

BS EN ISO 13680:2010



BSI Standards Publication

Petroleum and natural gas industries — Corrosion-resistant alloy seamless tubes for use as casing, tubing and coupling stock — Technical delivery conditions

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National foreword

This British Standard is the UK implementation of EN ISO 13680:2010. It supersedes BS EN ISO 13680:2008 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PSE/17/-/5, Casing, tubing and drill pipe.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Compliance with a British Standard cannot confer immunity from legal obligations.

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Date	Text affected
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English Version

**Petroleum and natural gas industries - Corrosion-resistant alloy
seamless tubes for use as casing, tubing and coupling stock -
Technical delivery conditions (ISO 13680:2010)**

Industries du pétrole et du gaz naturel - Tubes sans
soudure en acier allié résistant à la corrosion utilisés
comme tubes de cuvelage, tubes de production et tubes-
ébauches pour manchons - Conditions techniques de
livraison (ISO 13680:2010)

Erdöl- und Erdgasindustrie - Nahtlose Rohre aus
korrosionsbeständigen Legierungen zur Verwendung als
Futter- oder Steigrohre sowie Muffenvorrohre - Technische
Lieferbedingungen (ISO 13680:2010)

This European Standard was approved by CEN on 30 August 2010.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN Management Centre has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Foreword

This document (EN ISO 13680:2010) has been prepared by Technical Committee ISO/TC 67 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" in collaboration with Technical Committee CEN/TC 12 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 2011, and conflicting national standards shall be withdrawn at the latest by March 2011.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN ISO 13680:2008.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

Endorsement notice

The text of ISO 13680:2010 has been approved by CEN as a EN ISO 13680:2010 without any modification.

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Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 13680 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*.

This third edition cancels and replaces the second edition (ISO 13680:2008), of which it constitutes a minor revision, with changes to 4.1.2; 4.1.14; 4.1.16; 4.1.19; 5.2 p) and 5.2 q); 6.1; 6.5; 6.6; 7.2; 7.7; 7.11.1 and 7.11.2; 9.3.3; 9.8.2; 9.8.3; 9.16.7; 9.16.13; 9.16.14; 11.2.4; 13.3; and Tables A.1, A.27, A.28, C.2, C.15, C.18, C.27 and C.28.

It is the intent of ISO/TC 67 that the second and third edition of ISO 13680 both be applicable, at the option of the purchaser, for a period of six months from the first day of the calendar quarter immediately following the date of publication of this third edition, after which period the second edition will no longer be applicable.

Introduction

It is necessary that users of this International Standard be aware that further or differing requirements can be needed for individual applications. This International Standard is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This can be particularly applicable where there is innovative or developing technology. Where an alternative is offered, it is the responsibility of the vendor to identify any variations from this International Standard and provide details.

This International Standard includes provisions of various nature. These are identified by the use of certain verbal forms:

SHALL is used to indicate that a provision is MANDATORY;

SHOULD is used to indicate that a provision is not mandatory, but RECOMMENDED as good practice;

MAY is used to indicate that a provision is OPTIONAL.

Petroleum and natural gas industries — Corrosion-resistant alloy seamless tubes for use as casing, tubing and coupling stock — Technical delivery conditions

WARNING — It is the purchaser's responsibility to specify the product specification level (PSL), corrosion-resistant alloy (CRA) group, category, grade, delivery conditions and any other requirements in addition to those specified herewith to ensure that the product is adequate for the intended service environment. ISO 15156 (all parts) or NACE MR0175/ISO 15156 should be considered when making specific requirements for H₂S-containing environment; see Annex G.

1 Scope

This International Standard specifies the technical delivery conditions for corrosion-resistant alloy seamless tubulars for casing, tubing and coupling stock for two product specification levels:

- PSL-1, which is the basis of this International Standard;
- 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 ISO 15156-3 and Annex G of this International Standard.

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 International Standard are special alloys in accordance with ISO 4948-1 and ISO 4948-2.

This International Standard is applicable to the following four groups of product:

- 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).

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

NOTE 2 The connection or joining method can influence the corrosion performance of the materials specified in this International Standard.

NOTE 3 It is necessary to recognize that not all PSL-1 categories and grades can be made cracking resistant in accordance with ISO 15156-3 and are, therefore, not included in PSL-2.

