not acceptable. The quantity specified should be sufficient to demonstrate consistency in meeting requirements as assessed using a statistically significant dataset (see H.3.2). MPQT shall include validation of the applicable processes described in 6.3 or F.3.4. The purchaser may specify additional validation requirements.

When agreed by the purchaser and manufacturer, MPQT of the manufacturing route may be performed on agreed product dimensions (a single size and weight for tubulars or a single diameter for bars) that is representative of a range of product sizes. All of the sizes covered by such an MPQT shall be made by the same manufacturing route, similar deformation scheme and process parameters. When a single MPQT is used to qualify a range of product sizes, the manufacturer shall provide justification based on the manufacturing process for all the applicable sizes, noting any manufacturing differences between the sizes that can influence performance and/or reproducibility.

If the manufacturer has produced the product in the past in an industrial basis with the same manufacturing route, the MPQT may be replaced by a controlled report of already tested and certified properties. Acceptance of report shall be at the option of the purchaser.

The manufacturer shall assess the validity of the MPQT report as a minimum every five years. At the acceptance of the purchaser, an MPQT older than five years may be deemed valid if the manufacturer performs and documents a risk assessment that establishes no significant change to the process since the MPQT was performed.

For groups 1, 2, 3 and 4, the MPQT program is part of the information needed to be supplied for consideration of the insertion of a new alloy and/or grade in this document (see H.4). The submittal record shall include a summary of the applicable mechanical, metallographic, corrosion and NDE test results. The submittal shall include the mean, range and standard deviation for quantitative test results. For a new group 5 product, the requirement process in API 6ACRA for addition of new alloys and/or alloy material destinations shall apply.

H.3.2 Material properties and dimensional requirements

Material properties and dimensional requirements as in Clauses 7 and 8 for tubulars, or F.4 and Table F.1 for bars, shall be verified. Inspection and testing shall be conducted as per Clause 9 or F.5, for tubulars and bars respectively, subject to the following modifications. No retest provision is allowed.

For two lengths from each assessed heat and lot, five sections evenly distributed along the length shall be sampled for longitudinal tensile and hardness testing in four quadrants. Impact or flattening testing, as applicable, shall be performed in the samples corresponding to each end and the middle of the length. The remaining lengths used for validation shall be, as a minimum, sampled for longitudinal tensile and hardness testing in one quadrant at alternate ends.

Mechanical property statistical analyses shall be performed to demonstrate that the processes are in-control. The purchaser and manufacturer shall agree on the statistical criteria for an in-control process. The minimum/maximum limits within this document are not statistical criteria per se. The manufacturer shall report the capability analyses, state the criteria for being in-control and state conclusions. The report shall include the mean, range and standard deviation for quantitative test results.

For group 2 tubulars, impact test at low temperature as per 9.8 and pitting corrosion test as per 9.9 shall be conducted and meet the requirements of 7.8 and 7.9.2, respectively.

By agreement between purchaser and manufacturer, other test methods (such as H_2S corrosion testing in accordance with NACE TM0177 or NACE TM0316 for PSL-2, groups 1, 2 and 3) can be specified.

H.4 Information supplied for consideration of inclusion of a new alloy and/or grade in this document for groups 1, 2, 3 and 4

The submitter should review the requirements in this document. For consistency in the submittal, the submittal shall use the terminology, processes and methods stated in this document. If new terminology, processes and methods should be considered, the submitter shall clearly state and define the new terminology, processes and methods in the proposal. For consideration of the insertion of a new alloy and/or grade in this document, the submitter shall provide

a) the material characteristics of the CRA alloy and grade, including the following:

   — typical range of applications, such as corrosion resistance (e.g. resistance to sulphide stress cracking, stress corrosion cracking, etc.);

   — dimensional range of the product(s) with respect to nominal outside diameter, wall thickness if applicable and length;

   — group on which the material can be included;

   — full nominal chemical composition;

   — for alloys intended for PSL-2, UNS number and qualification report in conformance with ISO 15156-3:2020, Annex B;

   — minimum PREN number, if applicable;

   — proposed category based on nominal Cr, Ni and Mo contents;

   — delivery condition;

   — grade or grades (specified minimum yield strength);

   — brief description of the alloy structure and detrimental phases;

   — product type (tubing, casing, coupling stock, accessory material, bar stock or other);

b) details of the manufacturing process as per H.2 and processes requiring validation as per 6.5 and F.3.4. The submitter shall clearly state if new/different manufacturing processes, not included in Clause 6, should be considered with justification;

c) material properties, proposed acceptance limits and required testing and inspection methods to verify the conformance, following the same structure of this document for Clauses 7 to 9 for tubulars, or F.4 and F.5 for bars, in the applicable USC or SI units, including the following:

   — chemical composition with all intentionally added and controlled elements, with ranges. If the material could have susceptibility for the formation of detrimental precipitates, the submittal should include more conservative limits than included in the UNS number for the appropriate elements to suppress/mitigate precipitate formation;

   — tensile properties (yield strength, tensile strength, percent elongation, and percent reduction of area, as applicable);

   — hardness properties (mean hardness number and hardness number limits, hardness test method/scale for through-wall and surface hardness, as applicable);

   — impact properties, as applicable (minimum mean absorbed energy for average of three impact specimens and minimum individual impact specimen, minimum lateral expansion and minimum percent shear area, as applicable);

- flattening properties, as applicable;
- chromium depletion, as applicable (minimum surface chromium acceptance criterion for each material condition);
- macrostructure and microstructure, as applicable (test location(s), orientation, proposed test method, photographs of macrostructure and microstructure, etchant(s), magnification(s) and requirements). If example reference photomicrographs would be beneficial to clarify microstructure acceptance in this document, the submittal shall include photomicrographs with clear headers stating location, orientation, magnification, etchant, "pass" or "fail" (with stated reason for failure);
- cleanliness, as applicable (see Annex E for cleanliness evaluation and the groups where this evaluation applies as required within this document);
- corrosion acceptance requirements, as applicable (test method and acceptance criteria);
- dimensional requirements (including tolerances in diameter, wall thickness, length, straightness, drift, as applicable);
- linear density;
- surface finish (including imperfection level);
- NDE (acceptance criteria and details of proposed differences to this document if any);
- otherproposed additions or changes within this document along with justifications;

d) normative references not currently included in this document if applicable;

e) report of MPQT program as per H.3;

f) reports of manufacturing of the intended product or products (laboratory manufacturing scale is not acceptable), including:

- quantities and sizes, including number of heats, lots and lengths produced, either in a single or in multiple runs, and
- field experience, if available.

NOTE Field experience record is typically limited to the supply record and those details of field environmental conditions shared to the manufacturer (ideally, pH, temperature, water cut, total pressure, elemental sulphur, partial pressure of H_2S and CO_2 or other parameters that determine the resistance to general, localized and cracking corrosion resistance of the material). This environmental data may not reflect the actual field conditions experienced by the supplied product. The field supply record typically also includes the product chemistry, UNS number, grade, product dimensions (nominal outside diameter, wall thickness if applicable and length), quantities, number of heats and lots.

Special attention on using the same terms and definitions as this document should be taken.

Particular attention should also be given to properly describe the changes that the alloy may require, in terms of process, requirements and testing (frequency, testing and inspection methods different from the ones already specified in Clause 9 or F.5, for tubulars and bars respectively).

Annex I
(informative)

Photographic examples of microstructures, groups 2, 3 and 4

I.1 General

Figures I.1 to I.6 are representative photographic examples of acceptable and unacceptable microstructures for groups 2, 3 and 4.

These micrographs are representative of the worst field, observed at an original magnification of 500x. The amount of precipitates has been determined by ASTM E1245 method.

