BS EN 13445-2:2014

BSI Standards Publication

Unfired pressure vessels

Part 2: Materials

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National foreword

This British Standard is the UK implementation of EN 13445-2:2014. It supersedes BS EN 13445-2:2009+A2:2012 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PVE/1, Pressure Vessels.

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

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Foreword

This document (EN 13445-2:2014) has been prepared by Technical Committee CEN/TC 54 “Unfired pressure vessels”, the secretariat of which is held by BSI.

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of an identical text or by endorsement, at the latest by December 2014, and conflicting national standards shall be withdrawn at the latest by December 2014.

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 has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this document.

This European Standard consists of the following Parts:

— Part 1: *General*.

— Part 2: *Materials*.

— Part 3: *Design*.

— Part 4: *Fabrication*.

— Part 5: *Inspection and testing*.

— Part 6: *Requirements for the design and fabrication of pressure vessels and pressure parts constructed from spheroidal graphite cast iron*.

— CR 13445-7, *Unfired pressure vessels — Part 7: Guidance on the use of conformity assessment procedures*.

— Part 8: *Additional requirements for pressure vessels of aluminium and aluminium alloys.*

— CEN/TR 13445-9, *Unfired pressure vessels — Part 9: Conformance of EN 13445 series to ISO 16528*

Although these Parts may be obtained separately, it should be recognised that the Parts are inter-dependant. As such the manufacture of unfired pressure vessels requires the application of all the relevant Parts in order for the requirements of the Standard to be satisfactorily fulfilled.

Corrections to the standard interpretations where several options seem possible are conducted through the Migration Help Desk (MHD). Information related to the Help Desk can be found at http://www.unm.fr (en13445@unm.fr). A form for submitting questions can be downloaded from the link to the MHD website. After subject experts have agreed an answer, the answer will be communicated to the questioner. Corrected pages will be given specific issue number and issued by CEN according to CEN Rules. Interpretation sheets will be posted on the website of the MHD.

This document supersedes EN 13445-2:2009. This new edition incorporates the Amendments which have been approved previously by CEN members, and the corrected pages up to Issue 5 without any further technical change. Annex Y provides details of significant technical changes between this European Standard and the previous edition.

Amendments to this new edition may be issued from time to time and then used immediately as alternatives to rules contained herein. It is intended to deliver a new Issue of EN 13445:2014 each year, starting with the present document as Issue 1, consolidating these Amendments and including other identified corrections.

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, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

This Part of this European Standard specifies the requirements for materials (including clad materials) for unfired pressure vessels and supports which are covered by EN 13445-1:2014 and manufactured from metallic materials; it is currently limited to steels with sufficient ductility but it is, for components operating in the creep range, also limited to sufficiently creep ductile materials .

It specifies the requirements for the selection, inspection, testing and marking of metallic materials for the fabrication of unfired pressure vessels.

2 Normative references

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

EN 764-1:2004, *Pressure equipment — Terminology — Part 1: Pressure, temperature, volume, nominal size*

EN 764-2:2012, *Pressure equipment — Part 2: Quantities, symbols and units*

EN 764-3:2002, *Pressure equipment — Part 3: Definition of parties involved*

EN 1092-1:2007, *Flanges and their joints — Circular flanges for pipes, valves, fittings and accessories, PN designated — Part 1: Steel flanges*

EN 10028-2:2009, *Flat products made of steels for pressure purposes — Part 2: Non-alloy and alloy steels with specified elevated temperature properties*

EN 10028-3:2009, *Flat products made of steels for pressure purposes — Part 3: Weldable fine grain steels, normalized*

EN 10028-4:2009, *Flat products made of steels for pressure purposes — Part 4: Nickel alloy steels with specified low temperature properties*

EN 10028-5:2009, *Flat products made of steels for pressure purposes — Part 5: Weldable fine grain steels, thermomechanically rolled*

EN 10028-6:2009, *Flat products made of steels for pressure purposes — Part 6: Weldable fine grain steels, quenched and tempered*

EN 10028-7:2007, *Flat products made of steels for pressure purposes — Part 7: Stainless steels*

EN 10164:2004, *Steel products with improved deformation properties perpendicular to the surface of the product — Technical delivery conditions*

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

EN 10216-3:2013, *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 3: Alloy fine grain steel tubes*

EN 10216-4:2013, *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 4: Non-alloy and alloy steel tubes with specified low temperature properties*

EN 10217-3:2002, EN10217-3:2002/A1:2005, *Welded steel tubes for pressure purposes — Technical delivery conditions — Part 3: Alloy fine grain steel tubes*

EN 10217-4:2002, EN 10217-4:2002/A1:2005, *Welded steel tubes for pressure purposes — Technical delivery conditions — Part 4: Electric welded non-alloy steel tubes with specified low temperature properties*

EN 10217-6:2002, EN 10217-6:2002/A1:2005, *Welded steel tubes for pressure purposes — Technical delivery conditions — Part 6: Submerged arc welded non-alloy steel tubes with specified low temperature properties*

EN 10222-3:1998, *Steel forgings for pressure purposes — Part 3: Nickel steels with specified low temperature properties*

EN 10222-4:1998, EN 10222-4:1998/A1:2001, *Steel forgings for pressures purposes — Part 4: Weldable fine grain steels with high proof strength*

EN 10269:1999, EN 10269:1999/A1:2006, *Steels and nickel alloys for fasteners with specified elevated and/or low temperature properties*

EN 10273:2007, *Hot rolled weldable steel bars for pressure purposes with specified elevated temperature properties*

EN 12074:2000, *Welding consumables — Quality requirements for manufacture, supply and distribution of consumables for welding and allied processes*

EN 13445-1:2014, *Unfired pressure vessels — Part 1: General*

EN 13445-3:2014, *Unfired pressure vessels — Part 3: Design*

EN 13445-4:2014, *Unfired pressure vessels — Part 4: Fabrication*

EN 13445-5:2014, *Unfired pressure vessels — Part 5: Inspection and testing*

EN 13479:2004, *Welding consumables — General product standard for filler metals and fluxes for fusion welding of metallic materials*

EN ISO 148-1:2010, *Metallic materials — Charpy pendulum impact test — Part 1: Test method* (ISO 148-1:2010)

EN ISO 204:2009, *Metallic materials — Uniaxial creep testing in tension — Method of test* (ISO 204:2009)

EN ISO 898-1:2013, *Mechanical properties of fasteners made of carbon steel and alloy steel — Part 1: Bolts, screws and studs with specified property classes — Coarse thread and fine pitch thread* (ISO 898-1:2013)

EN ISO 898-2:2012, *Mechanical properties of fasteners made of carbon steel and alloy steel — Part 2: Nuts with specified property classes — Coarse thread and fine pitch thread* (ISO 898-2:2012)

EN ISO 2566-1:1999, *Steel — Conversion of elongation values — Part 1: Carbon and low alloy steels* (ISO 2566-1:1984)

EN ISO 2566-2:1999, *Steel — Conversion of elongation values — Part 2: Austenitic steels* (ISO 2566-2:1984)

EN ISO 3506-1:2009, *Mechanical properties of corrosion-resistant stainless-steel fasteners — Part 1: Bolts, screws and studs* (ISO 3506- 1:2009)

EN ISO 3506-2:2009, *Mechanical properties of corrosion-resistant stainless-steel fasteners — Part 2: Nuts* (ISO 3506-2:2009)

EN ISO 6892-1:2009, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature* (ISO 6892-1:2009)

CEN ISO/TR 15608:2013, *Welding — Guidelines for a metallic material grouping system* (ISO/TR 15608:2013)

3 Terms, definitions, symbols and units

3.1 Terms and definitions

For the purposes of this European Standard the terms and definitions given in EN 13445-1:2014, EN 764-1:2004, EN 764-3:2002 and the following terms and definitions shall apply.

3.1.1
minimum metal temperature T_M
the lowest temperature determined for any of the following conditions (also see 3.1.2, 3.1.3):

— normal operations;

— start up and shut down procedures;

— possible process upsets, such as flashings of fluid, which have an atmospheric boiling point below 0 °C;

— during pressure or leak testing.

3.1.2
temperature adjustment term T_S
relevant to the calculation of the design reference temperature T_R and is dependent on the calculated tensile membrane stress at the appropriate minimum metal temperature

NOTE 1 Values for T_S are given in Table B.2-12.

NOTE 2 For tensile membrane stress reference is made to EN 13445-3:2014, Annex C.

3.1.3
design reference temperature T_R
the temperature used for determining the impact energy requirements and is determined by adding the temperature adjustment T_S to the minimum metal temperature T_M:

$$T_R = T_M + T_S$$

3.1.4
impact test temperature T_{KV}
the temperature at which the required impact energy has to be achieved (see B.2).

3.1.5
impact energy KV
the energy absorbed by a sample of material when subjected to a Charpy-V-notch test in accordance with EN ISO 148-1:2010

3.1.6
reference thickness e_B
thickness of a component to be used to relate the design reference temperature T_R of the component with its required impact test temperature T_{KV}, (see Tables B.2-2 to B.2-7 and Figures B.2-1 to B.2-11). For unwelded parts the reference thickness e_B is equal to the nominal wall thickness (including corrosion allowance). For welded parts the reference thickness is defined in Table B.4-1.

3.1.7
weld creep strength reduction factor (WCSRF)
factor to account for creep strength reduction at the weldment

3.2 Symbols and units

For the purpose of this part, the symbols and units of EN 764-2:2012 apply together with those given in Table 3.2-1 and Table 3.2-2.

Table 3.2-1 — Quantities for space and time

Quantity	Symbol	Unit
time	t	s, min, h, d, a
frequency	f	Hz
dimension	any Latin letter [a]	mm
length	l	mm
thickness	e	mm
corrosion allowance	c	mm
diameter	d, D	mm
radius	r, R	mm
area	A, S	mm^2
volume, capacity	V	mm^3 [b, c]
weight	W	N, kN
density	ρ	kg/mm^3 [d]
second moment of area	I	mm^4
section modulus	Z	mm^3
acceleration	γ	m/s^2
plane angle	any Greek letter [a]	rad, °

[a] Symbols may use any lower-case letter, except for those defined elsewhere in this table.

[b] Volume may also be given in m^3 or L.

[c] Litre "L" is a non-SI unit which may be used with SI units and their multiples.

[d] Density may also be given in kg/m^3.

Table 3.2-2 — Mechanical quantities

Quantity [a]	Symbol [b]	Unit
force	F	N
moment	M	N·mm
pressure	p, P	bar [c], MPa
Temperature	T	°C
linear expansion coefficient	α	μm/m°C
normal stress	σ	MPa
shear stress	τ	MPa
nominal design stress	f	MPa
tensile strength	R_{m}	MPa
ultimate tensile strength at temperature T	$R_{\mathrm{m/T}}$	MPa
yield strength	R_{e}	MPa
yield strength at temperature T	$R_{\mathrm{e/T}}$	MPa
upper yield strength	R_{eH}	MPa
1 % proof strength	$R_{\mathrm{p1,0}}$	MPa
0,2 % proof strength	$R_{\mathrm{p0,2}}$	MPa
0,2 % proof strength at temperature T	$R_{\mathrm{p0,2/T}}$	MPa
modulus of elasticity	E	MPa
shear modulus	G	MPa
Poisson's ratio	υ	–
strain	ε	%
elongation after fracture	A	%
impact energy	KV	J
hardness	HB, HV	–
Joint coefficient	z	–
safety factor	S	–
Mean 1 % creep strain limit at calculation temperature T and lifetime t	$R_{\mathrm{p1,0/T/t}}$	MPa
Mean creep rupture strength at calculation temperature T and lifetime t	$R_{\mathrm{m/T/t}}$	MPa
Weld creep strength reduction factor	z_{c}	-

[a] Quantities without a temperature index normally refer to room temperature.

[b] Some of these symbols, such as R, f, are not part of ISO 31.

[c] "bar" is a non-SI unit which may be used with SI units and their multiples. The unit bar shall be used on nameplates, certificates, drawings, pressure gauges and instrumentation and is always used as a gauge pressure. This is in line with the requirements of the Pressure Equipment Directive 97/23/EC.

4 Requirements for materials to be used for pressure-bearing parts

4.1 General

4.1.1 Materials to be used for pressure-bearing parts shall meet the general requirements of 4.1 and the special provisions of 4.2, if applicable. Materials for pressure bearing parts shall be ordered complying with the technical delivery conditions in 4.3.

Marking of materials for pressure-bearing parts shall be performed in accordance with 4.4.

Materials shall be selected to be compatible with anticipated fabrication steps and to be suitable for the internal fluid and external environment. Both normal operating conditions and transient conditions occurring during fabrication transport, testing and operation shall be taken into account when specifying the materials.

NOTE 1 The requirements of 4.1 and 4.2 should also be fulfilled when technical delivery conditions are developed for European material standards, European approval of materials or particular material appraisals.

NOTE 2 When technical delivery conditions for pressure-bearing parts are developed, the structure and requirements of EN 764-4:2002 should be met. Exceptions should be technically justified.

The materials shall be grouped in accordance with CEN ISO/TR 15608:2013 to relate manufacturing and inspection requirements to generic material types.

NOTE 3 Materials have been allocated into these groups in accordance with their chemical composition and properties in view of manufacture and heat treatment after welding.

4.1.2 Materials for pressure-bearing parts compliant with the requirements of this European Standard shall be accompanied by inspection documents in accordance with EN 10204:2004. Certificate of specific control (3.1 or 3.2 certificate) shall be required for all steels if Design by Analysis – Direct Route according to Annex B of EN 13445-3:2014 is used.

NOTE The type of inspection document should be in accordance with EN 764-5:2002 and include a declaration of compliance to the material specification.

4.1.3 The materials shall be free from surface and internal defects which can impair their intended usability.

4.1.4 Steels shall have a specified minimum elongation after fracture measured on a gauge length

$$L_o = 5{,}65\sqrt{S_o} \qquad (4.1\text{-}1)$$

where

S_o is the original cross sectional area within the gauge length.

The minimum elongation after fracture in any direction shall be $\geq$ 14 %;

However, lower elongation values may also be applied (e.g. for fasteners or castings), provided that appropriate measures are taken to compensate for these lower values and the specific requirements are verifiable.

NOTE Examples for compensation:

— application of higher safety factors in design;

— performance of burst tests to demonstrate ductile material behaviour.

4.1.5 When measured on a gauge length other than that stated in 4.1.4, the minimum elongation after fracture shall be determined by converting the elongation given in 4.1.4 in accordance with

— EN ISO 2566-1:1999 for carbon and low alloy steels;

— EN ISO 2566-2:1999 for austenitic steels.

4.1.6 Steels shall have a specified minimum impact energy measured on a Charpy-V-notch impact test specimen (EN ISO 148-1:2010) as follows:

— ≥ 27 J for ferritic and 1,5 % to 5 % Ni alloy steels;

— ≥ 40 J for steels of material group 8, 9.3 and 10

at a test temperature in accordance with Annex B, but not higher than 20 °C. The other requirements of Annex B shall also apply.

4.1.7 The chemical composition of steels intended for welding or forming shall not exceed the values in Table 4.1-1. Line 2 of the table refers to vessels or parts designed using Design by Analysis – Direct Route according to Annex B of EN 13445-3:2014. Exceptions shall be technically justified.

Table 4.1-1 — Maximum carbon-, phosphorus- and sulphur contents for steels intended for welding or forming

Steel group (according to Table A-1)	Maximum content of cast analysis		
	% C	% P	% S
Steels (1 to 6 and 9)	0,23[a]	0,035	0,025
Steels (1 to 6 and 9) when DBA – Direct Route is used [c]	0,20	0,025	0,015
Ferritic stainless steels (7.1)	0,08	0,040	0,015
Martensitic stainless steels (7.2)	0,06	0,040	0,015
Austenitic stainless steels (8.1)	0,08	0,045	0,015[b]
Austenitic stainless steels (8.2)	0,10	0,035	0,015
Austenitic-ferritic stainless steels (10)	0,030	0,035	0,015

[a] Maximum content of product analysis 0,25 %.

[b] For products to be machined a controlled sulphur content of 0,015 % to 0,030 % is permitted by agreement provided the resistance to corrosion is satisfied for the intended purpose.

[c] In addition the ratio on thickness reduction (ratio of initial thickness of slab/ingot to the thickness of the final plate) shall be equal or greater than:

— 4 for NL2 steels and steels of material group 9;

— 3 for other materials.

4.2 Special provisions

4.2.1 Special properties

4.2.1.1 General

Where the behaviour of a material can be affected by manufacturing processes or operating conditions, to an extent that would adversely affect the safety or service life of the pressure vessel, this shall be taken into consideration when specifying material.