2 Conformance

2.1 Dual normative references

In the interests of worldwide application of this International Standard, ISO/TC 67 has decided, after detailed technical analysis, that certain of the normative documents listed in Clause 3 and prepared by ISO/TC 67 or another ISO Technical Committee 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”.

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.

2.2 Units of measurement

In this International Standard, 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, compliance with the requirements of this International Standard as expressed in one system provides compliance with 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.

3 Normative references

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

ISO 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 783, *Metallic materials — Tensile testing at elevated temperature*

ISO 4885, *Ferrous products — 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 (scales A, B, C, D, E, F, G, H, K, N, T)*

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

ISO 6929, *Steel products — Definitions and classification*

ISO 8501-1:2007, *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 9303, *Seamless and welded (except submerged arc-welded) steel tubes for pressure purposes — Full peripheral ultrasonic testing for the detection of longitudinal imperfections*

ISO 9304, *Seamless and welded (except submerged arc-welded) steel tubes for pressure purposes — Eddy current testing for the detection of imperfections*

ISO 9305, *Seamless steel tubes for pressure purposes — Full peripheral ultrasonic testing for the detection of transverse imperfections*

ISO 9402, *Seamless and welded (except submerged arc-welded) steel tubes for pressure purposes — Full peripheral magnetic transducer/flux leakage testing of ferromagnetic steel tubes for the detection of longitudinal imperfections*

ISO 9598, *Seamless steel tubes for pressure purposes — Full peripheral magnetic transducer/flux leakage testing of ferromagnetic steel tubes for the detection of transverse imperfections*

ISO 10124, *Seamless and welded (except submerged arc-welded) steel tubes for pressure purposes — Ultrasonic testing for the detection of laminar imperfections*

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

ISO 10543, *Seamless and hot-stretch-reduced welded steel tubes for pressure purposes — Full peripheral ultrasonic thickness testing*

ISO 11484, *Steel products — Employer's qualification system for non-destructive testing (NDT) personnel*

ISO 11496, *Seamless and welded steel tubes for pressure purposes — Ultrasonic testing of tube ends for the detection of laminar imperfections*

ISO 12095, *Seamless and welded steel tubes for pressure purposes — Liquid penetrant testing*

ISO 13665, *Seamless and welded steel tubes for pressure purposes — Magnetic particle inspection of the tube body for the detection of surface imperfections*

ISO 14284, *Steel and iron — Sampling and preparation of samples for the determination of chemical composition*

ISO 15156-3:2009¹⁾, *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*

1) Cancelled and replaced ISO 15156-3:2003.

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

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

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

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

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

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

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

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

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

ASTM E45-05e3, *Standard Test Methods for Determining the Inclusion Content of Steel*

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 E709, *Standard Guide for Magnetic Particle Testing*

NACE MR0175/ISO 15156, *Petroleum and Natural Gas Industries — Materials for Use in H₂S-containing Environments in Oil and Gas Production*

4 Terms, abbreviated terms, symbols and definitions

4.1 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.

4.1.1

casing

pipe intended to line the walls of a drilled well

4.1.2

cast 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

4.1.3

cold-hardened

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

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

NOTE 2 The percentage of cold hardening depends on the specified strength level for each material grade, as shown in Table A.3 or Table C.3 for the cold-hardened condition.

4.1.4

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

4.1.5

coupling stock

seamless thick-wall tubular product used for the manufacture of coupling blanks

4.1.6

defect

imperfection having sufficient magnitude to warrant rejection of the product based on the criteria defined in this International Standard

4.1.7

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

4.1.8

imperfection

discontinuity on the product surface or in the product wall that can be detected by visual inspection or non-destructive examination (NDE) method outlined in this International Standard

4.1.9

label 1

dimensionless designation for the size or specified outside diameter that may be used when ordering pipe

4.1.10

label 2

dimensionless designation for the linear density that may be used when ordering pipe

NOTE Linear density is sometimes designated by the deprecated term “mass per unit length”.

4.1.11

linear imperfection

imperfection including, but not limited to, seams, laps, cracks, plug scores, cuts and gouges

4.1.12

manufacturer

firm, company or corporation that operates facilities for making seamless pipes for casing, tubing or coupling stock

4.1.13

pipe

plain end casing, tubing and pup joint as group

4.1.14

product

tubular product

pipe and/or coupling stock, either individually or collectively, as applicable

4.1.15

pup joint

casing or tubing shorter than range 1

4.1.16

quench hardening

quenching

heat treatment requiring austenitization followed by cooling, under conditions such that austenite transforms into martensite

NOTE 1 Quench hardening is often followed by tempering.