I.2 Example of just acceptable microstructure, group 2

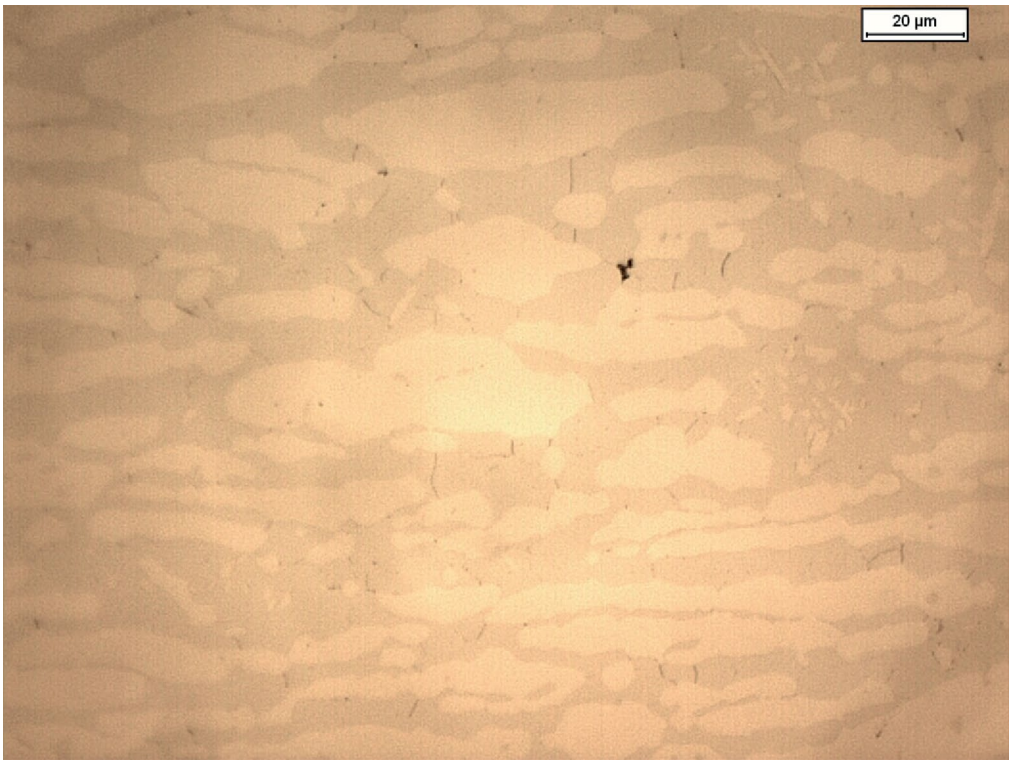


Figure I.1—Just acceptable microstructure: Discrete/standalone intermetallic precipitates not greater than 10 µm (0.40 mil). Electrolytic etching using 10 % NaOH

I.3 Examples of unacceptable microstructure, group 2

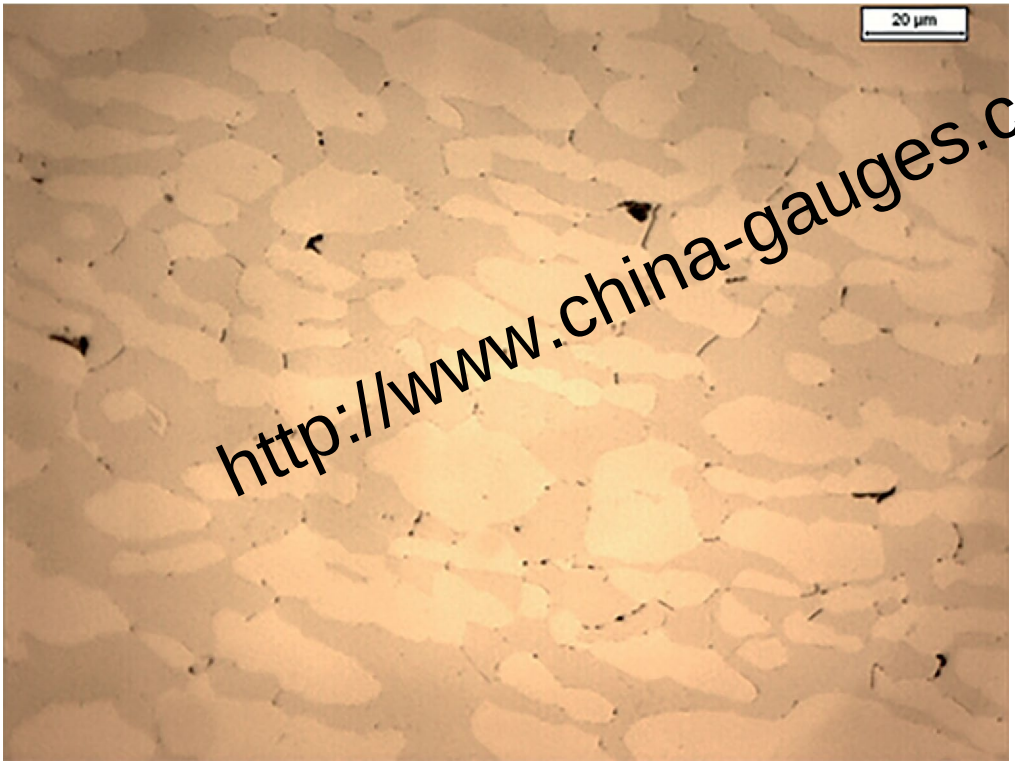


Figure I.2—Unacceptable microstructure regarding intermetallic phases. Electrolytic etching using 10 % NaOH

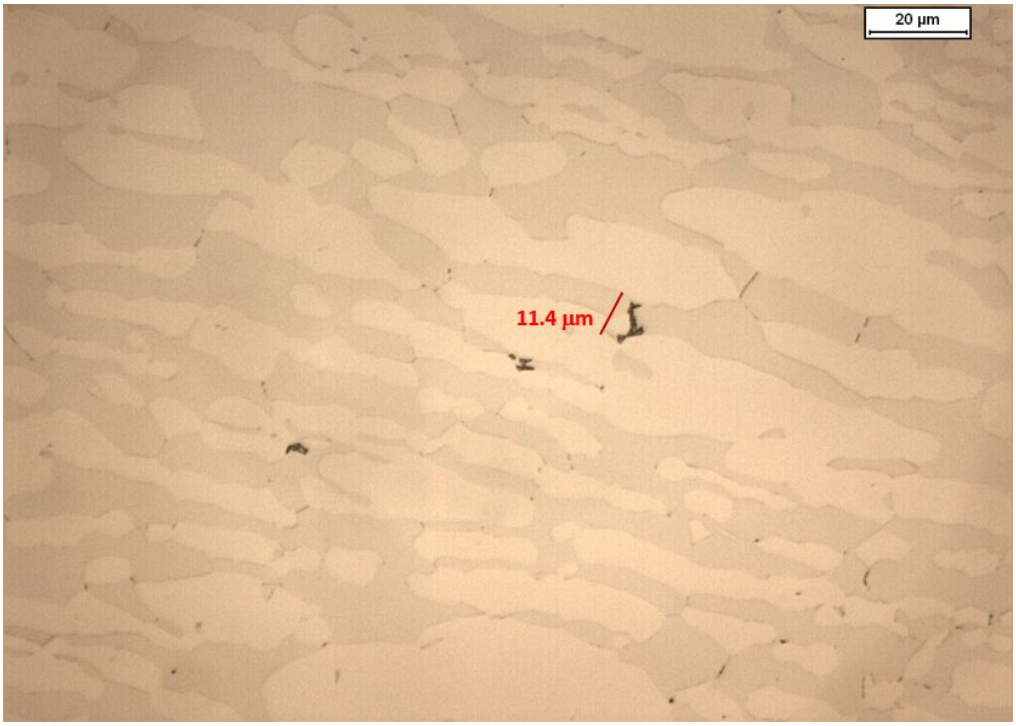


Figure I.3—Unacceptable microstructure: intermetallic particle greater than 10 µm (0.40 mil). Electrolytic etching using 10 % NaOH