Adverse effects may arise from:

— manufacturing processes: e.g. degree of cold forming and heat treatment;

— operating conditions: e.g. hydrogen embrittlement, corrosion, scaling and ageing behaviour of the material after cold forming.

4.2.1.2 Lamellar tearing

Where lamellar tearing due to the joint design and loading needs to be addressed, steels shall be used which have improved deformation properties perpendicular to the surface and verified in accordance with EN 10164:2004.

NOTE For guidance see EN 1011-2.

4.2.2 Design temperature above 20 °C

4.2.2.1 A material shall only be used for pressure parts within the range of temperatures for which the material properties required by EN 13445-3:2014 are defined in the technical specification for the material. If the technical delivery condition does not contain the specific material values required for the allowable temperature TS the values required in EN 13445-3:2014 for the design shall be determined by linear interpolation between the two adjacent values. Values shall not be rounded up.

For other than austenitic and austenitic-ferritic stainless steels, the specified value of R_{eH} ($R_{p0,2}$) at room temperature (RT) may be used for temperatures less than or equal to 50 °C. Interpolation between 50 °C and 100 °C shall be performed with the values of RT and 100 °C and using 20 °C as the starting point for interpolation. Above 100 °C linear interpolation shall be performed between the tabulated values given in the table.

4.2.2.2 As the impact properties may be affected by long or frequent holding of the material at elevated temperatures, it is presupposed that the temperatures and periods of exposure to elevated temperatures be recorded for review during in-service inspection. The influence of such exposure upon the lifetime expectancy shall be estimated and recorded.

For operations such as drying and cleaning of pressure vessels, steels with specified low temperature properties but without elevated temperature 0,2 % proof strength values may however be used at elevated temperatures for drying and cleaning processes provided that the values of 0,2 % proof strength used in design calculations for elevated temperatures shall be obtained by multiplying the specified minimum yield strength values at 20 °C by the factor given in Table 4.2-1.

Table 4.2-1 — Yield strength reduction factors for low temperature steels

Steel	Temperature T			
	100 °C	200 °C	250 °C	300 °C
Quenched and tempered	0,75	0,68	0,64	0,60
Normalised or thermomechanically treated	0,70	0,58	0,53	0,48

Interpolation shall be carried out as in 4.2.2.1.

4.2.3 Prevention of brittle fracture

The requirements in Annex B shall apply.

4.2.4 Design properties in the creep range

4.2.4.1 Creep properties of base material

For interpolation and extrapolation of creep properties given in the materials standard, see EN 13445-3:2014, Clause 19.

When creep properties are not available from a materials standard, they shall be determined using EN ISO 204:2009.

4.2.4.2 Creep properties of weldments

Creep properties of weld joints subjected to stresses normal to the weld can differ significantly from those of the base material.

For the design of vessels in the creep range, this is taken into account in EN 13445-3:2014 by making use of a weld creep strength reduction factor z_c obtained from tests on weldments. If no data are available, a default value of z_c is used.

An acceptable method to determine z_c by cross-weld tests is given in Annex C (see also [17]).

4.2.5 Specific requirements for steels for fasteners

Fasteners include bolts, studs and nuts.

Free cutting steel shall not be used. Bolting made of carbon steel or Ni alloy ferritic steel with $>$ 3,5 % nickel shall not be used above 300 °C.

The specified minimum tensile strength of bar material of ferritic and martensitic steel for bolts shall not exceed 1 000 MPa. The minimum elongation of bar material after fracture shall be at least A_5 = 14 %.

Impact requirements for ferritic and martensitic steels are specified in B.2.2.4.

Bolt material with a design temperature below −160 °C shall be impact tested at −196 °C.

Hydrogen embrittlement, fatigue or relaxation properties shall be taken into account where appropriate.

NOTE 1 Detailed requirements on the surface condition and internal soundness of the bar can be necessary for some applications.

NOTE 2 Materials for fasteners compliant with the requirements of this standard should be certified on the basis of EN 10204:2004.

4.3 Technical delivery conditions

4.3.1 European Standards

The European Standards for plates, strips, bars, tubes, forgings and castings for pressure purposes shall be used.

NOTE 1 Table E.2-1 provides an overview on materials for pressure purposes specified in harmonised standards.

NOTE 2 Table E.1-1 contains an informative summary of European Materials Standards referred to and of European Standards covering components of pressure-bearing parts.

Special provisions due to fabrication and operation shall be taken into account, if appropriate.

4.3.2 European Approval for Materials

A material specified in an EMDS for pressure vessels shall only be used within its range of application and if 4.1 and 4.2 have been taken into consideration.

4.3.3 Particular material appraisals

Materials other than those specified in 4.3.1 and 4.3.2 may also be used provided that they have been undergone a particular material appraisal and if 4.1 and 4.2 have been taken into consideration.

4.3.4 Clad products

Technical delivery conditions for clad products for pressure parts shall be in accordance with the requirements of Annex D.

NOTE 1 European Standards specifying technical delivery conditions for clad products for pressure purposes are not currently available.

NOTE 2 Examples of national documents covering technical delivery condition for clad steels are given in [2] to [4].

4.3.5 Welding consumables

Technical delivery conditions for welding consumables used of pressure parts and attachments to pressure parts shall be in accordance with EN 13479:2004 and EN 12074:2000.

NOTE Equivalent national/international specifications are accepted which fulfil the same criteria with respect to the requirements for the Quality Assurance System and the requirements for manufacture, supply, distribution, test methods and evaluation of consumables.

4.4 Marking

The marking of the products or delivery units shall ensure traceability between the product or delivery unit and the inspection documents.

For European standardised materials the marking shall fulfil the requirements of the relevant product standard.

For materials not contained in a European Standard the marking shall at least contain:

— the material specification (reference, material designation);

— the manufacturers name or mark;

— the stamp of the inspection representative, if applicable.

For material supplied with specific inspection the marking shall include an identification which permits the correlation between the product or delivery unit and the relevant inspection document.

5 Requirements for materials to be used for non-pressure parts

For non-pressure parts, e.g. for supporting lugs, skirts, baffles and similar parts welded to pressure vessels, material shall be used which are supplied to material specifications covering at least requirements for the chemical composition and the tensile properties. These materials shall not limit the operating conditions of the material to which they are attached.

Annex A
(normative)

Grouping system for steels for pressure equipment

Steels shall be grouped as shown in Table A-1. The figures given in group 1 are referring to the ladle analysis of the materials. The figures given in group 4 to 10 are based on the element content used in the designation of the alloys.

Table A-1 — Grouping system for steels (extract from CEN ISO/TR 15608:2013)

Group	Sub-group	Type of steel
1		Steels with a specified minimum yield strength $R_{eH} \leq 460$ MPa [a] and with analysis in %: C ≤ 0,25 Si ≤ 0,60 Mn ≤ 1,70 Mo ≤ 0,70[b] S ≤ 0,045 P ≤ 0,045 Cu ≤ 0,40[b] Ni ≤ 0,5[b] Cr ≤ 0,3 (0,4 for castings)[b] Nb ≤ 0,05 V ≤ 0,12[b] Ti ≤ 0,05
	1.1	Steels with a specified minimum yield strength $R_{eH} \leq 275$ MPa
	1.2	Steels with a specified minimum yield strength 275 MPa $< R_{eH} \leq 360$ MPa
	1.3	Normalised fine grain steels with a specified minimum yield strength $R_{eH} > 360$ MPa
	1.4	Steels with improved atmospheric corrosion resistance whose analysis may exceed the requirements for the single elements as indicated under 1
2		Thermomechanically treated fine grain steels and cast steels with a specified minimum yield strength $R_{eH} > 360$ MPa
	2.1	Thermomechanically treated fine grain steels and cast steels with a specified minimum yield strength 360 MPa $< R_{eH} \leq 460$ MPa
	2.2	Thermomechanically treated fine grain steels and cast steels with a specified minimum yield strength $R_{eH} > 460$ MPa
3		Quenched and tempered steels and precipitation hardened steels except stainless steels with a specified minimum yield strength $R_{eH} > 360$ MPa
	3.1	Quenched and tempered steels with a specified minimum yield strength 360 MPa $< R_{eH} \leq 690$ MPa
	3.2	Quenched and tempered steels with a specified minimum yield strength $R_{eH} > 690$ MPa
	3.3	Precipitation hardened steels except stainless steels

Table A-1 (*concluded*)

Group	Sub-group	Type of steel
4		Low vanadium alloyed Cr-Mo-(Ni) steels with Mo ≤ 0,7 % and V ≤ 0,1 %
	4.1	Steels with Cr ≤ 0,3 % and Ni ≤ 0,7 %
	4.2	Steels with Cr ≤ 0,7 % and Ni ≤ 1,5 %
5		Cr-Mo steels free of vanadium with C ≤ 0,35 %[c]
	5.1	Steels with 0,75 % ≤ Cr ≤ 1,5 % and Mo ≤ 0,7 %
	5.2	Steels with 1,5 % < Cr ≤ 3,5 % and 0,7 < Mo ≤ 1,2 %
	5.3	Steels with 3,5 % < Cr ≤ 7,0 % and 0,4 < Mo ≤ 0,7 %
	5.4	Steels with 7,0 % < Cr ≤ 10 % and 0,7 < Mo ≤ 1,2 %
6		High vanadium alloyed Cr-Mo-(Ni) steels
	6.1	Steels with 0,3 % ≤ Cr ≤ 0,75 %, Mo ≤ 0,7 % and V ≤ 0,35 %
	6.2	Steels with 0,75 % < Cr ≤ 3,5 %, 0,7 % < Mo ≤ 1,2 % and V ≤ 0,35 %
	6.3	Steels with 3,5 % < Cr ≤ 7,0 %, Mo ≤ 0,7 % and 0,45 % ≤ V ≤ 0,55 %
	6.4	Steels with 7,0 % < Cr ≤ 12,5 %, 0,7 % < Mo ≤ 1,2 % and V ≤ 0,35 %
7		Ferritic, martensitic or precipitation hardened stainless steels with C ≤ 0,35 % and 10,5 % ≤ Cr ≤ 30 %
	7.1	Ferritic stainless steels
	7.2	Martensitic stainless steels
	7.3	Precipitation hardened stainless steels
8		Austenitic steels
	8.1	Austenitic stainless steels with Cr ≤ 19 %
	8.2	Austenitic stainless steels with Cr > 19 %
	8.3	Manganese austenitic stainless steels with 4 % < Mn ≤ 12 %
9		Nickel alloyed steels with Ni ≤ 10 %
	9.1	Nickel alloyed steels with Ni ≤ 3 %
	9.2	Nickel alloyed steels with 3 % < Ni ≤ 8 %
	9.3	Nickel alloyed steels with 8 % < Ni ≤ 10 %
10		Austenitic ferritic stainless steels (duplex)
	10.1	Austenitic ferritic stainless steels with Cr ≤ 24 %
	10.2	Austenitic ferritic stainless steels with Cr > 24 %

[a] In accordance with the specification of the steel product standards, R_{eH} may be replaced by $R_{p0,2}$ or $R_{t0.5}$.

[b] A higher value is accepted provided that Cr + Mo + Ni + Cu + V ≤ 0,75 %.

[c] "Free of vanadium" means not deliberately added to the material.

Annex B
(normative)

Requirements for prevention of brittle fracture at low temperatures

B.1 General

This annex distinguishes between pressure equipment that has design temperature for normal operation higher or lower than 50 °C.

For pressure equipment with normal operation temperatures higher than 50 °C B.5 applies. If B.5 is not applicable, the following rules for lower normal operation temperatures shall be used.

For pressure equipment with design temperature equal to or less than 50 °C this annex specifies three alternative methods for establishing criteria for the prevention of low temperature brittle fracture[1)] of steels in the form of plate, strip, tubes, fittings, forgings, castings, flanges, fasteners and weldments used in pressure parts. The criteria are based on impact energy requirements at specified temperatures for the base material, heat affected zone (including the fusion line) and weld metals.

The three methods are:

Method 1 Code of Practice:

a) Technical requirements based on the choice of $T_R = T_{27J}$ as specified in harmonised European Material Standards and on the assumption that it is possible to achieve these minimum properties after fabrication. Calculated from the principles of fracture mechanics used for method 2 for C and CMn steels with yield strength < 460 MPa and

b) based on operating experience for Ni-alloyed steels with Ni ≥ 3 % up to 9 %, for austenitic steels and for bolts and nuts.

Method 2 Method developed from the principles of fracture mechanics and from operating experiences:

A more flexible approach than method 1 for derivation of technical requirements applicable to C, CMn, fine grain steels, Ni-alloyed steels with not more than 1,5 % of Ni with a specified minimum yield strength ≤ 500 MPa and for austenitic-ferritic steels with a specified minimum yield strength ≤ 550 MPa. This method can be applied for these steels to a wider range of thicknesses and temperatures than method 1 because T_R must not be equal to T_{27J} (see Figures B.2–1 to B.2–11). In addition, for ferritic steels with max 355 MPa in PWHT condition operation experience was considered for higher thicknesses.

Method 3 The application of a fracture mechanics analysis. This general method is applicable to cases not covered by methods 1 or 2. This method may also be used to justify deviations from the requirements of method 1 or 2. Only general guidance is given on the use of this method which shall only be used in agreement with the parties concerned.

1) Including temperatures at pressure tests

Each of the three methods may be used independently. It is only necessary to satisfy the requirement of any one method.

All applicable combinations of the temperatures T_M (minimum metal temperature) and T_S (temperature adjustment term) shall be considered and the lowest possible T_R-value (design reference temperature) shall be used for the determination of the required material impact test temperature.

NOTE For definitions of temperature terms see 3.1.1 to 3.1.4.

B.2 Material selection and impact energy requirements

B.2.1 Introduction

The methods specified in B.2.2 (method 1) or B.2.3 (method 2) shall be used to determine the impact energy required to avoid brittle fracture. Alternatively, B.2.4 (method 3) may be used to determine the required toughness. The method used shall be fully documented, in order to ensure that compliance can be verified.

Reference thickness for constructional details is defined in Table B.4-1.

B.2.2 Method 1

B.2.2.1 General

Method 1 allows the selection of materials taken from harmonised European material standards with regard to prevention of brittle fracture. Table B.2–1 gives an overview to the following tables by steel type and product form.

The weld metal, the heat affected zone and other parts affected by manufacturing processes shall satisfy the same impact energy requirements as the guaranteed minimum properties for the base material at T_R given in the tables.

The Table lists design reference temperatures for maximum thickness at given strength levels represented by steels from harmonised European material standards with guaranteed minimum strength and impact properties. Where it is not possible to achieve these minimum properties after fabrication, a tougher starting material shall be selected.

Table B.2–1 — Guide to material selection

Table	Material or product form	Steel group	Clause
B.2–2	Plates and strips	Ferritic steels	B.2.2.2
B.2–3	Seamless and welded pipes		
B.2–4	Bars		
B.2–5	Forgings		
B.2–6	Ni alloyed steels (1,5 < Ni $\leq$ 5 %)	Ferritic steels	B.2.2.3
B.2–7	Ni-alloyed steel (9 % Ni)		
B.2–8	Bolts and nuts	Ferritic steels Austenitic steels	B.2.2.4
B.2–9			
B.2–10			
B.2–11	Austenitic steel grades	Austenitic steels	B.2.2.5

NOTE Requirements for austenitic-ferritic steels are only given in B.2.3 (method 2).

Where test pieces of at least 5 mm wide can not be obtained the material need not be subject to impact testing.

Values of the design reference temperature T_R shall be calculated from the metal temperature T_M using the values of the temperature adjustment T_S given in Table B.2–12.

B.2.2.2 Ferritic steels

Tables B.2–2 to B.2–5 list ferritic steels taken from harmonised European material standards with specified impact properties below –10 °C.

The tabulated value of T_R is based on the impact test temperature T_{KV} for KV = 27 J.