NOTE 2 Adapted from ISO 4885.

4.1.17

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

4.1.18

tempering

heat treatment requiring heating, one or more times, to a specific temperature below the lower critical temperature and holding at that temperature

NOTE 1 Tempering is often preceded by quench hardening.

NOTE 2 Adapted from ISO 4885.

4.1.19

test lot

lot

unit formed by products from the same heat, with the same specified outside diameter and wall thickness, the same grade, the same manufacturing process, the same final heat-treatment conditions, the same cold hardening parameters (if applicable) and in the range length as defined in Table A.16 and Table C.16

NOTE The maximum number of products in a test lot is found in Table A.21 and Table C.21.

4.1.20

tubing

pipe placed in a well to produce or inject fluids

4.2 Symbols

A	cross-sectional area of the tensile test specimen, expressed in square millimetres (square inches), based on specified outside diameter or nominal specimen width and specified wall thickness, rounded to the nearest 10 mm ² (0.01 in ²), or 490 mm ² (0.75 in ²), whichever is smaller
C_v	Charpy V-notch energy requirement, expressed in joules (foot pounds)
D	outside diameter of the product, expressed in millimetres (inches)
d	inside diameter of the product, expressed in millimetres (inches)
e	minimum elongation in 50,8 mm (2.0 in) gauge length, expressed in percent
f	factor (for hydrostatic test): 0,8 (0.8) for all grades and sizes
m	mass
p	hydrostatic test pressure, expressed in megapascals (thousand pounds per square inch)
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 millimetres (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)

4.3 Abbreviated terms

AOD	argon oxygen decarburization
CH	cold-hardened
EMI	electromagnetic inspection
ESR	electro-slag remelting
HF	hot-finished
HRC	Rockwell hardness C scale
L + T	longitudinal plus transverse
MT	magnetic-particle inspection
NA	not applicable
NDE	non-destructive examination
PRE	pitting-resistance equivalent number
PSL	product specification level

QT	quenched and tempered
SA	solution-annealed
UT	ultrasonic testing
VAD	vacuum arc degassing
VAR	vacuum arc remelting
VIM	vacuum induction melting
VOD	vacuum oxygen decarburization

5 Information to be supplied by the purchaser

WARNING — It is the purchaser's responsibility to specify the PSL, CRA group, category, grade, delivery conditions and any other requirements in addition to those specified herewith to ensure that the product is adequate for the intended service environment. ISO 15156 (all parts) or NACE MR0175/ISO 15156 should be considered when making specific requirements for H₂S-containing environment; see Annex G.

5.1 The purchaser shall state the following minimum information, as applicable, in the enquiry and purchase agreement:

Requirement		Reference
a)	Quantity of product	—
b)	Product designation: coupling stock 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 International Standard	—
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.15 or Table C.15 or as specified in purchase agreement
f)	Coupling stock dimensions, expressed in millimetres (inches)	As specified in purchase agreement
g)	Length range	8.2; Table A.16 or Table C.16 or as specified in purchase agreement
h)	Length for coupling stock	As specified in purchase agreement
i)	Critical thickness for impact testing of coupling stock	7.4.2
j)	Tolerances on outside diameter, wall thickness and mass of coupling stock	8.3.1
k)	Inspection by the purchaser	Annex D

5.2 The purchaser shall also state on the purchase agreement the requirements, where applicable, concerning the following stipulations, which are at the purchaser's option; if PSL-2 is not specified, the product will be supplied according to the requirements of PSL-1:

Requirement		Reference
a)	Chemical composition	7.1
b)	Mechanical properties at elevated temperature	7.2
c)	PSL-2	Annex G
d)	Impact test temperature if lower than $-10\text{ }^{\circ}\text{C}$ ($14\text{ }^{\circ}\text{F}$)	7.4.6
e)	Special surface condition	7.10
f)	Second outside surface NDE method for group 1 materials	9.16.9
g)	Chromium depletion	9.3.3
h)	Surface protection for group 1 materials	12
i)	Hydrostatic test	7.12 and 9.14
j)	Corrosion testing	7.8
k)	Ferrite content for material 13-1-0	7.9.1
l)	Alternate drift mandrel	8.3.4
m)	End sizing by cold expansion	6.3.2
n)	Additional marking that is consistent with 11.1	11.1
o)	Surface protection	12.2
p)	For UNS N06975, $w_{\text{Mo+W}} \geq 6\text{ \%}$ mass fraction	Table A.28 or Table C.28
q)	Additional flattening tests for groups 3 and 4 materials	7.7