I.4 Examples of acceptable microstructure, groups 3 and 4

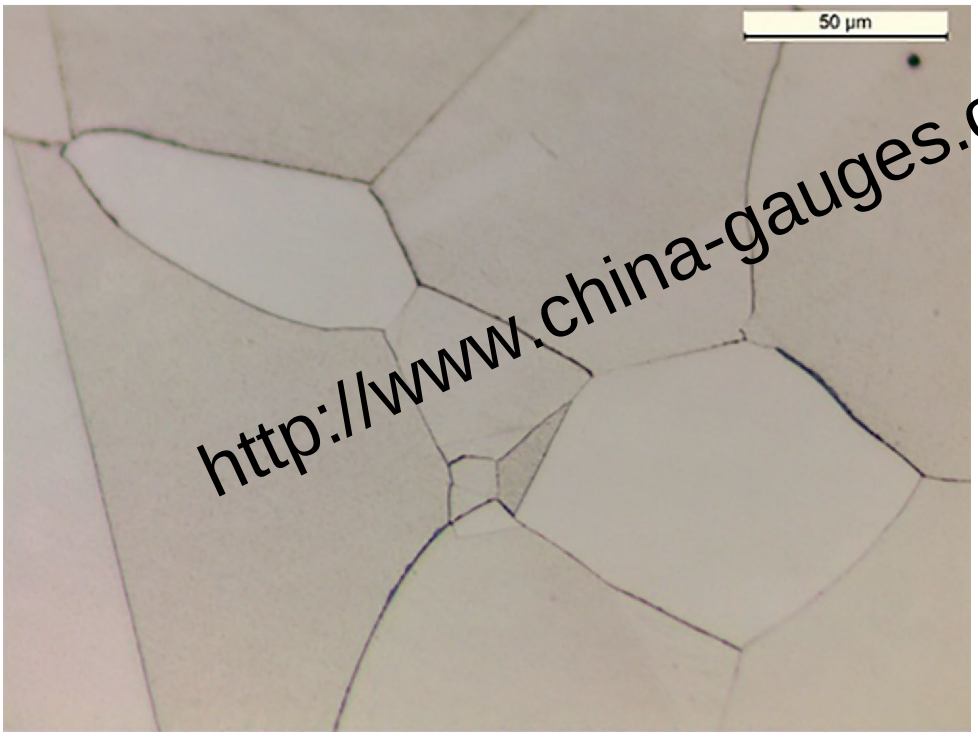


Figure I.4—Acceptable microstructure: isolated intergranular precipitates. Etchant: 10 g $FeCl_3$, 100 ml ethanol, 30 ml HCl and 70 ml H_2O

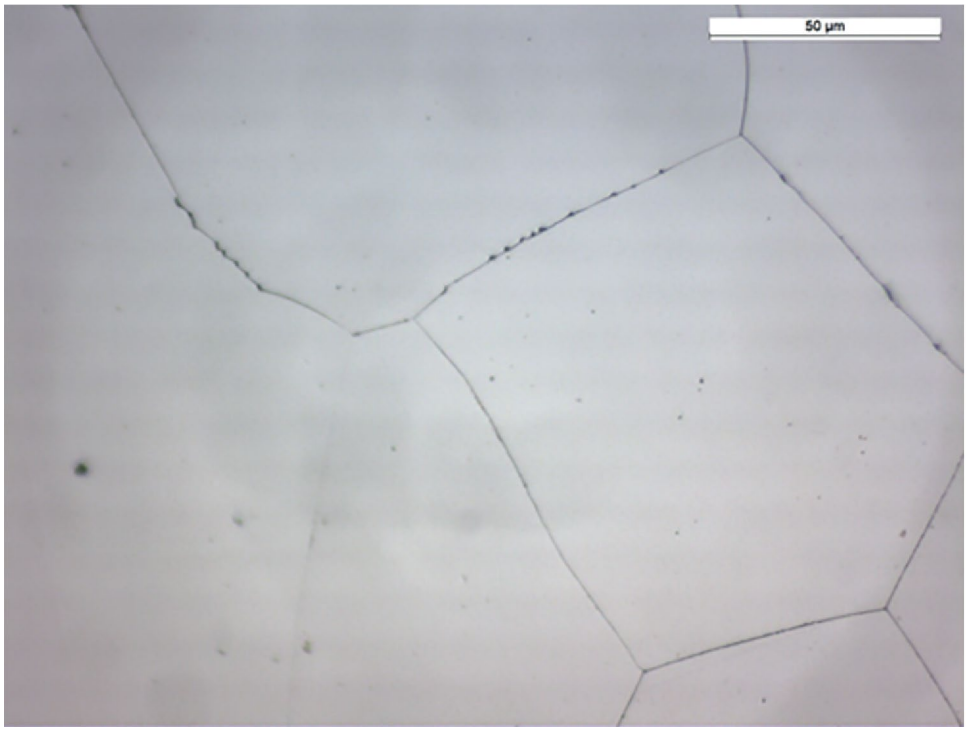


Figure I.5—Acceptable microstructure: isolated intergranular precipitates. Etchant: 10 g $FeCl_3$, 100 ml ethanol, 30 ml HCl and 70 ml H_2O

I.5 Examples of unacceptable microstructure, groups 3 and 4

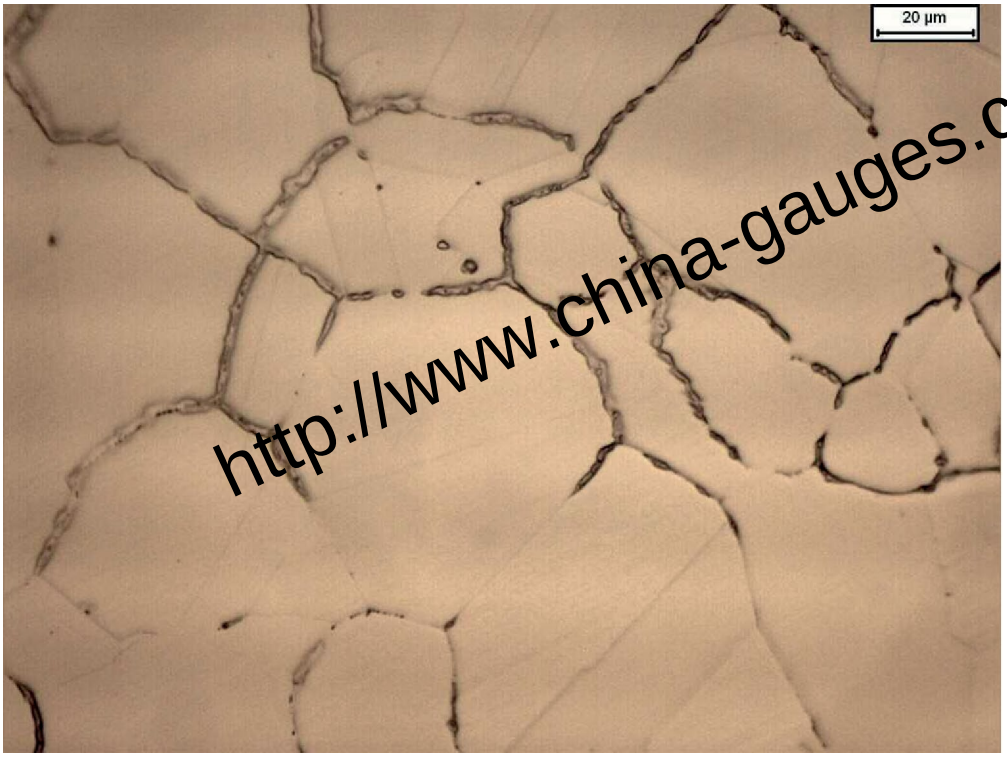


Figure I.6—Unacceptable microstructure: Coarse and abundant intergranular precipitates. Etchant: 10 g $FeCl_3$, 100 ml ethanol, 30 ml HCl and 70 ml H_2O

Annex J
(informative)

Identification/explanation of modifications

The API Subcommittee on Tubular Goods (SC 5) voted to adopt ISO 13680:2020 as American National Standard API 5CRA and determined that the modifications detailed in Table J.1 were necessary. These technical modifications from the ISO standard have been incorporated directly into the text.