Table B.2–2 — General requirements for prevention of brittle fracture — Reference thicknesses for plates and strips

Plates and Strips								
No. as per Table E.2-1	European Standard	Grade	Material No.	Max. reference thickness e_B mm		Design reference temperature T_R °C	Material group to CEN ISO/ TR 15608:2013	Remarks
				AW	PWHT			
1	EN 10028-2:2009	P235GH	1.0345	35	200	– 20	1.1	
2		P265GH	1.0425	35	200			
3		P295GH	1.0481	35	110		1.2	
4		P355GH	1.0473	35	70			
29	EN 10028-3:2009	P275NH	1.0487	35	200	– 20	1.1	
30		P275NL1	1.0488	35	200	– 40		
31		P275NL2	1.1104	35	200	– 50		
32		P355N	1.0562	35	70	– 20	1.2	
33		P355NH	1.0565	35	70	– 20		
34		P355NL1	1.0566	35	70	– 40		
35		P355NL2	1.1106	35	70	– 50		
39	EN 10028-4:2009	11MnNi5-3	1.6212	35	80	– 60	9.1	
40		13MnNi6-3	1.6217	35	70	– 60		
41		15NiMn6	1.6228	35	70	– 80		
50	EN 10028-5:2009	P355M	1.8821	35	-	– 20	1.2	a)
51		P355ML1	1.8832	35	-	– 40		a)
52		P355ML2	1.8833	35	-	– 50		a)
53		P420M	1.8824	35	-	– 20	2.1	a)
54		P420ML1	1.8835	35	-	– 40		a)
55		P420ML2	1.8828	35	-	– 50		a)
59	EN 10028-6:2009	P355Q	1.8866	35	70	– 20	1.2	
60		P355QH	1.8867	35	70	– 20		
61		P355QL1	1.8868	35	70	– 40		
62		P355QL2	1.8869	35	70	– 60		

a) TMCP steels shall not be Post Weld Heat Treated

If the planned component thickness is greater than that given in Table B.2-2 alternative Charpy toughness requirements are provided in chapter B.2.3.1.

Table B.2–3 — General requirements for prevention of brittle fracture — Reference thicknesses for seamless and welded tubes

Seamless and welded tubes								
No. as per Table E.2-1	European Standard	Grade	Material No.	Max. reference thickness e_B mm AW	Max. reference thickness e_B mm PWHT	Design reference temperature T_R °C	Material group to CEN ISO/ TR 15608:2013	Remarks
231	EN 10216-3:2013	P275NL1	1.0488	35	100	– 40	1.1	[a]
232		P275NL2	1.1104	35	100	– 50		[a]
233		P355N	1.0562	35	70	– 20	1.2	
234		P355NH	1.0565	35	70	– 20		
235		P355NL1	1.0566	35	70	– 40		
236		P355NL2	1.1106	35	70	– 50		
248	EN 10216-4:2013	P215NL	1.0451	10	10	– 40	1.1	[a]
249		P255QL	1.0452	35	40	– 40		[a]
250		P265NL	1.0453	25	25	– 40		[a]
251		26CrMo4-2	1.7219	15	40	– 60	5.1	[a]
252		11MnNi5-3	1.6212	35	40	– 60	9.1	[a]
253		13MnNi6-3	1.6217	35	40	– 60	9.1	[a]
306	EN 10217-3:2004	P275NL1	1.0488	35	40	– 40	1.1	[a]
307		P275NL2	1.1104	35	40	– 50		[a]
308		P355N	1.0562	35	40	– 20	1.2	[a]
309		P355NH	1.0565	35	40	– 20		[a]
310		P355NL1	1.0566	35	40	– 40		[a]
311		P355NL2	1.1106	35	40	– 50		[a]
316	EN 10217-4:2004	P215NL	1.0451	10	10	– 40	1.1	[a]
317		P265NL	1.0453	16	16	– 40	1.1	[a]
321	EN 10217-6:2004	P215NL	1.0451	10	10	– 40	1.1	[a]
322		P265NL	1.0453	25	25	– 40	1.1	[a]

[a] Thickness limitation results from wall thickness limitation in the European material standards and in the European component standards respectively.

Table B.2–4 — General requirements for prevention of brittle fracture with reference thickness for bars

Bars								
No. as per Table E.2-1	European Standard	Grade	Material No.	Max. reference thickness e_B		Design reference temperature T_R (°C)	Material group to CEN ISO/ TR 15608:2013	Remarks
				AW	PWHT			
147	EN 10273:2007	P275NH	1.0487	35	75	– 20	1.1	
148		P355NH	1.0565	35	55		1.2	
150		P355QH	1.8867	35	55		1.2	

Table B.2–5 — General requirements for prevention of brittle fracture with reference thickness for forgings

Forgings								
No. as per Table E.2-1	European Standard	Grade	Material No.	Max. ref.. thickness e_B		Design reference temperature T_R (°C)	Material group to CEN ISO/TR 15608:2013	Remarks
				AW	PWHT			
367	EN 10222-3:1998	13MnNi6-3	1.6217	35	70	– 60	9.1	
369		15NiMn6	1.6228	35	50	– 80	9.1	
378	EN 10222-4:1998	P285QH	1.0478	35	85	– 20	1.2	
380		P355QH	1.0571	35	60	– 20	1.2	
382		P420QH	1.8936	35	50	– 20	3.1	

B.2.2.3 Ni –alloyed steels (Ni > 1,5 %)

Table B.2-6 lists Ni alloyed steels up to and including 5 % Nickel taken from harmonised European material standards.

Table B.2-7 lists Ni alloyed steels with 9 % Nickel taken from harmonised European material standards.

The tabulated value of T_R is based on the impact test temperature T_{KV} for KV = 27 J.

Table B.2–6 — General requirements for prevention of brittle fracture with reference thickness for Ni-alloyed steels with 1,5 % < Ni ≤ 5 %

Ni-alloyed steel, 1,5 % < Ni [a] ≤ 5 %								
No. as per Table E.2-1	European Standard	Grade	Material No.	Max. reference thickness e_B AW	Max. reference thickness e_B PWHT	Design reference temperature T_R (°C)	Material group to CEN ISO/TR 15608:2013	Remarks
plates and strips								
42	10028-4:2009	12Ni14	1.5637	35	80	– 100	9.2	[b]
43		X12Ni5	1.5680	35	80	– 120		
seamless tubes								
254	EN 10216-4:2013	12Ni14	1.5637	25	—	– 100	9.2	[b]
255		12Ni14		35	40	– 90		[b]
256		X12Ni5	1.5680	25	—	– 120		
257		X12Ni5		35	40	– 110		
forgings								
370	EN 10222-3:1998	12Ni14	1.5637	35	—	– 100	9.2	[b]
371		12Ni14		35	50			[b]
372		12Ni14		35	70			[b]
373		X12Ni5	1.5680	35	—	– 120		
374		X12Ni5		35	50			

a) Nickel content is nominal.

b) If used at – 105 °C (e. g. ethylene application), then 27 J shall be guaranteed at this temperature.

NOTE Thickness limitation result from wall thickness limitation in European material standards.

Table B.2–7 — General requirements for prevention of brittle fracture with reference thickness for Ni-alloyed steels with 9 % Ni

9 % - Ni [a] alloys							
No. as per Table E.2-1	European Standard	Grade	Material No.	Max. reference thickness e_B AW | PWHT	Design reference temperature T_R (°C)	Material group to CEN ISO/TR 15608:2013	Remarks
plates and strips							
44	10028-4:2009	X8Ni9	1.5662	— [b]	–196	9.3	
48		X7Ni9	1.5663				
seamless tubes							
258	EN 10216-4:2013	X10Ni9	1.5682	— [b]	–196	9.3	
Forgings							
375	EN 10222-3:1998	X8Ni9	1.5662	— [b]	–196	9.3	

a) Nickel content is nominal.

b) Materials can be used to maximum thickness permitted in harmonised European material standards.

B.2.2.4 Bolts and nuts

For other bolts and nuts than given in Table B.2-8 a specified impact energy of minimum 40 J is required at T_{KV} = RT for T_M = ≥ –10 °C (where RT means Room Temperature).

If T_M is lower than –10 °C, specified impact energy of minimum 40 J is required at $T_{KV} \leq T_M$.

Except bolting material made from austenitic stainless steels specified in Table B.2-9 and B.2-10, bolting material with a design temperature below –160 °C shall be impact tested at –196 °C.

Table B.2–8 — General requirements for prevention of brittle fracture with reference thickness for nuts and bolts for TM ≥ -10 °C

European Standard	Type of material [a]	Thickness limitation	Impact test KV for $T_M \geq -10$ °C	Test temperature / value
EN 10269:1999	All steels	According to EN 10269:1999	According to EN 10269:1999, Table 4	According to EN 10269:1999, Table 4
EN ISO 898-1:2013	5.6	M ≤ 39	M ≥ 16	RT [b] / 40 J
	8.8	M ≤ 39	M ≥ 16	RT [b] / 52 J
EN ISO 898-2:2012	5	M ≤ 39	None	—
	8	M ≤ 39	None	—

a) Starting material shall comply with EN 10269:1999.

b) According to EN ISO 148-1:2010, the room temperature, RT, is equal to 23 °C ± 5 C

Table B.2–9 — General requirements for prevention of brittle fracture with reference thickness for nuts and bolts, bolting material according to EN 10269:1999

Type of material	Thickness limitation	Impact test	T_M	Remark
1.4307, 1.4301, 1.4303, 1.4404, 1.4401, 1.4948, 1.4919, 1.4941, 1.4980 a)	According to EN 10269:1999, Table 7	According to EN 10269:1999, Table 4	–196 °C	Verification required for diameter or thickness > 20 mm
1.4429, 1.4910,	According to EN 10269:1999, Table 7	According to EN 10269:1999, Table 4	–273 °C	Verification required for diameter or thickness > 20 mm
1.5523, 1.1133 1.6563	According to EN 10269:1999, Table 7	According to EN 10269:1999, Table 7	–20 °C	—
1.7218	$d \leq 60$ mm	According to EN 10269:1999, Table 7	–60 °C	—
	60 < $d \leq 100$ mm		–50 °C	
1.6582, 1.6580, 1.7225	According to EN 10269:1999, Table 7	According to EN 10269:1999, Table 7	–40 °C	—
1.5680	$d \leq 45$ mm	According to EN 10269:1999, Table 7	–120 °C	—
	45 < $d \leq 75$ mm		–110 °C	
1.5662	According to EN 10269:1999, Table 7	According to EN 10269:1999, Table 7 at –196°C	–196 °C	—
a) When used at –273 °C, verification testing at –196 °C according to Table 7 of EN 10269:1999 is required.				

Table B.2–10 — General requirements for prevention of brittle fracture with reference thickness for nuts and bolts

Standard	Type of material [a]		Thickness limitation	T_M	Impact test
EN ISO 3506-1:2009	A2, A3	50	M ≤ 39	– 196 °C	None
		70	M ≤ 24		
EN ISO 3506-1:2009	A4, A5	50	M ≤ 39	– 60 °C [b]	None
		70	M ≤ 24		
EN ISO 3506-2:2009	A2, A3, A4, A5	50	M ≤ 39	– 196 °C	None
		70	M ≤ 24		
[a] Starting material shall comply with EN 10269:1999.					
[b] –196 °C for studs					

B.2.2.5 Lowest minimum metal temperatures for austenitic stainless steels

Solution annealed austenitic stainless steels according to Table B.2-11 can be applied down to temperature T_M without impact testing, except when impact testing is required by the material standard. E.g. EN 10028-7 requires impact testing at room temperature above 20 mm thickness for use at cryogenic temperatures (below -75 °C according to EN 10028-7:2007).

Table B.2–11 — Austenitic stainless steels and their lowest minimum metal temperature T_M

Material	Material number	T_M (in °C)
X1NiCrMoCu 31-27-4	1.4563	− 273
X1CrNiMoN 25-22-2	1.4466	
X1CrNi 25-21	1.4335	
X2CrNiMoN 17-13-3	1.4429	
X2CrNiMoN 17-11-2	1.4406	
X2CrNiMoN 18-12-4	1.4434	
X2CrNiMo 18-15-4	1.4438	
X2CrNiN 18-10	1.4311	
X2CrNiMo 18-14-3	1.4435	
X2CrNi 19-11	1.4306	
X6CrNiTi 18-10	1.4541	− 196
X1CrNiMoCuN 25-25-5	1.4537	
X1NiCrMoCuN 25-20-7	1.4529	
X1CrNiMoCuN 20-18-7	1.4547	
X1NiCrMoCu 25-20-5	1.4539	
X2CrNiMoN 17-13-5	1.4439	
X6CrNiMoTi 17-12-2	1.4571	
X3CrNiMo 17-13-3	1.4436	
X6CrNiMoNb 17-12-2	1.4580	
X2CrNiMo 17-12-3	1.4432	
X5CrNiMo 17-12-2	1.4401	
X2CrNiMo 17-12-2	1.4404	
X6CrNiNb 18-10	1.4550	
X5CrNi 18-10	1.4301	
X2CrNi 18-9	1.4307	
GX5CrNi9-10	1.4308	
GX5CrNiMo19-11-2	1.4408	
GX2NiCrMo28-20-2	1.4458	
GX2CrNi19-11	1.4309	
GX2CrNiMo19-11-2	1.4409	

Where the design temperature is below −105 °C weld metal and heat affected zones for austenitic stainless steels shall meet additional requirements of EN 13445-4:2014, Clause 8.

B.2.2.6 Temperature adjustment

T_S is a temperature adjustment which can be used under the conditions given in Table B.2–12.

Table B.2–12 — Temperature adjustment T_s [a]

Condition	Ratio of pressure induced general membrane stress f and maximum allowable design stress f_d			Membrane stress [b]
	$f / f_d > 0{,}75$	$0{,}75 \geq f / f_d > 0{,}25$	$f / f_d \leq 0{,}25$	≤ 50 MPa
Non welded or post-weld heat treated	0 °C	$T_s = 70 - 80 \times f / f_d$ [°C]	+ 50 °C	+ 50 °C
As welded	0 °C	0 °C	0 °C	+ 40 °C

[a] Except for material group 9.1, 9.2 and 9.3, T_R shall not be lower than –110 °C for ferritic and austenitic-ferritic steels.

[b] The membrane stress shall take account of internal and external pressure and dead weight. For walls and pipes of heat exchangers the restraint of free end displacement of the heat exchanger pipes should also be taken into account.

B.2.3 Method 2

B.2.3.1 General

This method 2 applies to C, CMn, fine grain steels, Ni-alloyed steels with not more than 1,5 % Ni and with a specified minimum yield strength ≤ 500 MPa and to austenitic-ferritic steels with a specified minimum yield strength ≤ 550 MPa. This method 2, based on fracture mechanics [16,32] can be used to determine the requirements to avoid brittle fracture in these steels, and may be used at a design reference temperature T_R which is lower than the design reference temperature T_R derived by method 1. In this procedure the design reference temperature T_R is not equal to the impact test temperature T_{KV}. The diagrams show the relationship between T_R and T_{KV} depending on reference thickness and material strength. Distinction is made for as-welded (AW) and post weld heat treated (PWHT) condition. This method does not apply to thermomechanically-rolled steels thicker than 35 mm. Two alternatives are provided in Tables B.2-13 and B.2-14 (Nomograms for reference thickness up to 35 mm in AW-condition and up to 110 mm in PWHT condition) and Table B.2-15 (for reference thickness up to 200 mm).

For constructional details reference thickness e_B is defined in Table B.4-1.

Table B.2–13 and B.2–14 show which figure shall be used to determine the impact test temperature T_{KV} or the design reference temperature T_R. The condition "non-welded" shall be treated as the condition PWHT. Parent material, welds and HAZs shall meet the impact energy KV at impact test temperature $T_{KV.}$

Table B.2-15 provides toughness requirements for components with thickness up to 200 mm in PWHT condition. The weld metal, the heat affected zones and other parts affected by manufacturing processes shall satisfy the same impact energy requirements as given in the table B.2-15 at T_R.

NOTE Table B.2-15 complies with Method 2 basic principles and allows the use of pressure components with reference thickness e_B up to 200 mm thickness, when Nomograms of Method 2 do not apply anymore. However, the application of Table B.2-15 for lower thicknesses than 110 mm is not restricted, but will result in higher toughness requirements as can be derived from Figures B.2-1 to B.2-7 or Method 1.

Linear interpolation between strength and thickness levels given in the Figures B.2–1 to B.2–11 is allowed. Alternatively the next higher strength class or wall thickness can be used. Lower test temperatures than T_{KV} are admissible for the same requirements.

The temperature adjustment given in Table B.2–12 applies also to method 2. Extrapolations for temperature ranges beyond the temperature ranges as given in the nomograms are not permissible.