6 Manufacturing process

6.1 Manufacturing of corrosion-resistant alloys

The alloys covered by this International Standard 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 such as swaging or expanding 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 swaging process has not detrimentally affected the corrosion properties, by agreement between the purchaser and manufacturer, group 1 pipe may be cold swaged 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. However, end sizing by cold expansion shall be only 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 detrimentally influence the corrosion performance of the materials specified in this International Standard.

6.4 Straightening

For group 1 martensitic material and for group 2 material delivered in the solution-annealed condition, the pipe shall not be subjected to either tensile or expansion cold-working, except for that which is incidental to normal straightening operations, and to no more than 3 % plastic strain, after the final heat-treatment operation.

Group 1 pipes shall be hot-rotary straightened, when necessary, after heat 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 rotary straightened, provided it is then stress-relieved at 510 °C (950 °F) or higher.

Light gag-press straightening shall be permitted, providing that the plastic strain does not exceed 3 %.

6.5 Process requiring validation

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

Those processes requiring validation are

- non-destructive examination (see 9.16.8);
- final heat treatment (including final heat treatment before any cold hardening);
- cold hardening (if applicable).

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 are performed and conformance with specification requirements has been shown.

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.

In Table A.28 or Table C.28, the chemical analysis for alloy for PSL-2 products is listed.

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

For group 2 material only, products in accordance with this International Standard 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.28 or Table C.28 for PSL-2 products.

7.2 Tensile properties

Tensile properties at room temperature of pipes covered by this International Standard shall meet the requirements given in Table A.3 or Table C.3 for PSL-1 products or in Table A.27 or Table C.27 for PSL-2 products.

In addition, the requirements in a) or b) shall also be met.

- a) The measured tensile strength shall be 70 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 35 MPa (5 ksi) or greater difference between the measured tensile strength and the measured yield strength. However, as this requirement can be difficult to achieve for some alloys and grades, by agreement between the purchaser and the manufacturer, the 35 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 International Standard shall meet the requirements given in Table A.3 or Table C.3 for PSL-1 products or in Table A.27 or Table C.27 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 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, the critical thickness shall be specified on the purchase agreement.

For coupling stock, the critical thickness should not be less than 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 specimens 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 less than the specified wall thickness for the pipe or coupling stock tested.

7.4.4 Alternative size impact test specimens

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

7.4.5 Sub-size test specimens

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

7.4.6 Test temperature

The test temperature shall be $-10\text{ }^{\circ}\text{C}$ ($14\text{ }^{\circ}\text{F}$). An alternative lower test temperature may be specified on the purchase agreement or selected by the manufacturer for any grade. The tolerance on the test temperature shall be $\pm 3\text{ }^{\circ}\text{C}$ ($\pm 5\text{ }^{\circ}\text{F}$).

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

7.5.1 General

Coupling stock 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 1, where

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

Table 1 — Expressions for the minimum absorbed energy requirement for full-size test specimens of coupling stock

Unit system and group		Transverse requirement C_v	Longitudinal requirement C_v
1		2	3
SI units of joules	Group 1	$Y_{S,max} \times (0,001\ 18\ t + 0,012\ 59)$ or 40 J, whichever is greater; see Table A.9	$Y_{S,max} \times (0,001\ 18\ t + 0,012\ 59)$ or 40 J, whichever is greater; see Table A.10
	Groups 2, 3 and 4	$Y_{S,max} \times (0,001\ 18\ t + 0,012\ 59)$ or 27 J, whichever is greater; see Table A.11	NA ^a
USC units of foot-pounds	Group 1	$Y_{S,max} \times (0,152\ t + 0,064)$ or 29 ft-lb, whichever is greater; see Table C.9	$Y_{S,max} \times (0,152\ t + 0,064)$ or 29 ft-lb, whichever is greater; see Table C.10
	Groups 2, 3 and 4	$Y_{S,max} \times (0,152\ t + 0,064)$ or 20 ft-lb, whichever is greater; see Table C.11	NA ^a
^a When transverse Charpy V-notch tests ½ size or greater are not possible for groups 2, 3 and 4, then flattening tests are required.			