NOTE Also see the API Foreword for additional information regarding editorial changes.

(Red font text to be deleted)

(Blue font text to be added or edited)

Table J.1—Identification of modifications

No.	Clause/subclause	Modifications
1	Warning statement 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 should be considered when making specific requirements for H_2S-containing environment; see Annex G. Other variables which can contribute to hydrogen embrittlement should be considered. There are other sources of hydrogen besides H_2S containing environments, which are not addressed by the ISO 15156 series.	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 15156:2020 series should be considered when making specific requirements for H_2S-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 H_2S-containing environments, which are not addressed by the ISO 15156:2020 series.
2	**1 Scope** This document specifies the technical delivery conditions for corrosion-resistant alloy seamless tubular products for casing, tubing, coupling stock and accessory material (including coupling stock and accessory material from bar) for two product specification levels: — 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. NOTE 2 For the purpose of this document, NACE MR0175 is equivalent to the ISO 15156 series. NOTE 4 Not all PSL-1 categories and grades can be made cracking resistant in accordance with the ISO 15156 series and are, therefore, not included in PSL-2.	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-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 15156:2020 series. NOTE 2 For the purpose of this document, NACE MR0175 is equivalent to the ISO 15156:2020 series. NOTE 4 Not all PSL-1 categories and grades can be made cracking resistant in accordance with the ISO 15156:2020 series and are, therefore, not included in PSL-2.
3	**2 Normative references** The following documents 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 15156 (all parts), Petroleum and natural gas industries—Materials for use in H_2S-containing environments in oil and gas	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 15156:2020 (all parts), *Petroleum and natural gas industries—Materials for use in H2S-containing environments in oil and gas production*

No.	Clause/subclause	Modifications
	production ISO 15156-3:2015, *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* ASTM E709, *Standard Guide for Magnetic Particle Testing*	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* ASTM E3024, *Standard Practice for Magnetic Particle Testing for General Industry*
4	**3.1.7** **coupling stock** seamless thick-wall *tubular product* (3.1.8) used for the manufacturer of *coupling blanks* (3.1.6).	seamless thick-wall *product* (3.1.8) used for the manufacturer of *coupling blanks* (3.1.6).
5	**3.1.8** **defect** *imperfection* (3.1.11) having sufficient magnitude to warrant rejection of the *length* (3.1.14)	*imperfection* (3.1.11) having sufficient magnitude to warrant rejection of the *length* (3.1.14) based on criteria defined in this standard
6	**3.1.17** **pipe** plain end *casing* (3.1.3), *tubing* (3.1.23) and *pup joint* (3.1.19) as group	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
7	**3.1.18** **product** **tubular product**	**3.1.18** **product**
8	**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), the American Society for Testing and Materials (ASTM) or 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”.	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”.
9	**Table 1—Minimum information to be supplied by purchaser** g) Length range	g) Length requirements
10	**Table 2—Additional requirements on purchase agreements** s) Alternate drift mandrel w) Specimen preparation (grinding/polishing/pickling) for pitting corrosion test x) Retest provision for pitting corrosion test	s) Alternative drift mandrel w) Specimen preparation (grinding/polishing/pickling) for group 2 pitting corrosion test x) Retest provision for group 2 pitting corrosion test
11	**6.4 Straightening** For group 1, pipes shall be hot-rotary straightened, when necessary, after heat	**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

No.	Clause/subclause	Modifications
	treatment, 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 pipe 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 fiber strain is not exceeding the value validated by the manufacturer at the time of process validation (see 6.5). For groups 2, 3 and 4, pipes 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).	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 fiber 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).
12	**6.5 Process requiring validation** Those processes requiring validation are — 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, and Validation of heat treatment shall include verification of chromium depletion as per 6.2. Validation of cold straightening shall include verification of mechanical properties. 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. The tested length shall be representative of material that has been subject to the maximum induced fiber 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.	**6.5 Processes requiring validation** **6.5.1** Those processes requiring validation are — 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 **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 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 fiber 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 fiber strain shall take into account maximum deflection, equipment set-up such as distance between supports and product dimensional range.
13	**7.4.2 Critical thickness** For accessories, the critical thickness shall be no less than the thickness of the cross-section	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

No.	Clause/subclause	Modifications
	of the accessory with the lowest *t/D* ratio, where *D* is the specified outside diameter and *t* is the calculated wall thickness at that section.	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).
14	**7.9.1 General** Corrosion testing for quality control purposes is not mandatory and is not normally required. At the purchaser's option, quality control corrosion testing may be specified in the purchase agreement.	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 mandatory and is not normally required.
15	**7.10.1 Group 1** For category 13-1-0, the ferrite content may exceed 5 % by agreement between purchaser and manufacturer.	For category 13-1-0, the ferrite content may exceed 2 % by agreement between purchaser and manufacturer.
16	**7.10.2 Group 2** 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 microhardness 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 this specification.	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 microhardness 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.
17	**8.2 Length** The pipes shall be delivered with the range lengths listed in Table A.17 or Table C.17.	Unless otherwise agreed between the purchaser and manufacturer, the pipes shall be delivered with the length requirements listed in Table A.17 or Table C.17.
18	**8.3.4 Drift requirements** An alternate drift mandrel size may be specified by the purchaser. For common alternate drift sizes, see Table A.20 or Table C.20.	An alternative drift mandrel size may be specified by the purchaser. For common alternative drift sizes, see Table A.20 or Table C.20.
19	**9.6.2 Test method** A single indentation 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.	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.
20	**9.6.6 Retests** If the new mean hardness number conforms to the requirements, the piece shall be accepted.	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.

No.	Clause/subclause	Modifications
	If the new mean hardness number fails to conform to the requirements, the piece shall be rejected.	
21	**9.11.3 Wall thickness at end of products** Wall thickness measurements shall be made with a mechanical calliper or with a calibrated non-destructive examination device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical calliper shall govern. The mechanical calliper shall be fitted with contact pins 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 ⅝ in) and larger, a maximum radius D/4 for products less than 168,28 mm (6 ⅝ 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).	Wall thickness measurements shall be made with a mechanical calliper, micrometer or with a calibrated non-destructive examination device of appropriate accuracy. When mechanical callipers or micrometers 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 ⅝ in.) and larger, a maximum radius D/4 for products less than 168.28 mm (6 ⅝ 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.).
22	**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 alternate 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.	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.
23	**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 an established written procedure. Visual inspection may be replaced by an	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 an established written procedure. If another method is applied with demonstrated capability of detecting defects as defined in 7.12, physical visual inspection is not required. Physical visual inspection may be replaced by a