Table B.2–13 — Impact energy requirements for C, CMn, fine grain steels, Ni-alloyed steels with not more than 1,5 % Ni

Specified minimum yield strength of base material MPa	Required impact energy KV (on 10 mm × 10 mm test pieces) J min	Figure defining required T_{KV}	
		Non welded or post-weld heat treated	As welded
$R_e \leq 275$	27	B.2-1	B.2-2
$R_e \leq 355$	27	B.2-3	B.2-4
$R_e \leq 460$	40	B.2-5	B.2-6
$R_e \leq 500$	40	B.2-7	B.2-8

Table B.2–14 — Impact energy requirements for austenitic-ferritic stainless steels

Specified minimum yield strength of base material MPa	Required impact energy KV (on 10 mm x 10 mm test pieces) J min	Figure defining required T_{KV} for all applications
$R_e \leq 385$	40	B.2-9
$R_e \leq 465$	40	B.2-10
$R_e \leq 550$	40	B.2-11

Table B.2-15 — Impact energy requirements for higher thickness for C, CMn, fine grain steels, Ni-alloyed steels with not more than 1,5 % Ni

Specified minimum yield strength of base material MPa	Required impact energy KV (on 10x10 mm specimen) at T_R J min	Maximum thickness mm
$R_e \leq 275$	27	200
$R_e \leq 355$	40	70 - 200
$R_e \leq 460$	60	65 - 200
$R_e \leq 500$	60	60 - 200

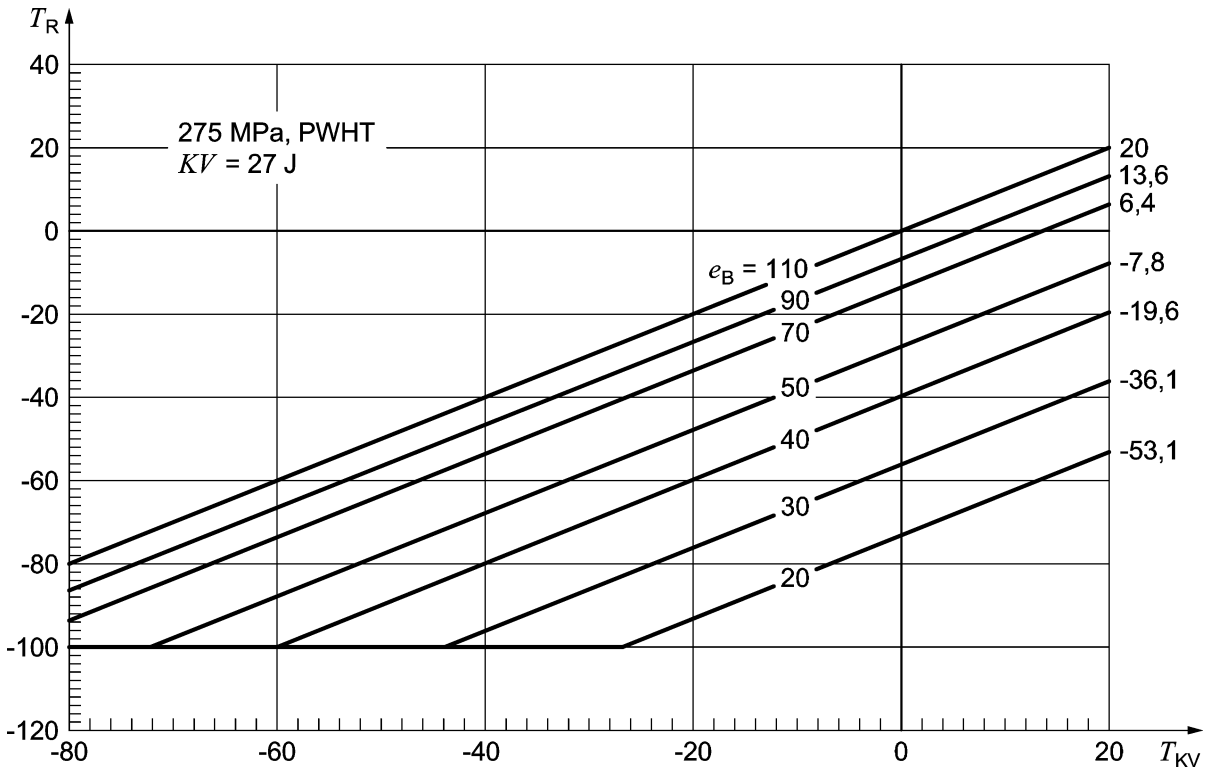
B.2.3.2 Procedure for base material less than 10 mm thick

T_R values and T_{KV} values shall be in accordance with Figures B.2–1 to B.2–11. The impact energy requirements are as specified in Tables B.2–13 and B.2–14.

For wall thicknesses < 20 mm the curve for 20 mm shall be used.

The required energies for the sub-sized specimens are given in Table B.3–1.

B.2.3.3 Nomograms for Method 2



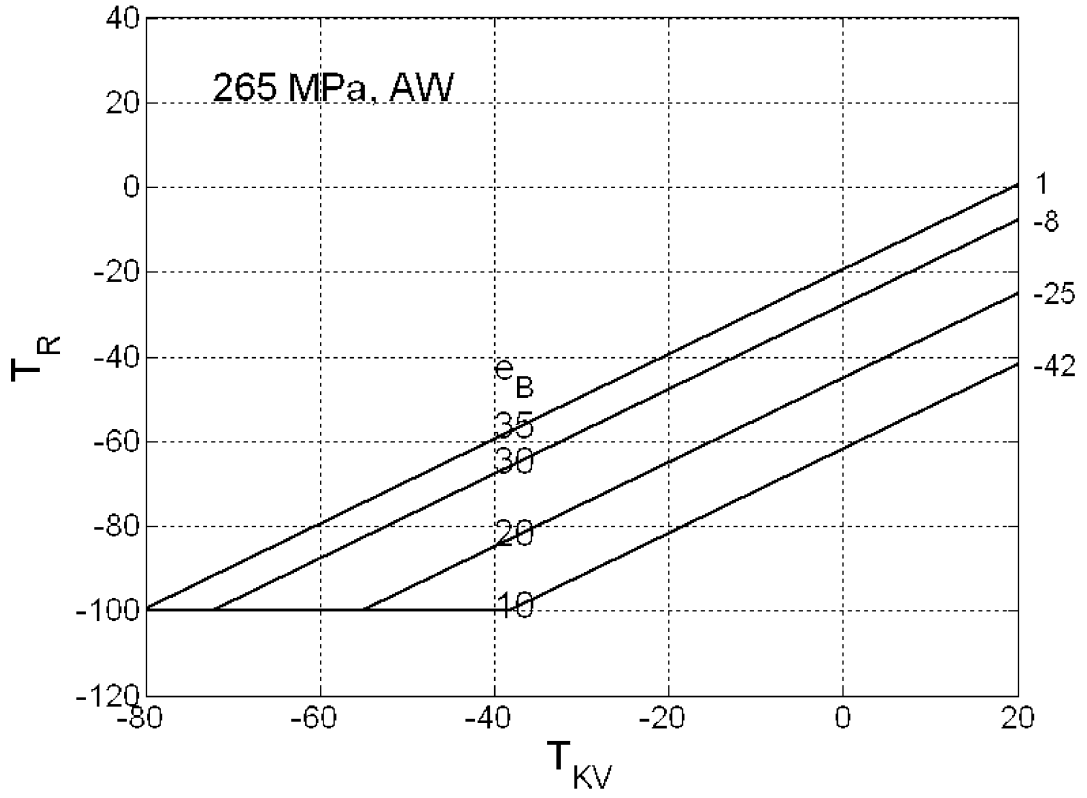
Key

T_R design reference temperature (°C)

T_{KV} material impact test temperature (°C)

e_B reference thickness (mm)

Figure B.2–1 — METHOD 2: Design reference temperature and impact test temperature, post weld heat treated (PWHT) condition, for $R_e \leq 275$ MPa and $KV \geq 27$ J



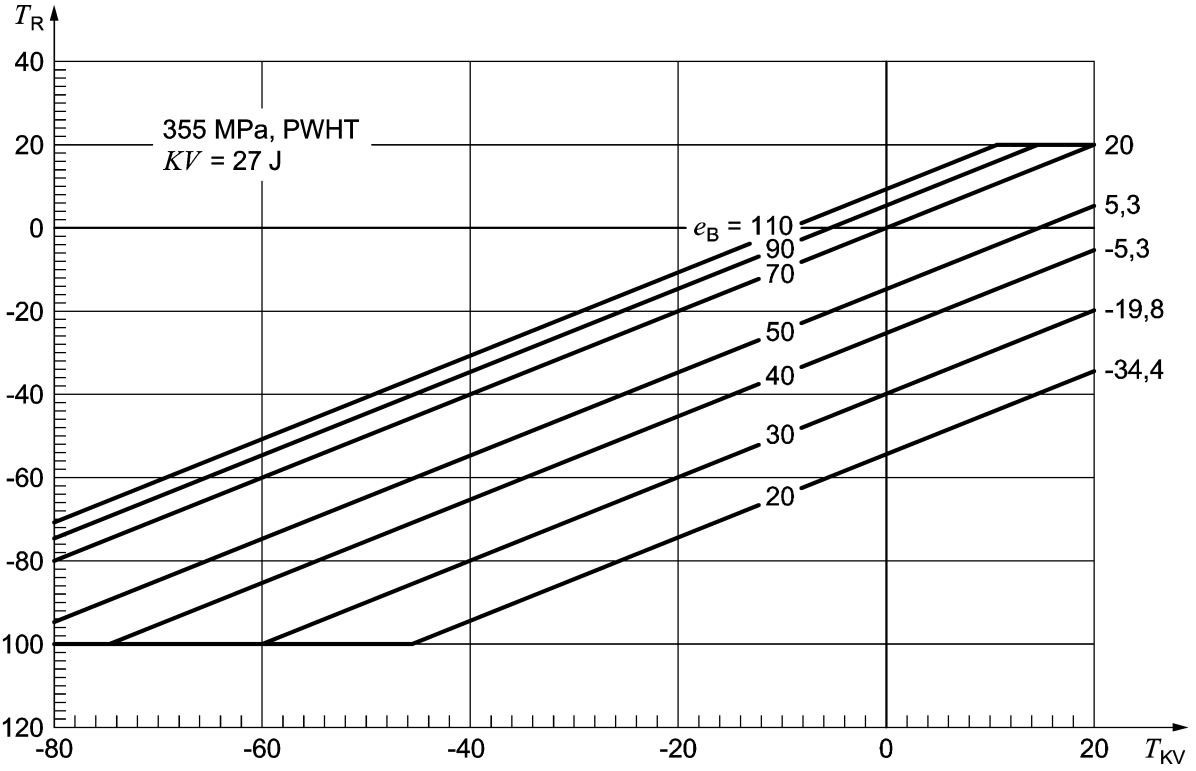
Key

T_R design reference temperature

T_{KV} material impact test temperature

e_B reference thickness

Figure B.2–2 — METHOD 2: Design reference temperature and impact test temperature as-welded (AW) condition, for $R_e \leq 265$ MPa and $KV \geq 27$ J



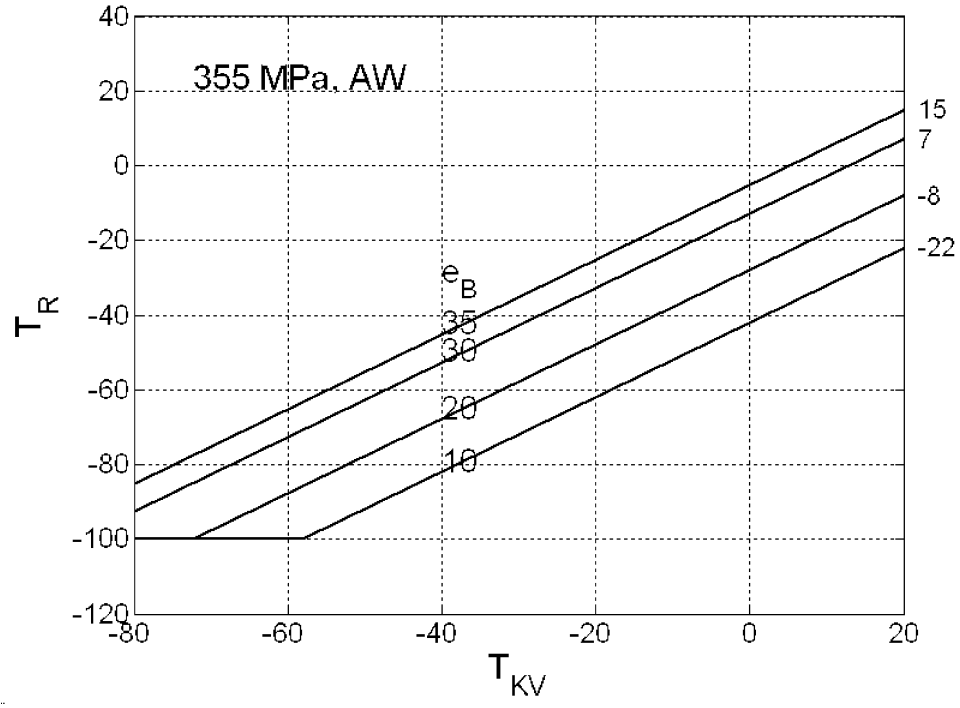
Key

T_R design reference temperature (°C)

T_{KV} material impact test temperature (°C)

e_B reference thickness (mm)

Figure B.2–3 — Method 2: Design reference temperature and impact test temperature, post weld heat treated (PWHT) condition, R_e ≤ 355 MPa and KV ≥ 27 J



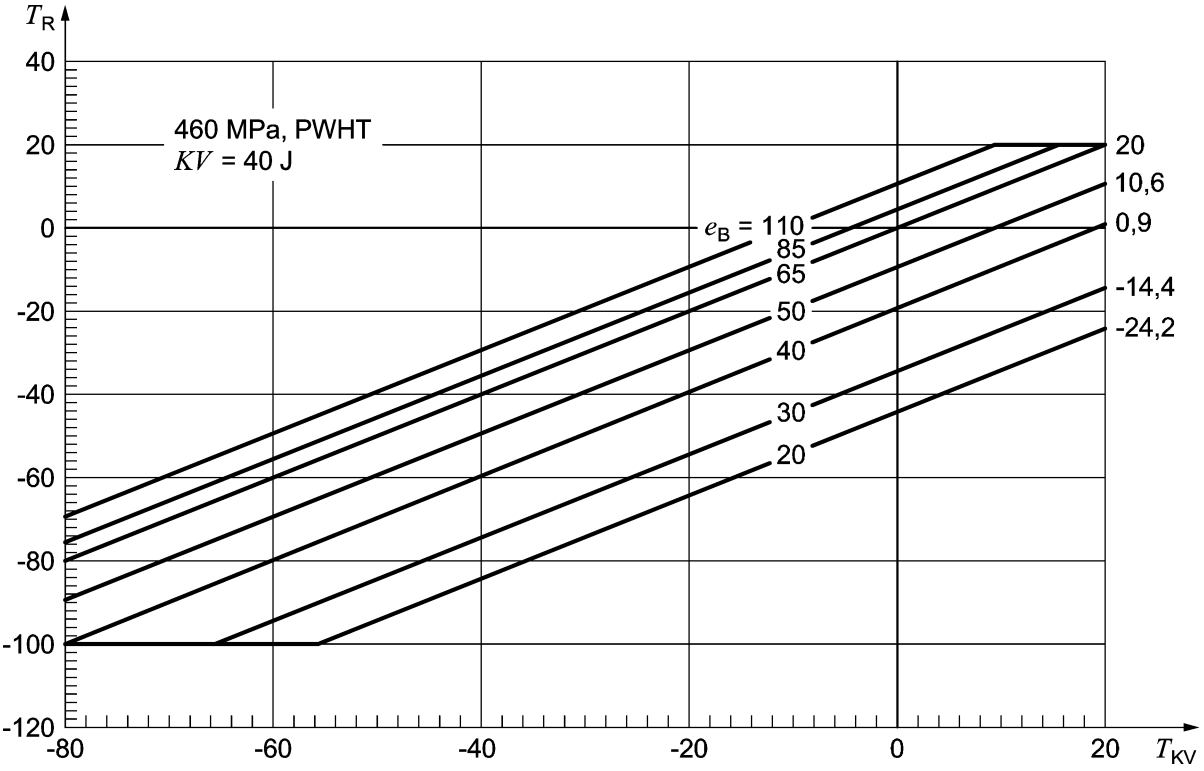
Key

T_R design reference temperature

T_{KV} material impact test temperature

e_B reference thickness

Figure B.2–4 — Method 2: Design reference temperature and impact test temperature as-welded (AW) condition, $R_e \leq 355$ MPa and $KV \geq 27$ J