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

The minimum absorbed energy requirement, C_v , for full-size test specimens is provided in Table A.12 or Table C.12, Table A.13 or Table C.13, and Table A.14 or Table C.14. The requirements are calculated based on the expressions given in Table 2, where

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

**Table 2 — Expressions for the minimum absorbed energy requirement
for full-size test specimens of pipe**

Unit system and group		Transverse requirement C_v	Longitudinal requirement C_v
1		2	3
SI units of joules	Group 1	$Y_{S,min} \times (0,001\,18\,t + 0,012\,59)$ or 40 J, whichever is greater; see Table A.12	$Y_{S,min} \times (0,001\,18\,t + 0,012\,59)$ or 40 J, whichever is greater; see Table A.13
	Groups 2, 3 and 4	$Y_{S,min} \times (0,001\,18\,t + 0,012\,59)$ or 27 J, whichever is greater; see Table A.14	NA ^a
USC units of foot- pounds	Group 1	$Y_{S,min} \times (0,152\,t + 0,064)$ or 29 ft-lb, whichever is greater; see Table C.12	$Y_{S,min} \times (0,152\,t + 0,064)$ or 29 ft-lb, whichever is greater; see Table C.13
	Groups 2, 3 and 4	$Y_{S,min} \times (0,152\,t + 0,064)$ or 20 ft-lb, whichever is greater; see Table C.14	NA ^a
^a When transverse Charpy V-notch tests ½ size or greater are not possible for groups 2, 3 and 4, then flattening tests are required.			

7.7 Flattening requirements

For groups 2, 3 or 4, flattening tests shall be made as an alternative to impact tests when the outside diameter or wall thickness precludes the machining of transverse impact test specimens 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 Equation (1) for SI units and by Equation (2) for USC units:

$$S = 100 - \{[3,845\,8 \ln(Y_{S,max}) - 24,344] \times D/t\} \quad (1)$$

$$S = 100 - \{[3,845\,8 \ln(Y_{S,max}) - 16,919] \times D/t\} \quad (2)$$

where

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

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

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

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

When the D/t ratio is outside the above limits, the required 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 Corrosion properties

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.

7.9 Microstructure properties

7.9.1 Group 1

For martensitic material, the delta ferrite content shall not exceed 5 %.

For category 13-1-0, the ferrite content may exceed 5 % by agreement between purchaser and manufacturer.

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

7.9.2 Group 2

The microstructure shall have a ferritic-austenitic structure.

The microstructure shall have grain boundaries with no continuous precipitates. Inter-metallic phases, nitrides and carbides shall not exceed 1,0 % in total. The sigma phase shall not exceed 0,5 %.

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 %.

7.9.3 Groups 3 and 4

The microstructures shall have grain boundaries with no continuous precipitates. Inter-metallic phases, nitrides and carbides shall not exceed 1,0 % in total. The sigma phase shall not exceed 0,5 %.

7.10 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.

7.11 Defects

7.11.1 Pipe

All pipe shall be free from the following defects:

- a) any quench crack or arc burn;
- b) any surface-breaking imperfection that is proven to reduce the net effective wall thickness below 87,5 % of the specified wall thickness for hot-finished products or 90 % for other products;
- c) any linear imperfection on the outside or inside surface, of any orientation, with a depth greater than 5 % of the specified wall thickness or 0,3 mm (0.012 in), whichever is greater, in the radial direction;

- d) any non-surface-breaking imperfection detected that, when outlined on the outside surface, has an area greater than 260 mm² (0.40 in²);
- e) any surface-breaking pipe-upset imperfection, of any orientation, with a depth greater than 5 % of the specified pipe body wall thickness; the minimum wall thickness in the upset run-out interval, and the maximum combined effect of coincident internal and external imperfections in all areas, shall not result in the remaining wall below the imperfections being less than 87,5 % of the specified wall thickness;
- f) on the internal upset configuration on all upset products, any sharp corner or drastic change of section that can cause a 90° hook-type tool to hang up (see Figure B.3).