No.	Clause/subclause	Modifications
	automatic inspection method, other than those stated in 9.17.9 or 9.17.10, if the method has validated and documented capability of detecting surface defects, as defined in 7.12, and has documented calibration reference standards and calibration frequency.	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 (see 9.17.8 as applicable), verification criteria and calibration procedures, including frequency.
24	**9.17.2 NDE personnel** 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. Non-destructive inspection shall be conducted by level 1, 2 or 3 personnel, using procedures approved by level 3 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.
25	**9.17.9 All product group 1** In addition, when specified in the purchaser agreement, all lengths shall be inspected for the detection of imperfections on the outside surface by one of the following methods: c) magnetic-particle inspection in accordance with ISO 10893-5 or ASTM E709.	In addition, when specified in the purchaser agreement, all lengths shall be inspected for the detection of longitudinal and transverse imperfections on the outside surface by one of the following methods: c) magnetic-particle inspection in accordance with ISO 10893-5 or ASTM E3024.
26	**9.17.13 Disposition of pipe containing defects** 2) liquid-penetrant inspection according to ISO 10893-4 or ASTM E165 or for group 1, magnetic-particle inspection according to ISO 10893-5 or ASTM E709, or	2) liquid-penetrant inspection according to ISO 10893-4 or ASTM E165 or for group 1, magnetic-particle inspection according to ISO 10893-5 or ASTM E3024, or
27	**9.17.14 Disposition of coupling stock and accessory material containing defects** 2) liquid-penetrant inspection according to ISO 10893-4 or ASTM E165 or for group 1, magnetic particle inspection according to ISO 10893-5 or ASTM E709, or	2) liquid-penetrant inspection according to ISO 10893-4 or ASTM E165 or for group 1, magnetic particle inspection according to ISO 10893-5 or ASTM E3024, or
28	**9.18 Positive material identification** All lengths of groups 2, 3 and 4 shall be	All lengths of groups 2, 3 and 4 shall be inspected by PMI. For group 1, PMI can be performed by

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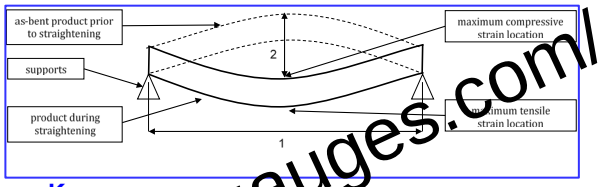
	inspected by PMI using a method in accordance with ASTM E1476 or API RP 578 to validate that the inspected lengths correspond to the specified material category. PMI shall be based as a minimum on the detection of Cr, Ni and Mo. For group 1, PMI can be performed by agreement between purchaser and manufacturer. In case of dispute, a new product chemical analysis in accordance with 9.3 shall govern. e) instrument verification method and frequency; the PMI equipment verification shall be performed on reference standard(s) once every lot and at least once every shift; f) methodology used for the verification of the composition of the reference standard, in which identification and recording of the serial number of each reference standard is required for each verification; g) records of training and qualification of personnel per test method and material group.	agreement between purchaser and manufacturer, PMI shall be performed using a method in accordance with ASTM E1476 or API RP 578 to validate that the inspected lengths correspond to the specified material category. PMI shall be based as a minimum on the detection of Cr, Ni and Mo. In case of dispute, a new product chemical analysis in accordance with 9.3 shall govern. e) instrument verification method and frequency; the PMI equipment verification shall be performed on reference standard(s) with at least two readings once every shift; f) methodology used for the verification of the composition of the reference standard, in which identification and recording of the serial number of each reference standard is required for each verification. Reference standards traceability to international, national or manufacturer-developed reference standards used for calibration or verification shall be documented; g) records of training and qualification of personnel per test method and material category. A record of training shall be made available to the purchaser upon request.
29	**11.3 Marking content and sequence** Product shall be marked in the following sequence: i) unique length number; Low-stress die-stamping or vibro-etching or equivalent are acceptable. When die stamping is specified in the purchase agreement (see 11.1), die stamping shall contain as a minimum the unique identification for each length (h. unique length number). The date of manufacture is defined as a three-digit number, consisting of the last digit of the year followed by a two-digit number indicating the month in which the markings are completed.	Each length shall be marked in the following sequence: i) unique length identification; Low-stress die-stamping or vibro-etching or equivalent are acceptable. When die stamping is specified in the purchase agreement (see 11.1), die stamping shall contain as a minimum the unique length identification. The date of manufacture is defined for marking purposes as the first two digits representing the month and the last two digits representing the year with a hyphen (dash) or slash in between (e.g., 04-21 or 04/21 for April 2021). Products manufactured in accordance with this edition of the specification during the period of overlap of application with the previous edition shall be identified by including the edition number after the manufacture date separated by a hyphen (dash) or slash (e.g., 2nd Edition during 1st Edition applicability, 04-21-2ED or 04/21/2ED for 2nd Edition). Once the new edition is effective, marking of the edition is at the manufacturer's discretion.
30	**13.2 Retention of records** Tests and inspections requiring retention of	Tests and inspections requiring retention of records

<table>
<tr><th>No.</th><th>Clause/subclause</th><th>Modifications</th></tr>
<tr><td></td><td>records are given in Table A.21 or Table C.21. Test certificates record retention is required (see 13.3). Calibration record retention is required. Such records shall be retained by the manufacturer and shall be available to the purchaser on request for a period of three years after the date of purchase from the manufacturer.</td><td>are given in Table A.21 or Table C.21. Test certificates record retention is required (see 13.3). Calibration record retention is required. Such records shall be retained by the manufacturer and shall be available to the purchaser on request for a period of five years after the date of purchase from the manufacturer.</td></tr>
<tr><td>31</td><td>13.3 Test certificates
k) visual inspection results;
p) statement of conformance with the metallurgical and manufacturing requirements of the ISO 15156 series for PSL-2.
NOTE For the purpose of this provision NACE MR0175 is equivalent to the ISO 15156 series.</td><td>k) statement of conformance to visual inspection;
p) statement of conformance with the metallurgical and manufacturing requirements of the ISO 15156:2020 series for PSL-2.
NOTE For the purpose of this provision NACE MR0175 is equivalent to the ISO 15156:2020 series.</td></tr>
<tr><td>32</td><td>14.3.2 Identification
f) number of pieces;</td><td>f) number of lengths;</td></tr>
<tr><td>33</td><td>Table A.2—Nominal analysis of corrosion-resistant alloy and material categories
Typical analysis</td><td>Nominal analysis</td></tr>
<tr><td>34</td><td>Table A.16—Specified dimensions and masses of pipe
Alternate
drift
diameter</td><td>Alternative
drift
diameter</td></tr>
<tr><td>35</td><td>Table A.17—Range length
<table><tr><th>Range 1 (R1)</th><th>Range 2 (R2)</th><th>Range 3 (R3)</th></tr></table>Maximum permissible variation on 100 % on each order item of 18,144 kg or more
Length [a]
[a] 0.61 m pup joints may be furnished up to 0.91 m long by agreement between manufacturer and purchaser; lengths other than those listed may be furnished by agreement between purchaser and manufacturer.</td><td>Table A.17—Length requirements
<table><tr><th>Range 1 [b] (R1)</th><th>Range 2 [b] (R2)</th><th>Range 3 [b] (R3)</th></tr></table>Maximum permissible variation on 100 % of each order item of 18,144 kg or more
Length [a,b]
[a] 0.61 m pup joints may be furnished up to 0.91 m long by agreement between manufacturer and purchaser.
[b] Lengths other than those listed may be furnished by agreement between purchaser and manufacturer.</td></tr>
<tr><td>36</td><td>Table A.20—Alternate drift mandrel dimensions
Length</td><td>Table A.20—Alternative drift mandrel dimensions
Length [a]
[a] For tubing, minimum drift mandrel length shall be 1067 mm.</td></tr>
<tr><td>37</td><td>Table A.21—Type and frequency of tests for non-upset and upset product
<table><tr><td>PMI</td><td>m (o [f])</td><td>Each length</td><td>9.18</td><td>7.1</td></tr></table></td><td><table><tr><td>PMI</td><td>m (o [f])</td><td>Each length</td><td>9.18</td><td>9.18</td></tr></table></td></tr>
</table>