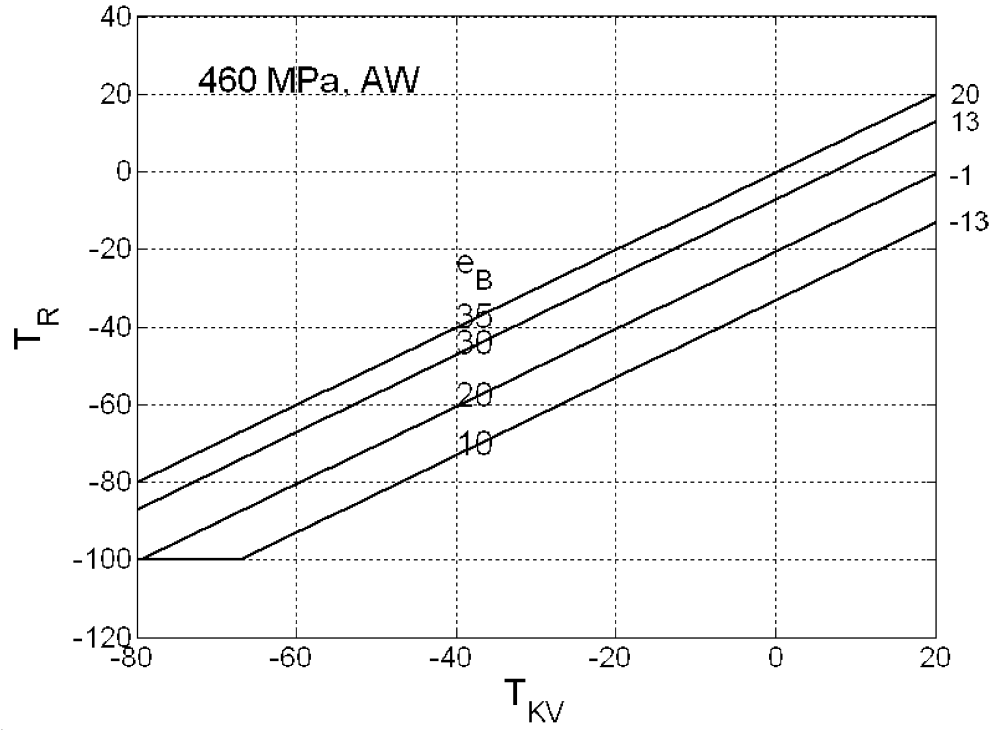
Key

T_R design reference temperature (°C)

T_{KV} material impact test temperature (°C)

e_B reference thickness (mm)

Figure B.2–5 — Method 2: Design reference temperature and impact test temperature, post weld heat treated (PWHT) condition, R_e ≤ 460 MPa and KV ≥ 40 J



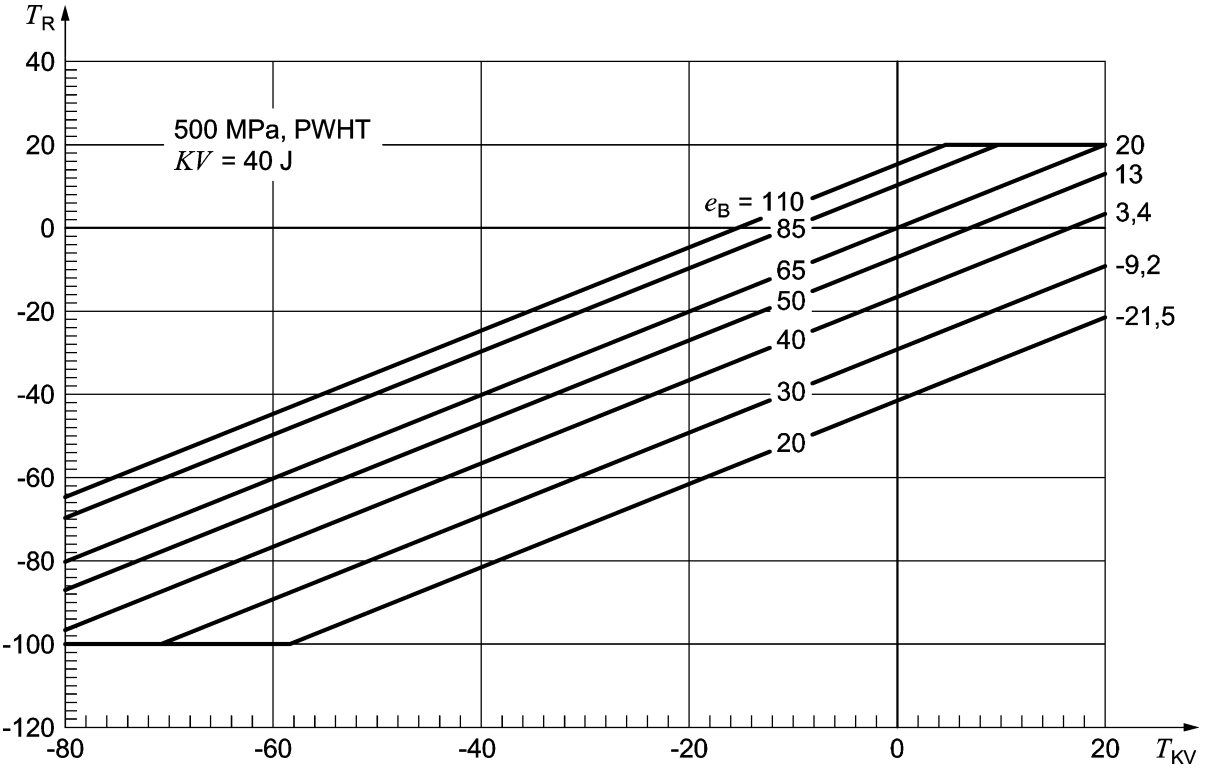
Key

T_R design reference temperature

T_{KV} material impact test temperature

e_B reference thickness

Figure B.2–6 — Method 2: Design reference temperature and impact test temperature as-welded (AW) condition, $R_e \leq 460$ MPa and $KV \geq 40$ J



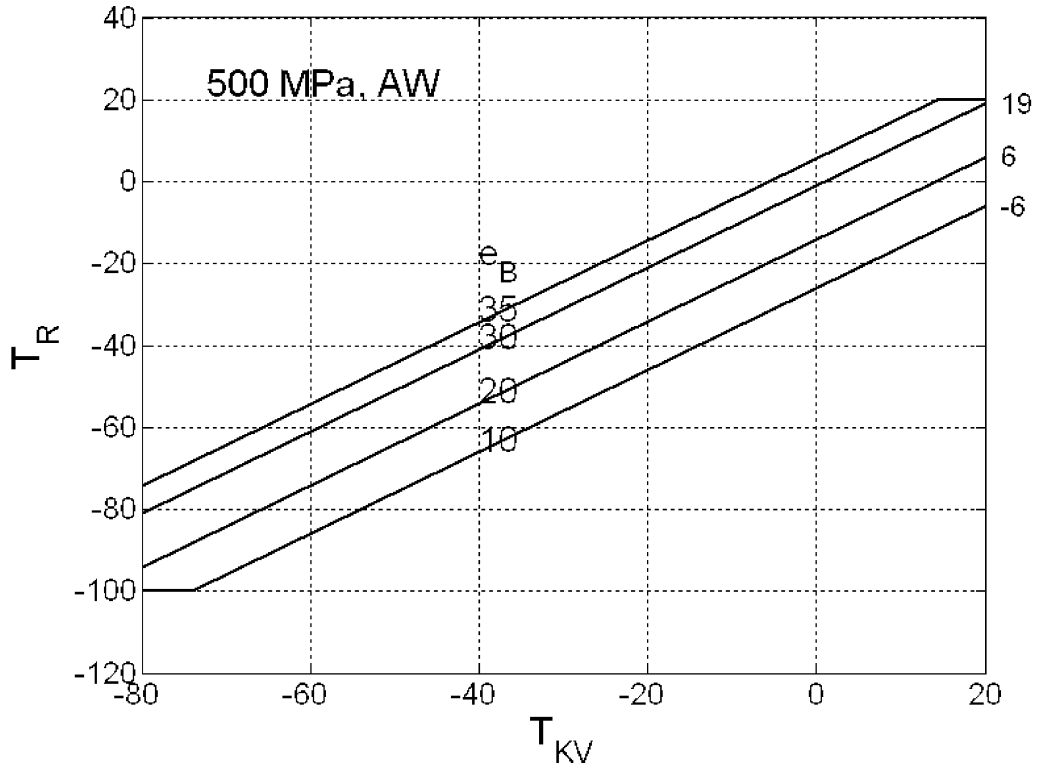
Key

T_R design reference temperature (°C)

T_{KV} material impact test temperature (°C)

e_B reference thickness (mm)

Figure B.2–7 — Method 2: Design reference temperature and impact test temperature, post weld heat treated (PWHT) condition, $R_e \leq 500$ MPa and $KV \geq 40$ J



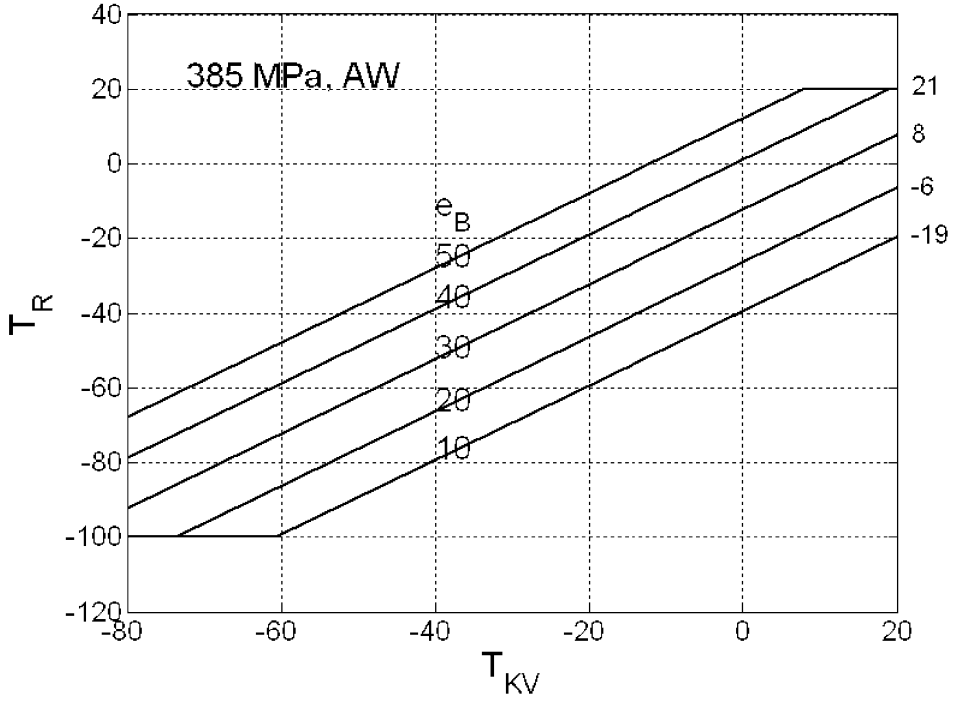
Key

T_R design reference temperature

T_{KV} material impact test temperature

e_B reference thickness

Figure B.2–8 — Method 2: Design reference temperature and impact test temperature as-welded (AW) condition, $R_e \leq 500$ MPa and $KV \geq 40$ J



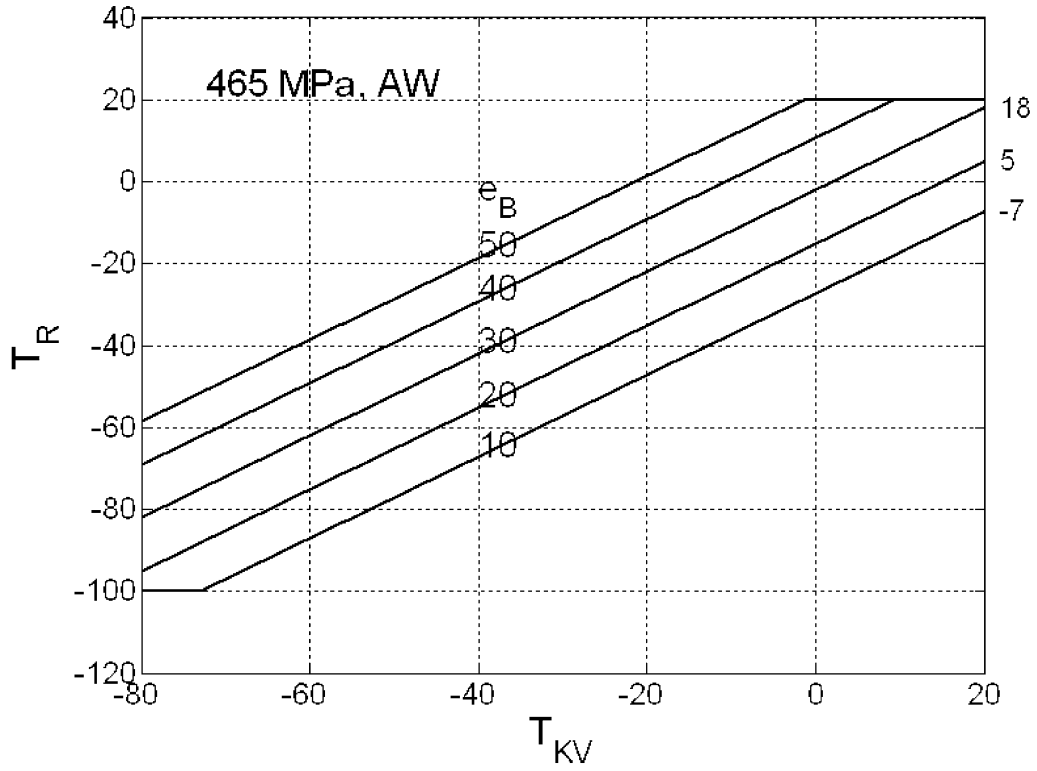
Key

T_R design reference temperature

T_{KV} material impact test temperature

e_B reference thickness

Figure B.2–9 — Method 2: Design reference temperature and impact test temperature for austenitic-ferritic steels, $e_B \leq 50$ mm, $R_e = 385$ MPa and $KV \geq 40$ J



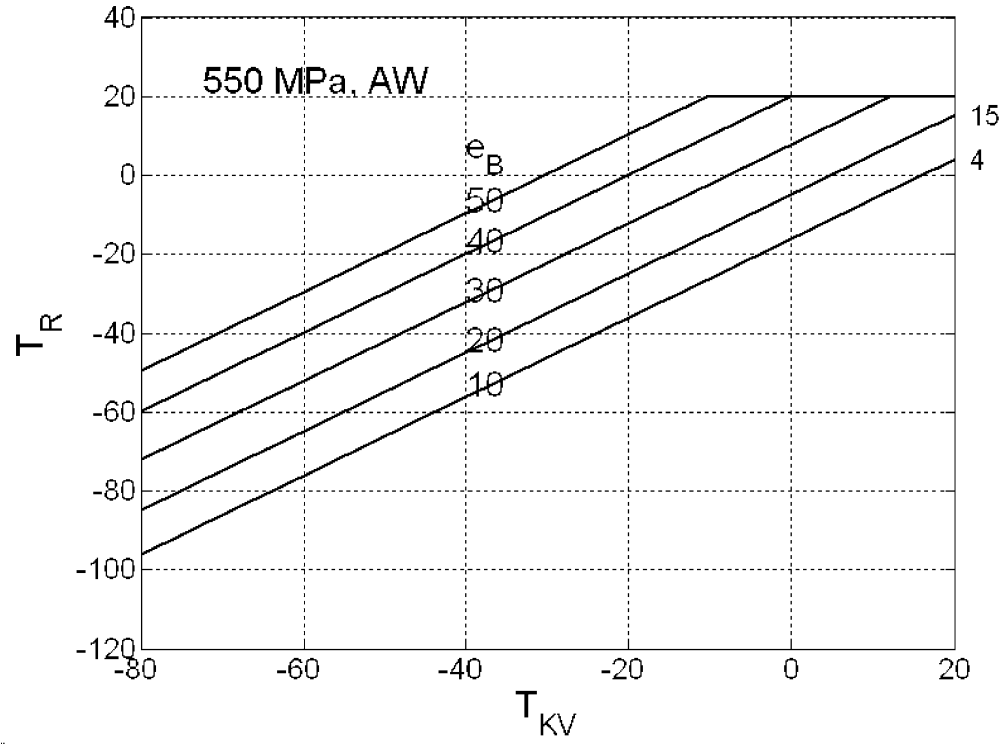
Key

T_R design reference temperature

T_{KV} material impact test temperature

e_B reference thickness

Figure B.2–10 — Method 2: Design reference temperature and impact test temperature for austenitic-ferritic steels, $e_B \leq 50$ mm, $R_c = 465$ MPa and $KV \geq 40$ J



Key

T_R design reference temperature

T_{KV} material impact test temperature

e_B reference thickness

Figure B.2–11 — Method 2: Design reference temperature and impact test temperature for austenitic-ferritic steels, $e_B \leq 50$ mm, $R_e = 550$ MPa and $KV \geq 40$ J

B.2.4 Method 3 — Fracture mechanics analysis

B.2.4.1 General

A fracture mechanics analysis may be used by the manufacturer as a basis for determining the suitability of particular vessels for their intended use for the following:

a) materials not currently covered by harmonised European standards;

b) those cases where the requirements of methods 1 and 2 for low temperature applications cannot be satisfied;

c) when imperfections which are outside the acceptance criteria for the non-destructive testing specified in EN 13445-5:2014 are detected;

d) where it is proposed to use materials in thickness thicker than permitted by the low temperature requirements.