7.11.2 Coupling stock

All coupling stock shall be free from any quench crack or arc burn. All coupling stock 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 7.11.1 d) shall apply.

7.11.3 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 above requirements are fulfilled.

7.12 Hydrostatic test

All HF, SA, and QT pipe shall be hydrostatically tested, unless otherwise specified in the purchase agreement.

CH pipe shall be tested if agreed upon between purchaser and manufacturer.

Due to possible limitations on some testing equipment, the hydrostatic test pressure may be, upon agreement with the purchaser, limited to 69 MPa (10 ksi). In this case, the manufacturer shall have a documented design basis to establish the physical limitation of the hydrostatic test equipment. This does not preclude conducting subsequent hydrostatic tests at a fibre stress not exceeding 80 % of yield strength, as specified in 9.14.

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 International Standard are given in Table A.15 or Table C.15. The masses included in Table A.15 or Table C.15 are calculated using a factor of 1. In order to determine the masses relating to the different materials, the masses in Table A.15 or Table C.15 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.15 or Table C.15 may be agreed at the time of enquiry and order.

8.1.3 For measurement of the diameter, an accuracy of one decimal place shall be used for label 1 larger than 6 %. In this International Standard, two decimal places are used for design purposes to ensure interchangeability.

8.2 Length

The pipes shall be delivered with the range lengths listed in Table A.16 or Table C.16.

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.17 or Table C.17.

For coupling stock, 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

The inside diameter, d , tolerance is governed by outside diameter and tolerance on mass.

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 length of pipe shall be drift-tested throughout its entire length. Standard drift sizes for casing and tubing shall be as specified in Table A.18 or Table C.18.

An alternate drift mandrel size may be specified by the purchaser. For common alternate drift sizes, see Table A.19 or Table C.19.

8.4 Product ends

Product shall be delivered with plain ends. All ends shall be free from harmful 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 International Standard.

If test or measuring equipment, whose calibration or verification is required under the provisions of this International Standard, 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.20 or Table C.20.

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 cast 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.28 or Table C.28;
- 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 cast for non-remelted alloy;
- 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 spectrographic analysis is used.

In cases of dispute, the method used for product analysis shall be agreed, taking into account the relevant existing International Standards.

NOTE ISO/TR 9769 or ASTM A751 or ASTM E1473 or 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 (4.1.19) 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 products per test lot (4.1.19) shall comply with the requirements of Table A.21 or Table C.21.

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 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.

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 comply with 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.27 or Table C.27 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 783 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 comply with the value agreed at the time of enquiry and order.

9.5.3 Invalidation of test

If any tensile specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

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 of product. Specimens shall not be judged defective simply because 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 cut from one end of the sample pipe. The test ring shall be a minimum of 12,7 mm ($\frac{1}{2}$ in) long.

9.6.2 Test method

A single quadrant hardness test specimen shall be tested as illustrated in Figure B.4. Three hardness indentations shall be made at each location (outer, midwall, inner) and the hardness numbers shall be averaged to give one mean hardness number for each location.

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 comply with 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.27 or Table C.27 for PSL-2 products.

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

9.6.3 Invalidation of tests

If any hardness specimen shows defective machining or develops flaws, it may be remachined or discarded and another specimen substituted.

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 of product. Specimens shall not be judged defective simply because they fail to meet the required properties.

9.6.4 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 piece shall be accepted.

If the new mean hardness number fails to conform to the requirements, the piece 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: 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.

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: Both ends of each length of coupling stock shall be tested.

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

- either demonstrate by traceability that all coupling stock 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
- provide a documented procedure for the cut-back of the end of the ingot or continuous-cast strand and for demonstration of the metal cleanliness that ensures that all delivered material conforms to the requirements of Annex E. Testing for material cleanliness shall be done periodically to demonstrate that the cleanliness criteria are under control. Relevant data shall be provided on request.

9.7.3 Impact test method

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

9.7.4 Flattening test method

9.7.4.1 Test method

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

Rings shall be flattened until the distance between plates is as specified in 7.7.

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

9.7.4.2 Acceptance/rejection criteria

Product shall meet the requirements of 7.7.

9.7.5 Impact test retest

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

If the results of the retest do not meet the specified requirements of this International Standard, 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 product 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 product 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 product. 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 product 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 product; 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 product 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 of product. Specimens shall not be judged defective simply because they fail to meet the required properties.