<table>
<tr><th>No.</th><th>Clause/subclause</th><th>Modifications</th></tr>
<tr><td>38</td><td>Annex B</td><td> 

Key
1 distance between straightener product supports
2 maximum applied deflection distance during straighteni
Figure B.9—Gag straightening</td></tr>
<tr><td>39</td><td>Table C.2—Nominal analysis of corrosion-resistant alloy and material categories
Typical analysis</td><td>Nominal analysis</td></tr>
<tr><td>40</td><td>Table C.16—Specified dimensions and masses of pipe
Alternate
drift
diameter</td><td>Alternative
drift
diameter</td></tr>
<tr><td>41</td><td>Table C.17—Range length
<table><tr><th>Range 1 (R1)</th><th>Range 2 (R2)</th><th>Range 3 (R3)</th></tr></table>Maximum permissible variation on 100 % on each order item of 40,000 lb or more
Length [a]
[a] 2 ft pup joints may be furnished up to 3 ft long by agreement between manufacturer and purchaser; lengths other than those listed may be furnished by agreement between purchaser and manufacturer.</td><td>Table C.17—Length requirements
<table><tr><th>Range 1 [b] (R1)</th><th>Range 2 [b] (R2)</th><th>Range 3 [b] (R3)</th></tr></table>Maximum permissible variation on 100 % of each order item of 40,000 lb or more
Length [a,b]
[a] 2 ft pup joints may be furnished up to 3 ft long by agreement between manufacturer and purchaser.
[b] Lengths other than those listed may be furnished by agreement between purchaser and manufacturer.</td></tr>
<tr><td>42</td><td>Table C.20—Alternate drift mandrel dimensions
Length</td><td>Table C.20—Alternative drift mandrel dimensions
Length [a]
[a] For tubing, minimum drift mandrel length shall be 42 in.</td></tr>
<tr><td>43</td><td>Table C.21—Type and frequency of tests for non-upset and upset product
<table><tr><td>PMI</td><td>m (o [f])</td><td>Each length</td><td>9.18</td><td>7.1</td></tr></table></td><td><table><tr><td>PMI</td><td>m (o [f])</td><td>Each length</td><td>9.18</td><td>9.18</td></tr></table></td></tr>
<tr><td>44</td><td>Table C.24—Acceptance level
Second method</td><td>Second method [b]</td></tr>
</table>

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45	**D.1 Inspection notice** Where the purchaser's inspector requires that the product be inspected or that the tests be witnessed, reasonable notice of the time shall be given by the manufacturer.	Where the purchaser's inspector desires that the product be inspected or that the tests be witnessed, reasonable notice of the time shall be given by the manufacturer.
46	**D.2 Plant Access** The inspector representing the purchaser shall have unrestricted access, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the products ordered. The manufacturer shall afford the inspector all reasonable facilities to demonstrate that the products are being manufactured in accordance with this document. All inspections should be made at the place of manufacture prior to shipment, unless otherwise specified on the purchase agreement, and shall be conducted so as not to interfere unnecessarily with the operation of the works.	All inspections should be made at the place of manufacture prior to shipment, unless otherwise specified on the purchase agreement, and shall be conducted so as not to interfere unnecessarily with the operation of the works.
47	**F.1 General** — PSL-2, which provides additional requirements for a product that is intended to be both corrosion resistant and cracking resistant for the environments and qualification method specified in Annex G and in the ISO 15156 series. NOTE 1 For the purpose of this document, NACE MR0175 is equivalent to the ISO 15156 series.	— PSL-2, which provides additional requirements for a product that is intended to be both corrosion resistant and cracking resistant for the environments and qualification method specified in Annex G and in the ISO 15156:2020 series. NOTE 1 For the purpose of this document, NACE MR0175 is equivalent to the ISO 15156:2020 series.
48	**Table F.2—Additional requirements on purchase agreements** g) Alternate test locations for tensile testing i) Alternate test locations for impact testing j) Alternate test locations for cleanliness evaluation k) Alternate test locations for microstructural examination	g) Alternative test locations for tensile testing i) Alternative test locations for impact testing j) Alternative test locations for cleanliness evaluation k) Alternative test locations for microstructural examination
49	**F.3.2 Forging and hot working processes**	**F.3.2 Hot working processes**
50	**F.3.3.2 Heat treatment condition** For group 1 PSL-2, heat treatment requirements of the ISO 15156 series shall	For group 1 PSL-2, heat treatment requirements of the ISO 15156:2020 series shall apply.

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	apply.	
51	**F.5.3.1 Tensile test for groups 1 and 2** Alternate test locations may be agreed between manufacturer and purchaser based on assessment of critical cross-section of the actual component to be manufactured from the heat-treated raw material.	Alternative test locations may be agreed between manufacturer and purchaser based on assessment of critical cross-section of the actual component to be manufactured from the heat-treated raw material.
52	**F.5.1 Test lot and rounding** For groups 1 and 2, maximum number of bars per test lot shall be	For groups 1 and 2, maximum number of bars per test lot at the time of heat treatment shall be
53	**F.5.4.2 Surface hardness** The frequency of surface hardness shall be each bar in the test lot. Hardness tests shall be performed at alternating ends of bars. An alternative lower surface hardness test frequency may be used by agreement between manufacturer and purchaser.	**F.5.4.2 Surface hardness for groups 1 and 2** The frequency of surface hardness shall be each bar in the test lot. Hardness tests shall be performed at alternating ends of bars, unless MPQT as per F.3.6 has been successfully performed in which case the alternating end requirement does not apply. An alternative lower surface hardness test frequency and/or end location sampling may be used by agreement between manufacturer and purchaser.
54	**F.5.4.3 Cross-section hardness**	**F.5.4.3 Cross-section hardness for groups 1 and 2**
55	**F.5.5.1 Impact test for groups 1 and 2** Alternate test locations may be agreed between manufacturer and purchaser based on assessment of critical cross-section of the actual component to be manufactured from the heat-treated raw material.	Alternative test locations may be agreed between manufacturer and purchaser based on assessment of critical cross-section of the actual component to be manufactured from the heat-treated raw material.
56	**F.5.6.1 Cleanliness evaluation for group 1** Alternate test locations may be agreed between manufacturer and purchaser based on assessment of critical cross-section of the actual component to be manufactured from the heat treated raw material.	Alternative test locations may be agreed between manufacturer and purchaser based on assessment of critical cross-section of the actual component to be manufactured from the heat treated raw material.
57	**F.5.7.1 Microstructural examination for groups 1 and 2** Alternate test locations maybe agreed between manufacturer and purchaser based on assessment of critical cross-section of the actual component to be manufactured from the heat-treated raw material.	Alternative test locations maybe agreed between manufacturer and purchaser based on assessment of critical cross-section of the actual component to be manufactured from the heat-treated raw material.
58	**F.5.9.2 Visual inspection** All bars shall be submitted to a visual	All bars shall be submitted to a visual inspection over the entire surface for the detection of imperfections in order to ensure conformance to the