NOTE Guidance on fracture mechanics analysis is given in publications [5] to [10] listed in the bibliography.

Such analyses shall be undertaken in accordance with the requirements of B.2.4.2 to B.2.4.5.

B.2.4.2 Fracture toughness properties shall be obtained in accordance with fracture toughness testing procedures using full-thickness single-edge notched-bend specimens or equivalent compact tension tests with fatigue cracks located through thickness in the weld centre-line and in parent material. Further test sampling of heat affected zone regions shall also be specified; particularly when fatigue or some other in-service crack growth mechanism may be significant.

When HAZ tests are specified special considerations are necessary with regard to the placement of the notch and metallurgical sectioning subsequent to testing.

B.2.4.3 For material not covered by the low temperature requirements of methods 1 or 2, a similar level of tolerance to fracture can be obtained by specifying fracture toughness requirements determined from the use of assessment procedures such as in [8] [9] with a reference defect size as determined by the manufacturer (e.g. a through wall flaw of total length equal to 10 mm, or a quarter wall thickness surface flaw with length six times its depth) and inputs of an equivalent stress (or strain) relating to the hydraulic test condition, for a defect in a region of stress concentration and subject to residual stresses equivalent to the room temperature yield strength of the base material for as welded components, or 30 % of yield for post weld heat treated components.

B.2.4.4 If non-destructive testing methods are employed which allow accurate sizing of defects, these values, together with information on the stress state of the critical regions in the vessel, shall be used with appropriate fracture assessment procedures to specify more accurate toughness requirements than those specified by method 1 or 2.

B.2.4.5 For materials which are covered by the low temperature requirements for method 1 or 2, but where the Charpy impact energy requirements cannot be met, a fitness-for-purpose assessment using representative fracture toughness data and inspection requirements may be employed to determine the integrity of the vessel for its intended use.

B.3 General test requirements

B.3.1 General

Where impact tests are required Charpy-V-notch tests shall be performed in accordance with EN ISO 148-1:2010. The impact energy requirements shall be met in the base material, heat affected zone and weld metal.

The specimen position shall be in accordance with the specifications in the technical delivery conditions of the product form for materials for pressure equipment. For welded joints the specimen position for weld metal and HAZ shall be in accordance with EN 13445-4:2014.

From each sample three specimens shall be tested for each of the required positions and material impact test temperature T_{KV}. The mean value of the three specimens shall be at least equal to the impact energy requirement. Only one specimen may show a lower value, but this value shall not be less than 70 % of this requirement.

The required values for base material shall refer to the transverse direction. If geometry does not allow to extract specimen in the transverse direction the impact energy values shall be taken from tests in the longitudinal direction. The minimum impact energy requirements specified for transverse test pieces shall then be multiplied by the factor 1,5 for C, CMn, fine grained, low alloyed steels and high strength steels.

B.3.2 Sub-sized specimens

If sub-sized Charpy specimens shall be used, the measured value of the Charpy energy shall be proportionally converted to the reference specimen thickness of 10 mm. Table B.3–1 gives an example for 7,5 mm and 5 mm thick specimens. Where test pieces at least 5 mm wide cannot be obtained, the material shall not be subject to impact testing.

Table B.3–1 — Impact requirements for sub-sized Charpy-V-notched specimen if the base material is less than 10 mm thick

Reference value	Sub sized specimen	
Specimen geometry		
10 mm × 10 mm	10 mm × 7,5 mm	10 mm × 5 mm
Minimum impact energy J		
27	20	14
40	30	20

If full size Charpy specimen can not be extracted from components and welds sub-sized specimens shall be tested. To represent the behaviour of a full thickness specimen a lower impact test temperature shall be applied. The temperature shifts shall be in accordance with Table B.3–2.

Impact tests should be performed on the maximum thickness which can be extracted from the component under consideration.

Table B.3–2 — Equivalent impact energy requirements when sub-sized specimens are extracted from thicker sections

Required impact energy	Specimen geometry	Sub-sized specimen requirement		
KV J	mm	KV J	Specimen geometry mm	Shift of impact test temperature °C
27	10 × 10	20 14	7,5 × 10 5,0 × 10	T_{KV} − 5 T_{KV} − 20
40	10 × 10	30 20	7,5 × 10 5,0 × 10	T_{KV} − 5 T_{KV} − 20
20	7,5 × 10	14	5,0 × 10	T_{KV} − 15
30	7,5 × 10	20	5,0 × 10	T_{KV} − 15
14	5,0 × 10	—	—	—
20	5,0 × 10	—	—	—

B.4 Welds

B.4.1 General

When materials are to be joined by welding, the choice of welding consumables and welding procedures shall ensure that in addition to the requirements of EN 13445-4:2014 the required impact energy properties are achieved in weld metal and heat affected zone regions, when tested in accordance with B.3.

The required impact energy shall be at least equal to the specified minimum impact energy for the base metal. The requirements of method 1 or 2 shall be met.

B.4.2 Welding procedure qualification

Welding procedure qualification shall be performed in accordance with EN 13445-4:2014.

B.4.3 Production test plates

For ferritic and austenitic-ferritic steels weld production test plates shall be performed in accordance with EN 13445-4:2014.

B.5 Materials for use at elevated temperatures

B.5.1 General

B.5 applies for pressure equipment:

— with design temperature for normal operation higher than 50 °C and where

— material temperature at start up, shut down and at possible process upsets is not lower than −10 °C and

— start up and shut down procedure is under controlled conditions as given in B.5.4 and

— conditions for pressure test as specified in B.5.5 are fulfilled

If any of these requirements is not satisfied the methods for low temperature materials shall be applied.

NOTE The limitation regarding start-up and shut-down, process upsets and pressure test are not applicable to austenitic stainless steels.

B.5.2 Materials

Materials shall have a specified minimum impact energy measured on a standard Charpy-V-notch impact test specimen (see EN ISO 148-1:2010) as follows:

— ≥ 27 J for ferritic steels and 1,5 % to 5 % Ni alloy steels;

— ≥ 40 J for steels of material group 8, 9.3 and 10

at a temperature not higher than 20 °C.

B.5.3 Welding procedure qualification and production test plates

Welding procedure qualification shall be performed in accordance with EN 13445-4:2014.

The weld production test plate shall be performed in accordance with EN 13445-4:2014.

B.5.4 Start up and shut down procedure

To avoid brittle fracture occurrence of pressure equipment made of ferritic or austenitic-ferritic steels during start-up and shut-down procedures, the pressure shall not exceed 50 % of the design pressure at temperatures lower than 20 °C.

This start-up and shut-down procedure need not to be considered, if the evaluation of the specified minimum impact values against method 2 allows design pressures at lower temperatures.

B.5.5 Pressure test

Hydrostatic pressure test of pressure vessels made of ferritic or austenitic-ferritic steels shall not be carried out at material temperatures lower than 10 °C.

This temperature limitation needs not to be considered, if the evaluation of the specified minimum impact values against method 2 allows design pressures at lower temperatures.

Table B.4-1 — Reference thickness e_B

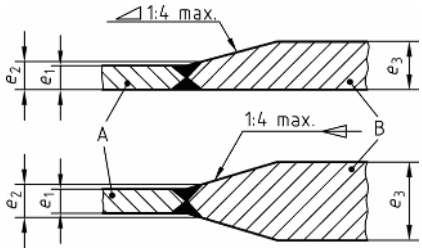
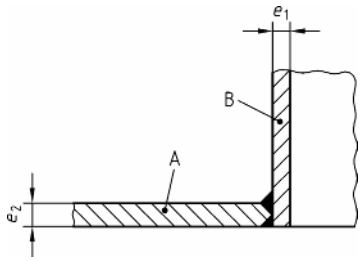
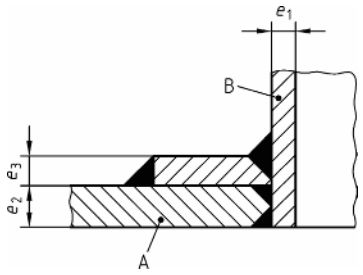
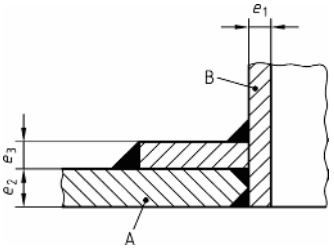
No.	Construction detail	as-welded (AW) or post weld heat treated (PWHT)	Reference thickness		
			Part A	Weld	Part B
1	Butt welded components of unequal thickness 	AW	e_1	e_2	e_2 check e_3 in Figures B.2–2, B.2–4, B.2–6, B.2–8 [a]
		PWHT	e_1	e_2	e_3
2	Branches and nozzles 	AW	e_2	e_2	e_1
		PWHT	e_2	e_2	e_1
3		AW	e_2	e_2 or e_3, if thicker	e_1
		PWHT	e_2	e_2 or e_3, if thicker	e_1
4		AW	e_2	e_2 or e_3, if thicker	e_1
		PWHT	e_2	e_2 or e_3 if thicker	e_1

Table B.4-1 — Reference thickness e_B (continued)

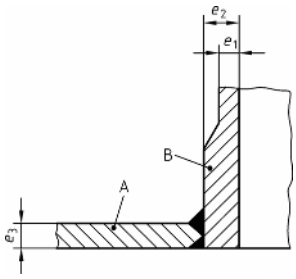
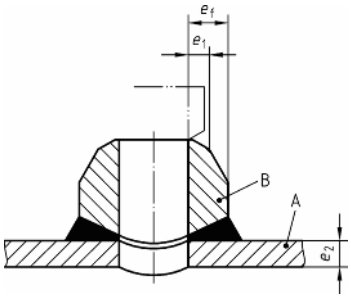
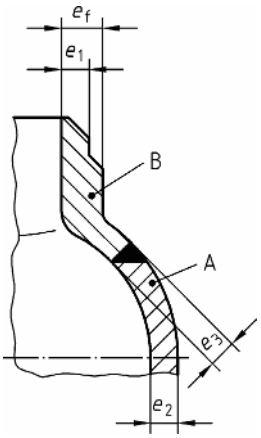
No.	Construction detail	as-welded (AW) or post weld heat treated (PWHT)	Reference thickness		
			Part A	Weld	Part B
5		AW	e_3	e_2 or e_3, if thicker	e_2
		PWHT	e_3	e_2 or e_3, if thicker	e_2
6		AW	e_2	e_2	e_1 or $e_f/4$ if thicker
		PWHT	e_2	e_2	e_1 [a] or $e_f/4$, if thicker if necessary check e_1 in Figures B.2–1, B.2–3, B.2–5, B.2–7 [a]
7		AW	e_2	e_3	e_3 or $e_f/4$, if thicker ,
		PWHT	e_2	e_3	e_3 [a] or $e_f/4$, if thicker if necessary check e_1 in Figures B.2–1, B.2–3, B.2–5, B.2–7 [a]

Table B.4-1 — Reference thickness e_B (continued)

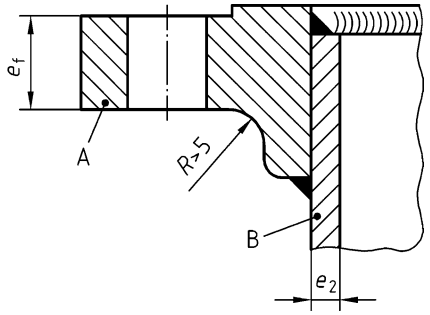
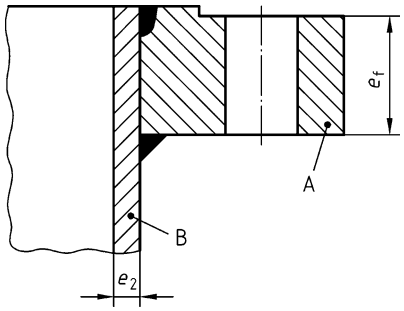
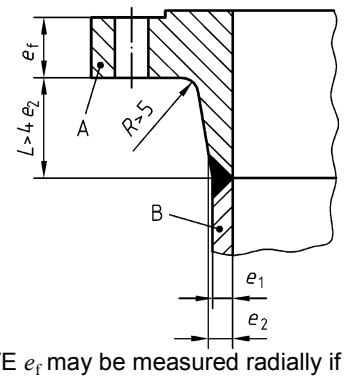
No.	Construction detail	as-welded (AW) or post weld heat treated (PWHT)	Reference thickness		
			Part A	Weld	Part B
8	Slip-on and plate flanges [c]  NOTE e_f may be measured radially if that gives an advantage	AW	e_2 *or* $e_f/4$, if thicker	e_2 *or* $e_f/4$, if thicker	e_2
		PWHT	e_2 *or* $e_f/4$, if thicker	e_2 *or* $e_f/4$, if thicker	e_2
9	 NOTE e_f may be measured radially if that gives an advantage	AW	e_2 *or* $e_f/4$, if thicker	e_2 *or* $e_f/4$, if thicker	e_2
		PWHT	e_2 *or* $e_f/4$, if thicker	e_2 *or* $e_f/4$, if thicker	e_2
10	Forged or cast welding neck flanges [c]  NOTE e_f may be measured radially if that gives an advantage	AW	e_2 [a] check $e_f/4$ in Figures B.2–1, B.2–3, B.2–5, B.2–7 [a]	e_2	e_1
		PWHT	e_2 or $e_f/4$, if thicker	e_2	e_1

Table B.4-1 — Reference thickness e_B (continued)

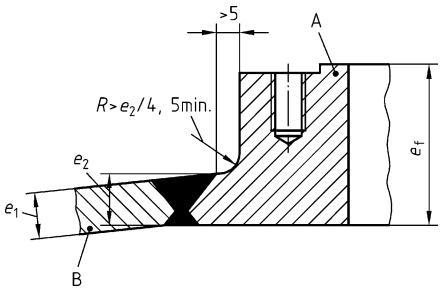
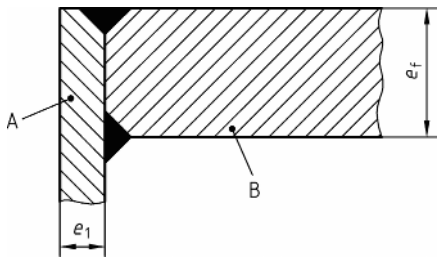
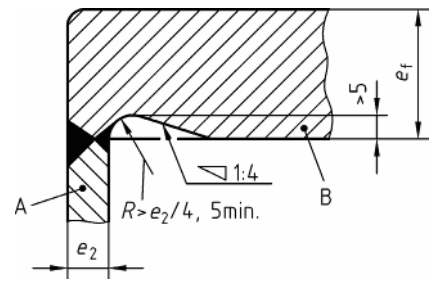
No.	Construction detail	as-welded (AW) or post weld heat treated (PWHT)	Reference thickness		
			Part A	Weld	Part B
11	Pad-type flanges  NOTE e_f may be measured radially if that gives an advantage	AW	e_2 [a] check $e_f/4$ in Figures B.2–2, B.2–4, B.2–6, B.2–8 [a]	e_2	e_1
		PWHT	e_2 or $e_f/4$, if thicker	e_2	e_1
12	Flat ends  	AW	e_1	e_1	$e_f/4$ or e_1, if thicker
		PWHT	e_1	e_1	$e_f/4$ or e_1, if thicker
13	 	AW	e_2	e_2	e_2 or check $e_f/4$, in Figures B.2–2, B.2–4, B.2–6, B.2–8
		PWHT	e_2	e_2	e_2 or $e_f/4$, if thicker

Table B.4-1 — Reference thickness e_B (continued)

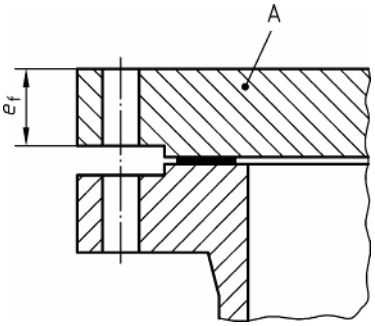
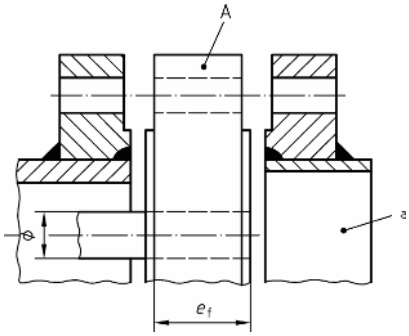
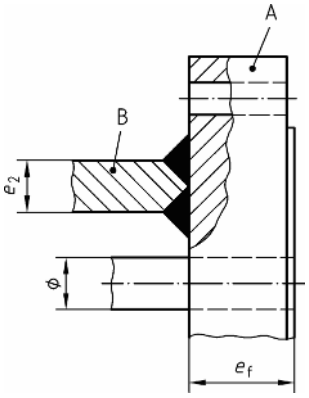
No.	Construction detail	as-welded (AW) or post weld heat treated (PWHT)	Reference thickness		
			Part A	Weld	Part B
14	Covers and blind flanges 	AW	$e_f/4$	—	—
		PWHT	$e_f/4$	—	—
15	Tube plates 	AW	[n. a.]	[n. a.]	[n. a.]
		PWHT	$e_f/4$	[n. a.]	[n. a.]
16		AW	$e_f/4$ or e_2, if thicker	e_2	e_2
		PWHT	$e_f/4$ or e_2, if thicker	e_2	e_2

Table B.4-1 — Reference thickness e_B (continued)

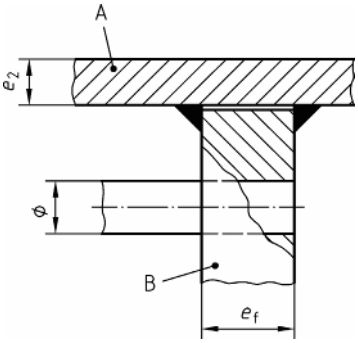
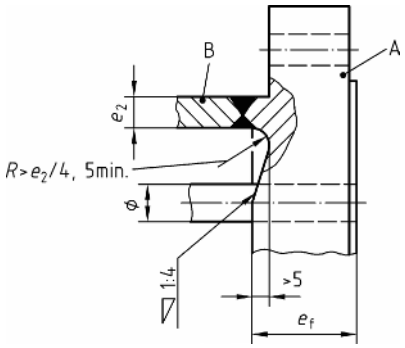
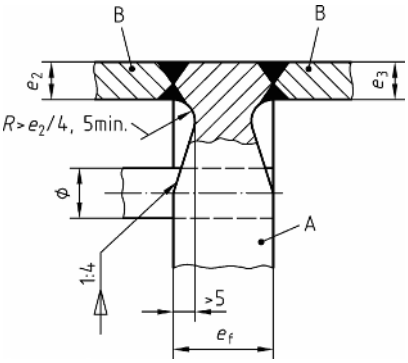
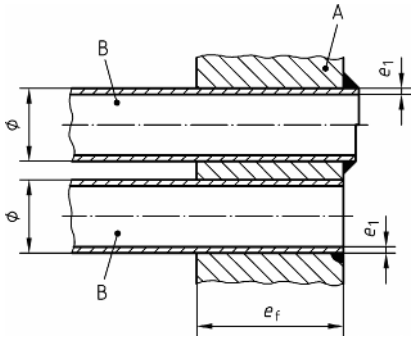
No.	Construction detail	as-welded (AW) or post weld heat treated (PWHT)	Reference thickness		
			Part A	Weld	Part B
17	Welded into shell/channel 	AW	e_2, check $e_f/4$ in Figures B.2–2, B.2–4, B.2–6, B.2–8	e_2	e_2 or $e_f/4$ if thicker
		PWHT	e_2 or $e_f/4$, if thicker	e_2	e_2 or $e_f/4$ if thicker
18	Forged tube plate with stubs 	AW	e_2 [a] check $e_f/4$ in Figures B.2–2, B.2–4, B.2–6, B.2–8[a])	e_2	e_2
		PWHT	$e_f/4$ or e_2, if thicker	e_2	e_2
19		AW	e_2 [a] or e_3, if thicker check $e_f/4$ in Figures B.2–2, B.2–4, B.2–6, B.2–8[a])	e_2 (e_3)	e_2 (e_3)
		PWHT	$e_f/4$ or e_2 or e_3, if thicker	e_2 (e_3)	e_2 (e_3)

Table B.4-1 — Reference thickness e_B (continued)

No.	Construction detail	as-welded (AW) or post weld heat treated (PWHT)	Reference thickness		
			Part A	Weld	Part B
20	Tube-to-tube plate connection 	AW	[n. a.]	e_1	e_1
		PWHT	b	e_1	e_1

NOTE 1 [n. a.] means "not applicable".

NOTE 2 e_1, e_2 and e_3 refer to the nominal thickness of the various components shown in the figures.

[a] The minimum test temperature of the two conditions: e_x (AW), e_y (PWHT or non-welded) shall be taken.

[b] Reference thickness of part A is unaffected by this connection.

[c] For welding neck flanges and slip on flanges according to EN 1092-1:2007, R shall be as given in EN 1092-1:2007.

Annex C
(informative)

Procedure for determination of the weld creep strength reduction factor (WCSRF)

The WCSRF will be taken as 1 when all the following conditions are fulfilled by the steel manufacturer:

C.1 Stress rupture tests on weldments made on specimens of the same steel products as used in the vessel and which are comparable as regards consumable shall be carried out according to the European Creep Collaborative Committee (E.C.C.C.) Recommendations [18].

C.2 Two test temperatures shall be selected within a range of +/– 30 °C about the mean design temperature. At each of these temperatures, creep tests shall be carried out at stresses selected to give durations up to 1/3 of the creep design life (typically 1 000 h, 3 000 h, 10 000 h, 30 000 h, 60 000 h, 100 000 h, etc.). It has to be shown that the lower limit of the achieved creep values of the welded joint are not lower than the lower accepted scatter band (−20 %) of specified mean values of the creep strength of the base material according to the materials standard. However if the failure is located in the Heat Affected Zone (HAZ), extrapolation is not allowed without further testing at longer times showing no further apparent decrease. In this case extrapolation may be made by a factor equivalent to the factor showing stabilised conditions used in these longer tests.

C.3 When no cracking in the HAZ has been found in the tests prescribed above, an additional set of tests at a higher temperature shall be made with the value of the Larson Miller Parameter (LMP) equal to or greater than that at the extrapolation point. This testing shall be made to confirm that the location of the failure does not change from the base material to HAZ. The temperature shall ideally be no more than 50 °C greater than the higher temperature test in C.2 (in order to avoid an unacceptable modification of the microstructure). The stress shall lead to a minimum testing time of 10 kh. The temperature and testing time shall be selected so that the creep Time Temperature Parameter (TTP) e.g. Larson Miller Parameter (LMP) in these tests is at least the value at the extrapolation point (time and temperature). A minimum of 3 samples shall be tested. The fracture location of the creep specimens shall be checked by microscopic examination.

C.4 If fracture location of the creep specimens in C.3 is within the base material, the WCSRF may be taken as unity for a time equal to the time achieved in the tests in C.2 multiplied by a maximum of 3.

C.5 When the creep strength properties of cross weld specimens fall below the minimum value given in the scatter band a specific weld reduction factor can be used based on the ratio of the average value of the creep strength compared to 80 % of the mean value of the base material.

Annex D
(informative)

Technical delivery conditions for clad products for pressure purposes

D.1 Introductory note

Until a European Standard for clad steel products for pressure purposes is available, the requirements for the technical delivery conditions of such products should form the basis for an agreement of the parties involved.

D.2 Requirements for the material

For the material of clad products the relevant conditions of EN 13445-2:2014 should apply.

In addition, where appropriate, requirements for impact tests of the kind described in D.4, item b, should be agreed at the time of enquiry and order.

D.3 Requirements for the deposited material

Clad steels should comply with the following general requirements.

In the case of clad steels where the cladding has a lower degree of elasticity than that of the base metal, a tensile test on the cladding after the base has been removed should show an elongation after fracture A_5 of at least 12 %.

The bond between the base and the cladding materials should be of such a nature that there is no delamination either in the course of manufacture or in service. Unless otherwise stipulated in the order, the shear strength of cladding with a tensile strength of less than 280 MPa should be more than half the minimum tensile strength of the cladding material and, for all other cladding materials, should not be less than 140 MPa, regardless of the direction of testing.

The bonded area should cover at least 95 % of the entire surface and no single unbonded area should cover more than 50 cm^2. In the case of clad steels which are highly stressed during manufacture (e.g. dished ends) or when in service (e.g. tube plates), additional requirements imposed by the purchaser (operator) can be necessary.

The cladding material should have a surface texture which corresponds to the cladding process and be of uniform thickness with tolerances not exceeding those given in Table D.3-1.

The permissible tolerances for the base material are given in the relevant dimensional standards for the various products.

Table D.3-1 — Limit deviations on thickness for cladding materials on clad steels

Nominal thickness mm	Limit deviations on thickness [a, b] mm
1,0	− 0,10
1,5	− 0,15
2,0	− 0,20
2,5	− 0,25
3,0	− 0,35
3,5	− 0,45
4,0	− 0,50
4,5	− 0,50
≥ 5,0	− 0,50

[a] Deviations from the values in this table are subject to special agreement.

[b] For intermediate thicknesses the Limit deviation indicated for the next smallest thickness in the table applies.

D.4 Qualification of the cladding procedure

Before commencing production, suitable cladding conditions should be verified by cladding procedure qualification tests, including welding procedure tests for weld overlay, if applicable. These conditions should be carefully observed when cladding the products in the plant.

The cladding procedure qualification tests should normally comprise:

a) tensile tests in accordance with EN ISO 6892-1:2009;

b) Charpy-V-notch impact tests in accordance with EN ISO 148-1:2010 at the temperature specified for test pieces taken from the cladded base material so that
   - one side of the test piece coincides with the bonded area between the base and deposited material;
   - the longitudinal direction of the test piece is transverse to the direction of rolling; and
   - the axis of the notch is perpendicular to the next surface of the base material (see Figure D.5-1, item d);

c) bend tests on test pieces which, as shown in Figure D.5-2 cover the bonded zone and are bent in a direction parallel to the bounding zone;

d) the examination of the hardness, micro- and macrostructure and chemical composition in the transition zone;

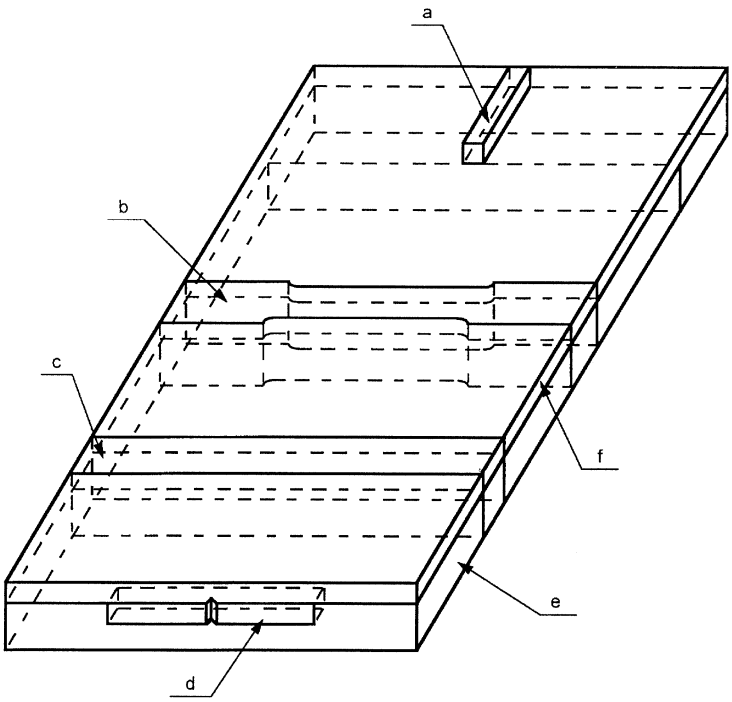
e) shear tests on shear specimens;

f) inspection of surface quality and conformity to dimensions;

g) ultrasonic testing of the bond between the base material and the cladding.

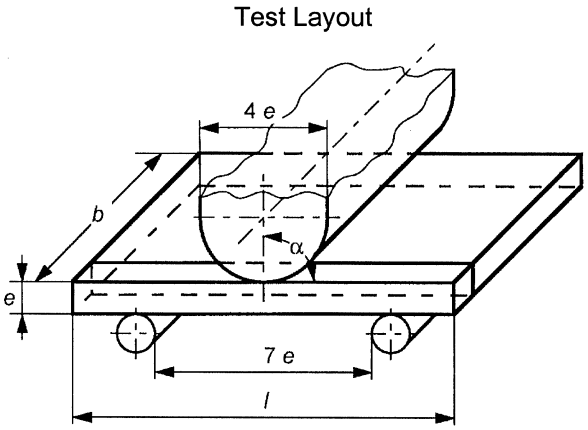
D.5 Production tests

Intervals samples of the base material clad under the same conditions as the products should be tested at consistent intervals during production. The types of tests to be carried out and the requirements to be complied with should be agreed on the basis of the results of the cladding procedure qualification tests specified in D.4 and practical experience.



a) shear test specimen
b) tensile test specimen
c) side bend test specimen
d) notched bar impact bend test specimen
e) material
f) cladding material

Figure D.5-1 — Position of test pieces



Dimensions of specimen:

Thickness: e = 10 mm

Width: b = thickness of finished product, but not greater than 80 mm (base and cladding material) If finished product is over 80 mm thick the base material may be removed.

Length: l = not less than 130 mm

Angle: α = 90°

Figure D.5-2 — Arrangement of bend tests for clad products

Annex E
(informative)

European steels for pressure purposes

E.1 European Standards for steels and steel components for pressure purposes

Table E.1-1 contains an informative summary on European Standards for steels and steel components for pressure purposes.

Table E.1-1 — European Standards for steels and steel components for pressure purposes

Product form	General requirements	Room temperature grades [a]	Elevated temperature grades	Fine grain steels			Low temperature grades	Stainless steels
				Normalised	Thermo-mechanically treated	Quenched and tempered		
Plate and strip	EN 10028-1	—	EN 10028-2	EN 10028-3	EN 10028-5	EN 10028-6	EN 10028-4	EN 10028-7
Rolled bar	—	—	EN 10273	—	—	—	—	EN 10272
Seamless tube	—	EN 10216-1	EN 10216-2	EN 10216-3	—	EN 10216-3	EN 10216-4	EN 10216-5
Electric welded tube	—	EN 10217-1	EN 10217-2	EN 10217-3	—	—	EN 10217-4	—
Submerged arc welded tube	—	EN 10217-1	EN 10217-5	EN 10217-3	—	—	EN 10217-6	—
Fusion welded tube	—	—	—	—	—	—	—	EN 10217-7
Fitting	—	EN 10253-2	EN 10253-2	EN 10253-2	EN 10253-2	EN 10253-2	EN 10253-2	EN 10253-4
Forging including forged bars	EN 10222-1	—	EN 10222-2	EN 10222-4	—	—	EN 10222-3	EN 10222-5
Casting	EN 10213	—	EN 10213	—	—	—	EN 10213	EN 10213
Steel for fastener	—	—	EN 10269	—	—	—	EN 10269	EN 10269

[a] room temperature values are given in all standards of this table

E.2 European standardised steels grouped according to product forms

The references in this table do not include the date of the standard, but they are dated references as given in Clause 2 and in Bibliography.