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	inspection over the entire surface for the detection of imperfections in order to ensure conformance to the requirements of F.4.8. The visual inspection shall be carried out according to an established written procedure. 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). The visual inspection shall be on the product in the final surface and mechanical processing condition, but before coating, if applicable.	requirements of F.4.8. The visual inspection shall be carried out according to an established written procedure. If another method is applied with demonstrated capability of detecting defects as defined in F.4.8, 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). The visual inspection shall be on the product in the final surface and mechanical processing condition, but before coating, if applicable. Physical visual inspection may be replaced by a visual technique, other than those stated in F.5.9.3 or F.5.9.4, if the system has validated and documented capability of detecting surface defects, as defined in F.4.8, and the manufacturer has documented capability records (per F.5.9.1 as applicable), verification criteria and calibration procedures, including frequency.
59	**F.5.9.6 Disposition of bar stock containing defects** 2) liquid-penetrant inspection according to ISO 3452-1 or ASTM E165 or magnetic particle inspection according to ISO 9934-1 or ASTM E709 for ferromagnetic materials, or	2) liquid-penetrant inspection according to ISO 3452-1 or ASTM E165 or magnetic particle inspection according to ISO 9934-1 or ASTM E3024 for ferromagnetic materials, or
60	**F.5.10 Dimensional inspection** Outside diameter shall be inspected per 9.11.2. Length shall be inspected per 9.13.	Outside diameter shall be inspected per 9.11.2 or by an alternative inspection method validated to be capable to ensure conformance with Table F.1 f). Length shall be inspected per 9.13 or by an alternative inspection method validated to be capable to ensure conformance with Table F.1 g).
61	**F.7.2 Retention of records** Tests and inspections as specified herein require retention of records. Test certificates record retention is required (see F.7.3). Such records shall be retained by the manufacturer and shall be available to the purchaser on request for a period of three years after the date of purchase from the manufacturer.	Tests and inspections as specified herein require retention of records. Test certificates record retention is required (see F.7.3). Such records shall be retained by the manufacturer and shall be available to the purchaser on request for a period of five years after the date of purchase from the manufacturer.
62	**F.7.3.1 Test certificates for groups 1 and 2** r) visual inspection results;	r) statement of conformance to visual inspection; v) statement of conformance with the metallurgical and manufacturing requirements of the ISO

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	v) statement of conformance with the metallurgical and manufacturing requirements of the ISO 15156 series for PSL-2.	15156:2020 series for PSL-2.
63	**G.1 General** This annex specifies requirements for product specification level 2 (PSL-2). PSL-2 may be specified by the purchaser or supplied at the option of the manufacturer. The requirements for PSL-2 are in addition to those for PSL-1, which form the basis of this document. PSL-2 product is intended to conform to the requirements of prequalified materials listed in the ISO 15156 series to provide a product that is both corrosion resistant and cracking resistant for the environments and qualification method specified in these Standards. For tubulars, PSL-2 may include any alloy in a category in Table A.2 or Table C.2, provided all requirements in the ISO 15156 series are fulfilled in addition to the requirements of this document. For bars in groups 1 and 2, PSL-2 products are listed in Table A.31 or Table C.31. All group 5 products are PSL-2. **WARNING 1—End sizing, connection manufacture or welding operations can influence the corrosion and cracking resistance of the materials specified in this annex. Demonstration of conformance to ISO 15156-3 is outside the scope of this document.** **WARNING 2—The corrosion-resistant alloys (CRAs) selected using the ISO 15156 series are resistant to cracking in defined H_2S-containing environments in oil and gas production but are not necessarily immune to cracking under all service conditions. It is the equipment user's responsibility to select the CRAs suitable for the intended service. When defining the severity of H2S-containing environments, exposures that can occur during system upsets or shutdowns, etc., should also be considered. Other variables which may contribute to hydrogen embrittlement should be considered. There are other sources of hydrogen besides H2S containing environments, which are not addressed by the ISO 15156 series.**	This annex specifies requirements for product specification level 2 (PSL-2). PSL-2 may be specified by the purchaser or supplied at the option of the manufacturer. The requirements for PSL-2 are in addition to those for PSL-1, which form the basis of this document. PSL-2 product is intended to conform to the requirements of prequalified materials listed in the ISO 15156:2020 series to provide a product that is both corrosion resistant and cracking resistant for the environments and qualification method specified in these Standards. For tubulars, PSL-2 may include any alloy in a category in Table A.2 or Table C.2, provided all requirements in the ISO 15156:2020 series are fulfilled in addition to the requirements of this document. For bars in groups 1 and 2, PSL-2 products are listed in Table A.31 or Table C.31. All group 5 products are PSL-2. **WARNING 1—End sizing, connection manufacture or welding operations can influence the corrosion and cracking resistance of the materials specified in this annex. Demonstration of conformance to ISO 15156-3:2020 of material affected by these processes is outside the scope of this document.** **WARNING 2—The corrosion-resistant alloys (CRAs) selected using the ISO 15156:2020 series are resistant to cracking in defined H_2S-containing environments in oil and gas production but are not necessarily immune to cracking under all service conditions. It is the equipment user's responsibility to select the CRAs suitable for the intended service. 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 H_2S-containing environments, which are not addressed by the ISO 15156:2020 series.**

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64	**G.2 PSL-2 product** Material categories and grades listed in Table A.2 or Table C.2 can be assessed for conformance to the applicable requirements of the ISO 15156 series. Documented information about deliveries (provided by manufacturers) and use as down hole tubular (provided by users) can also be taken into consideration. Some of the higher strength grades listed in Table A.2 or Table C.2 cannot be delivered as PSL-2 because of non-conformance to the requirements of the ISO 15156 series. Some requirements for PSL-2 can in some cases be more restrictive than the ones of the ISO 15156 series. In taking into account experience based on successful laboratory testing and/or satisfactory field experience specific to special applications, values other than those listed in Table A.28 or Table C.28 may be used by agreement between purchaser and manufacturer. However, the agreement shall demonstrate that the relevant requirements in the ISO 15156 series are fulfilled at that time. In some circumstances, this can require qualification according to ISO 15156-3:2015, Annex B. Such products may be designated as PSL-2 but shall be marked in accordance with the applicable requirements in G.3 and/or G.4. In addition, the agreed values and the corresponding test results shall be documented on the material certification.	Material categories and grades listed in Table A.2 or Table C.2 can be assessed for conformance to the applicable requirements of the ISO 15156:2020 series. Documented information about deliveries (provided by manufacturers) and use as down hole tubular (provided by users) can also be taken into consideration. Some of the higher strength grades listed in Table A.2 or Table C.2 cannot be delivered as PSL-2 because of non-conformance to the requirements of the ISO 15156:2020 series. Some requirements for PSL-2 can in some cases be more restrictive than the ones of the ISO 15156:2020 series. In taking into account experience based on successful laboratory testing and/or satisfactory field experience specific to special applications, values other than those listed in Table A.28 or Table C.28 may be used by agreement between purchaser and manufacturer. However, the agreement shall demonstrate that the relevant requirements in the ISO 15156:2020 series are fulfilled at that time. In some circumstances, this can require qualification according to ISO 15156-3:2020, Annex B. Such products may be designated as PSL-2 but shall be marked in accordance with the applicable requirements in G.3 and/or G.4. In addition, the agreed values and the corresponding test results shall be documented on the material certification.
65	**G.5 Process for update of alloys and/or grades** Applications for the entry of new alloys and/or grades shall be made to ISO/TC 67/SC 5. Only alloys or grades which are already included in ISO 15156-3 will be considered. Applications for new entries or alteration to existing entries shall be accompanied by supporting evidence as per Annex H.	Applications for the entry of new alloys and/or grades shall be made to ISO/TC 67/SC 5. Only alloys, grades or types of alloys which are already included in ISO 15156-3:2020 will be considered. Applications for new entries or alteration to existing entries shall be accompanied by supporting evidence as per H.4.
66	**H.2 Manufacturing processes** a) starting material manufacturing process: — casting method (ingot or continuous cast); — starting material further processing (rolling, forging). b) product manufacturing process:	a) starting material manufacturing process: — casting method (ingot, continuous cast or state other casting method); — starting material (e.g. ingot/billet or rolled/forged bar/machined bar, hot finished hollow or other). b) product manufacturing process (only seamless

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	— hot forming process and general equipment description, including total hot working ratio; — final forming process and general equipment description; — final heat treatment or cold hardening process and general equipment description; — final conditioning processes and general equipment description, including end sizing if applicable.	manufacturing is allowed): — hot forming process and general equipment description (e.g. hot finished, hot-rolled/forged, or hot-extruded), including total hot working ratio; — cold forming process and general equipment description (e.g. cold-hardened by cold drawing, cold pilgering or other); — final heat treatment conditions (e.g. quenched and tempered, solution-annealed, solution annealed and age-hardened), requirements (e.g. temperature, time, quench media or other) and general equipment description; — final conditioning processes and general equipment description, including straightening and end sizing if applicable.
67	**H.3.1 General** For groups 1, 2, 3 and 4, the MPQT program is part of the information needed to be supplied for consideration of the insertion of a new alloy and/or grade in this document (see H.4). For a new group 5 product, the requirement process in API 6ACRA for addition of new alloys and/or alloy material destinations shall apply.	For groups 1, 2, 3 and 4, the MPQT program is part of the information needed to be supplied for consideration of the insertion of a new alloy and/or grade in this document (see H.4). The submittal record shall include a summary of the applicable mechanical, metallographic, corrosion and NDE test results. The submittal shall include the mean, range and standard deviation for quantitative test results. For a new group 5 product, the requirement process in API 6ACRA for addition of new alloys and/or alloy material destinations shall apply.
68	**H.3.2 Material properties and dimensional requirements** Mechanical property statistical analyses shall be performed to demonstrate that the processes are in-control. The purchaser and manufacturer shall agree on the statistical criteria for an in-control process. The minimum/maximum limits within this document are not statistical criteria per se. The manufacturer shall report the capability analyses, state the criteria for being in-control and state conclusions.	Mechanical property statistical analyses shall be performed to demonstrate that the processes are in-control. The purchaser and manufacturer shall agree on the statistical criteria for an in-control process. The minimum/maximum limits within this document are not statistical criteria per se. The manufacturer shall report the capability analyses, state the criteria for being in-control and state conclusions. The report shall include the mean, range and standard deviation for quantitative test results.
69	**H.4 Information supplied for consideration of inclusion of a new alloy and/or grade in this document for groups 1, 2, 3 and 4** For consideration of the insertion of a new alloy and/or grade in this document, the manufacturer shall provide a) the material characteristics of the CRA	The submitter should review the requirements in this document. For consistency in the submittal, the submittal shall use the terminology, processes and methods stated in this document. If new terminology, processes and methods should be considered, the submitter shall clearly state and define the new terminology, processes and methods in the proposal. For consideration of the insertion of a new alloy and/or grade in this document, the submitter shall provide

No.	Clause/subclause	Modifications
	alloy and grade, including the following: — typical range of applications; — dimensional range of the product(s); — full typical chemical composition; — for alloys intended for PSL-2, UNS number and qualification report in conformance with ISO 15156-3:2015, Annex B; — grade or grades; b) all the details of the manufacturing process as per H.2; c) material properties, proposed acceptance limits and required testing and inspection methods to verify the conformance, following the same structure of this document for Clauses 7 to 9 for tubulars, or F.4 and F.5 for bars, including the following: — chemical composition with all intentionally added and controlled elements, with ranges; — tensile properties; — hardness properties; — impact or flattening properties, as applicable; — chromium depletion, as applicable; — macrostructure and microstructure (including cleanliness acceptance criteria), as applicable; — dimensional requirements (including tolerances in diameter, wall thickness, length, straightness); — NDE; — other inspections (drift); d) report of MPQT program as per H.3; e) reports of manufacturing of the intended product or products (laboratory manufacturing scale is not acceptable), including:	a) the material characteristics of the CRA alloy and grade, including the following: — typical range of applications, such as corrosion resistance (e.g. resistance to sulphide stress cracking, stress corrosion cracking, etc.); — dimensional range of the product(s), with respect to nominal outside diameter, wall thickness if applicable and length; — full nominal chemical composition; — for alloys intended for PSL-2, UNS number and qualification report in conformance with ISO 15156-3:2020, Annex B; — grade or grades (specified minimum yield strength); b) details of the manufacturing process as per H.2 and processes requiring validation as per 6.5 and F.3.4. The submitter shall clearly state if new/different manufacturing processes, not included in Clause 6, should be considered with justification; c) material properties, proposed acceptance limits and required testing and inspection methods to verify the conformance, following the same structure of this document for Clauses 7 to 9 for tubulars, or F.4 and F.5 for bars, in the applicable USC and SI units, including the following: — chemical composition with all intentionally added and controlled elements, with ranges. If the material could have susceptibility for the formation of detrimental precipitates, the submittal should include more conservative limits than included in the UNS number for the appropriate elements to suppress/mitigate precipitate formation; — tensile properties (yield strength, tensile strength, percent elongation, and percent reduction of area, as applicable); — hardness properties (mean hardness number and hardness number limits, hardness test method/scale for through-wall and surface hardness, as applicable); — impact properties, as applicable (minimum mean absorbed energy for average of three impact specimens and minimum individual impact specimen, minimum lateral expansion and minimum percent shear area, as applicable);

No.	Clause/subclause	Modifications
		— flattening properties, as applicable — chromium depletion, as applicable (minimum surface chromium acceptance criterion for each material condition); — macrostructure and microstructure, as applicable (test location(s), orientation, proposed test method, photographs of macrostructure and microstructure, etchant(s), magnification(s) and requirements). If example reference photomicrographs would be beneficial to clarify microstructure acceptance in this document, the submittal shall include photomicrographs with clear headers stating location, orientation, magnification, etchant, “pass” or “fail” (with stated reason for failure); — cleanliness, as applicable (see Annex E for cleanliness evaluation and the groups where this evaluation applies as required within this document); — corrosion acceptance requirements, as applicable (test method and acceptance criteria); — dimensional requirements (including tolerances in diameter, wall thickness, length, straightness, drift, as applicable); — NDE (acceptance criteria and details of proposed differences to this document if any); — other proposed additions or changes within this document along with justifications; d) normative references not currently included in this document if applicable; e) report of MPQT program as per H.3; f) reports of manufacturing of the intended product or products (laboratory manufacturing scale is not acceptable), including: NOTE Field experience record is typically limited to the supply record and those details of field environmental conditions shared to the manufacturer (ideally, pH, temperature, water cut, total pressure, elemental sulphur, partial pressure of H_2S and CO_2 or other parameters that determine the resistance to general, localized and cracking corrosion resistance of the material). This environmental data may not reflect the actual field conditions experienced by the supplied product. The field supply record typically also includes the product chemistry, UNS number, grade, product dimensions (nominal outside diameter, wall thickness if applicable and length), quantities, number of heats and lots.

Bibliography

[1] ISO 6506-1, *Metallic materials—Brinell hardness test—Part 1: Test method*

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

[3] ISO 11960, *Petroleum and natural gas industries—Steel pipes for use as casing or tubing for wells*

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[5] ISO 17781:2017, *Petroleum, petrochemical and natural gas industries—Test methods for quality control of microstructure of ferritic/austenitic (duplex) stainless steels*

[6] AMS 2750E, *Pyrometry*

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[8] ASTM A380, *Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems*

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[12] ASTM E407, *Standard Practice for Microetching Metals and Alloys*

[13] ASTM E1473, *Standard Test Methods for Chemical Analysis of Nickel, Cobalt, and High-Temperature Alloys*

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[16] NACE TM0316, *Four-Point Bend Testing of Materials for Oil and Gas Applications*

[17] NORSOK M-630, *Material data sheets and element data sheets for piping*

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