Table E.2-1 — European standardised steels grouped according to product forms

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
							min.	max.		
1	plate and strip	EN 10028-2	elevated temperature properties	P235GH	1.0345	N	0	250	1.1	
2	plate and strip	EN 10028-2	elevated temperature properties	P265GH	1.0425	N	0	250	1.1	
3	plate and strip	EN 10028-2	elevated temperature properties	P295GH	1.0481	N	0	250	1.2	
4	plate and strip	EN 10028-2	elevated temperature properties	P355GH	1.0473	N	0	250	1.2	
5	plate and strip	EN 10028-2	elevated temperature properties	16Mo3	1.5415	N, NT	0	250	1.2	[e]
6	plate and strip	EN 10028-2	elevated temperature properties	18MnMo4-5	1.5414	NT	0	150	1.2	
7	plate and strip	EN 10028-2	elevated temperature properties	18MnMo4-5	1.5414	QT	150	250	1.2	
8	plate and strip	EN 10028-2	elevated temperature properties	20MnMoNi4-5	1.6311	QT	0	250	3.1	
9	plate and strip	EN 10028-2	elevated temperature properties	15NiCuMoNb5-6-4	1.6368	NT	0	100	3.1	
10	plate and strip	EN 10028-2	elevated temperature properties	15NiCuMoNb5-6-4	1.6368	NT, QT	100	150	3.1	
11	plate and strip	EN 10028-2	elevated temperature properties	15NiCuMoNb5-6-4	1.6368	QT	150	200	3.1	
12	plate and strip	EN 10028-2	elevated temperature properties	13CrMo4-5	1.7335	NT	0	100	5.1	
13	plate and strip	EN 10028-2	elevated temperature properties	13CrMo4-5	1.7335	NT,QT	100	150	5.1	
14	plate and strip	EN 10028-2	elevated temperature properties	13CrMo4-5	1.7335	QT	150	250	5.1	
15	plate and strip	EN 10028-2	elevated temperature properties	13CrMoSi5-5	1.7336	NT, QT	0	100	5.1	
16	plate and strip	EN 10028-2	elevated temperature properties	13CrMoSi5-5	1.7336	QT	100	250	5.1	
17	plate and strip	EN 10028-2	elevated temperature properties	10CrMo9-10	1.7380	NT	0	60	5.2	
18	plate and strip	EN 10028-2	elevated temperature properties	10CrMo9-10	1.7380	NT,QT	60	100	5.2	

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
19	plate and strip	EN 10028-2	elevated temperature properties	10CrMo9-10	1.7380	QT	100	250	5.2	
20	plate and strip	EN 10028-2	elevated temperature properties	12CrMo9-10	1.7375	NT,QT	0	250	5.2	
21	plate and strip	EN 10028-2	elevated temperature properties	X12CrMo5	1.7362	NT	0	150	5.3	
22	plate and strip	EN 10028-2	elevated temperature properties	X12CrMo5	1.7362	QT	150	250	5.3	
23	plate and strip	EN 10028-2	elevated temperature properties	13CrMoV9-10	1.7703	NT	0	150	6.2	
24	plate and strip	EN 10028-2	elevated temperature properties	13CrMoV9-10	1.7703	QT	150	250	6.2	
25	plate and strip	EN 10028-2	elevated temperature properties	12CrMoV12-10	1.7767	NT	0	150	6.2	
26	plate and strip	EN 10028-2	elevated temperature properties	12CrMoV12-10	1.7767	QT	150	250	6.2	
27	plate and strip	EN 10028-2	elevated temperature properties	X10CrMoVNb9-1	1.4903	NT	0	150	6.4	
28	plate and strip	EN 10028-2	elevated temperature properties	X10CrMoVNb9-1	1.4903	QT	150	250	6.4	
29	plate and strip	EN 10028-3	fine grain steel normalised	P275NH	1.0487	N	0	250	1.1	
30	plate and strip	EN 10028-3	fine grain steel normalised	P275NL1	1.0488	N	0	250	1.1	
31	plate and strip	EN 10028-3	fine grain steel normalised	P275NL2	1.1104	N	0	250	1.1	
32	plate and strip	EN 10028-3	fine grain steel normalised	P355N	1.0562	N	0	250	1.2	
33	plate and strip	EN 10028-3	fine grain steel normalised	P355NH	1.0565	N	0	250	1.2	
34	plate and strip	EN 10028-3	fine grain steel normalised	P355NL1	1.0566	N	0	250	1.2	
35	plate and strip	EN 10028-3	fine grain steel normalised	P355NL2	1.1106	N	0	250	1.2	
36	plate and strip	EN 10028-3	fine grain steel normalised	P460NH	1.8935	N	0	100	1.3	
37	plate and strip	EN 10028-3	fine grain steel normalised	P460NL1	1.8915	N	0	100	1.3	
38	plate and strip	EN 10028-3	fine grain steel normalised	P460NL2	1.8918	N	0	100	1.3	

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
39	plate and strip	EN 10028-4	low temperature properties	11MnNi5-3	1.6212	N,NT	0	80	9.1	
40	plate and strip	EN 10028-4	low temperature properties	13MnNi6-3	1.6217	N,NT	0	80	9.1	
41	plate and strip	EN 10028-4	low temperature properties	15NiMn6	1.6228	N,NT,QT	0	80	9.1	
42	plate and strip	EN 10028-4	low temperature properties	12Ni14	1.5637	N,NT,QT	0	80	9.2	
43	plate and strip	EN 10028-4	low temperature properties	X12Ni5	1.5680	N,NT,QT	0	50	9.2	
44	plate and strip	EN 10028-4	low temperature properties	X8Ni9+NT640	1.5662	N+NT	0	50	9.3	
45	plate and strip	EN 10028-4	low temperature properties	X8Ni9+QT640	1.5662	QT	0	50	9.3	
46	plate and strip	EN 10028-4	low temperature properties	X8Ni9+QT680	1.5662	N+NT, QT	0	15	9.3	
47	plate and strip	EN 10028-4	low temperature properties	X8Ni9+QT680	1.5662	QT	15	50	9.3	
48	plate and strip	EN 10028-4	low temperature properties	X7Ni9	1.5663	N+NT, QT	0	15	9.3	
49	plate and strip	EN 10028-4	low temperature properties	X7Ni9	1.5663	QT	15	50	9.3	
50	plate and strip	EN 10028-5	fine grain steel, thermomechanically rolled	P355M	1.8821	M	0	63	1.2	[f]
51	plate and strip	EN 10028-5	fine grain steel, thermomechanically rolled	P355ML1	1.8832	M	0	63	1.2	[f]
52	plate and strip	EN 10028-5	fine grain steel, thermomechanically rolled	P355ML2	1.8833	M	0	63	1.2	[f]
53	plate and strip	EN 10028-5	fine grain steel, thermomechanically rolled	P420M	1.8824	M	0	63	2.1	[f]
54	plate and strip	EN 10028-5	fine grain steel, thermomechanically rolled	P420ML1	1.8835	M	0	63	2.1	[f]
55	plate and strip	EN 10028-5	fine grain steel, thermomechanically rolled	P420ML2	1.8828	M	0	63	2.1	[f]

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
56	plate and strip	EN 10028-5	fine grain steel, thermomechanically rolled	P460M	1.8826	M	0	63	2.1	[f]
57	plate and strip	EN 10028-5	fine grain steel, thermomechanically rolled	P460ML1	1.8837	M	0	63	2.1	[f]
58	plate and strip	EN 10028-5	fine grain steel, thermomechanically rolled	P460ML2	1.8831	M	0	63	2.1	[f]
59	plate and strip	EN 10028-6	fine grain steel, quenched/tempered	P355Q	1.8866	QT	0	150	1.2	
60	plate and strip	EN 10028-6	fine grain steel, quenched/tempered	P355QH	1.8867	QT	0	150	1.2	
61	plate and strip	EN 10028-6	fine grain steel, quenched/tempered	P355QL1	1.8868	QT	0	150	1.2	
62	plate and strip	EN 10028-6	fine grain steel, quenched/tempered	P355QL2	1.8869	QT	0	150	1.2	
63	plate and strip	EN 10028-6	fine grain steel, quenched/tempered	P460Q	1.8870	QT	0	150	3.1	
64	plate and strip	EN 10028-6	fine grain steel, quenched/tempered	P460QH	1.8871	QT	0	150	3.1	
65	plate and strip	EN 10028-6	fine grain steel, quenched/tempered	P460QL1	1.8872	QT	0	150	3.1	
66	plate and strip	EN 10028-6	fine grain steel, quenched/tempered	P460QL2	1.8864	QT	0	150	3.1	
67	plate and strip	EN 10028-6	fine grain steel, quenched/tempered	P500Q	1.8873	QT	0	150	3.1	
68	plate and strip	EN 10028-6	fine grain steel, quenched/tempered	P500QH	1.8874	QT	0	150	3.1	
69	plate and strip	EN 10028-6	fine grain steel, quenched/tempered	P500QL1	1.8875	QT	0	150	3.1	
70	plate and strip	EN 10028-6	fine grain steel, quenched/tempered	P500QL2	1.8865	QT	0	150	3.1	
71	plate and strip	EN 10028-6	fine grain steel, quenched/tempered	P690Q	1.8879	QT	0	150	3.1	
72	plate and strip	EN 10028-6	fine grain steel, quenched/tempered	P690QH	1.8880	QT	0	150	3.1	
73	plate and strip	EN 10028-6	fine grain steel, quenched/tempered	P690QL1	1.8881	QT	0	150	3.1	
74	plate and strip	EN 10028-6	fine grain steel, quenched/tempered	P690QL2	1.8888	QT	0	150	3.1	

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
75	plate and strip	EN 10028-7	stainless steel, austenitic	X2CrNiN18-7	1.4318	AT	0	75	8.1	
76	plate and strip	EN 10028-7	stainless steel, austenitic	X2CrNi18-9	1.4307	AT	0	75	8.1	
77	plate and strip	EN 10028-7	stainless steel, austenitic	X2CrNi19-11	1.4306	AT	0	75	8.1	
78	plate and strip	EN 10028-7	stainless steel, austenitic	X2CrNiN18-10	1.4311	AT	0	75	8.1	
79	plate and strip	EN 10028-7	stainless steel, austenitic	X5CrNi18-10	1.4301	AT	0	75	8.1	
80	plate and strip	EN 10028-7	stainless steel, austenitic	X5CrNiN19-9	1.4315	AT	0	75	8.1	
81	plate and strip	EN 10028-7	stainless steel, austenitic	X6CrNi18-10	1.4948	AT	0	75	8.1	
82	plate and strip	EN 10028-7	stainless steel, austenitic	X6CrNi23-13	1.4950	AT	0	75	8.2	
83	plate and strip	EN 10028-7	stainless steel, austenitic	X6CrNi25-20	1.4951	AT	0	75	8.2	
84	plate and strip	EN 10028-7	stainless steel, austenitic	X6CrNiTi18-10	1.4541	AT	0	75	8.1	
85	plate and strip	EN 10028-7	stainless steel, austenitic	X6CrNiTiB18-10	1.4941	AT	0	75	8.1	
86	plate and strip	EN 10028-7	stainless steel, austenitic	X2CrNiMo17-12-2	1.4404	AT	0	75	8.1	
87	plate and strip	EN 10028-7	stainless steel, austenitic	X2CrNiMoN17-12-2	1.4406	AT	0	75	8.1	
88	plate and strip	EN 10028-7	stainless steel, austenitic	X5CrNiMo17-12-2	1.4401	AT	0	75	8.1	
89	plate and strip	EN 10028-7	stainless steel, austenitic	X6CrNiMoTi17-12-2	1.4571	AT	0	75	8.1	
90	plate and strip	EN 10028-7	stainless steel, austenitic	X2CrNiMo17-12-3	1.4432	AT	0	75	8.1	
91	plate and strip	EN 10028-7	stainless steel, austenitic	X2CrNiMo18-14-3	1.4435	AT	0	75	8.1	
92	plate and strip	EN 10028-7	stainless steel, austenitic	X2CrNiMoN17-13-5	1.4439	AT	0	75	8.1	
93	plate and strip	EN 10028-7	stainless steel, austenitic	X1NiCrMoCu25-20-5	1.4539	AT	0	75	8.2	
94	plate and strip	EN 10028-7	stainless steel, austenitic	X5NiCrAlTi31-20	1.4958	AT	0	75	8.2	

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
95	plate and strip	EN 10028-7	stainless steel, austenitic	X5NiCrAlTi31-20+RA	1.4958+RA	AT+RA	0	75	8.2	
96	plate and strip	EN 10028-7	stainless steel, austenitic	X8NiCrAlTi32-21	1.4959	AT	0	75	8.2	
97	plate and strip	EN 10028-7	stainless steel, austenitic	X3CrNiMoBN17-13-3	1.4910	AT	0	75	8.2	
98	plate and strip	EN 10028-7	stainless steel, austenitic, special	X1CrNi25-21	1.4335	AT	0	75	8.2	
99	plate and strip	EN 10028-7	stainless steel, austenitic, special	X6CrNiNb18-10	1.4550	AT	0	75	8.1	
100	plate and strip	EN 10028-7	stainless steel, austenitic, special	X8CrNiNb16-13	1.4961	AT	0	75	8.1	
101	plate and strip	EN 10028-7	stainless steel, austenitic, special	X1CrNiMoN25-22-2	1.4466	AT	0	75	8.2	
102	plate and strip	EN 10028-7	stainless steel, austenitic, special	X6CrNiMoNb17-12-2	1.4580	AT	0	75	8.1	
103	plate and strip	EN 10028-7	stainless steel, austenitic, special	X2CrNiMoN17-13-3	1.4429	AT	0	75	8.1	
104	plate and strip	EN 10028-7	stainless steel, austenitic, special	X3CrNiMoN17-13-3	1.4436	AT	0	75	8.1	
105	plate and strip	EN 10028-7	stainless steel, austenitic, special	X2CrNiMoN18-12-4	1.4434	AT	0	75	8.1	
106	plate and strip	EN 10028-7	stainless steel, austenitic, special	X2CrNiMo18-15-4	1.4438	AT	0	75	8.1	
107	plate and strip	EN 10028-7	stainless steel, austenitic, special	X1NiCrMoCu31-27-4	1.4563	AT	0	75	8.2	
108	plate and strip	EN 10028-7	stainless steel, austenitic, special	X1CrNiMoCuN25-25-5	1.4537	AT	0	75	8.2	
109	plate and strip	EN 10028-7	stainless steel, austenitic, special	X1CrNiMoCuN20-18-7	1.4547	AT	0	75	8.2	
110	plate and strip	EN 10028-7	stainless steel, austenitic, special	X1NiCrMoCuN25-20-7	1.4529	AT	0	75	8.2	
111	plate and strip	EN 10028-7	stainless steel, austenitic-ferritic	X2CrNiN23-4	1.4362	AT	0	75	10.1	c
112	plate and strip	EN 10028-7	stainless steel, austenitic-ferritic	X2CrNiMoN22-5-3	1.4462	AT	0	75	10.1	c
113	plate and strip	EN 10028-7	stain, steel, austenitic-ferritic, special	X2CrNiMoCuN25-6-3	1.4507	AT	0	75	10.2	c
114	plate and strip	EN 10028-7	stain, steel, austenitic-ferritic, special	X2CrNiMoN25-7-4	1.4410	AT	0	75	10.2	c
115	plate and strip	EN 10028-7	stain, steel, austenitic-ferritic, special	X2CrNiMoCuWN25-7-4	1.4501	AT	0	75	10.2	c

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
116	bar	EN 10272	stainless steel, martensitic	X4CrNiMo16-5-1	1.4418	QT760	0	160	7.2	[e]
117	bar	EN 10272	stainless steel, austenitic	X2CrNi18-9	1.4307	AT	0	250	8.1	
118	bar	EN 10272	stainless steel, austenitic	X2CrNi19-11	1.4306	AT	0	250	8.1	
119	bar	EN 10272	stainless steel, austenitic	X2CrNiN18-10	1.4311	AT	0	250	8.1	
120	bar	EN 10272	stainless steel, austenitic	X5CrNi18-10	1.4301	AT	0	250	8.1	
121	bar	EN 10272	stainless steel, austenitic	X6CrNiTi18-10	1.4541	AT	0	250	8.1	
122	bar	EN 10272	stainless steel, austenitic	X2CrNiMo17-12-2	1.4404	AT	0	250	8.1	
123	bar	EN 10272	stainless steel, austenitic	X2CrNiMoN17-11-2	1.4406	AT	0	250	8.1	
124	bar	EN 10272	stainless steel, austenitic	X5CrNiMo17-12-2	1.4401	AT	0	250	8.1	
125	bar	EN 10272	stainless steel, austenitic	X6CrNiMoTi17-12-2	1.4571	AT	0	250	8.1	
126	bar	EN 10272	stainless steel, austenitic	X2CrNiMo17-12-3	1.4432	AT	0	250	8.1	
127	bar	EN 10272	stainless steel, austenitic	X2CrNiMo18-14-3	1.4435	AT	0	250	8.1	
128	bar	EN 10272	stainless steel, austenitic	X2CrNiMo17-13-5	1.4439	AT	0	250	8.1	
129	bar	EN 10272	stainless steel, austenitic	X1NiCrMoCu25-20-5	1.4539	AT	0	250	8.2	
130	bar	EN 10272	stainless steel, austenitic	X6CrNiNb18-10	1.4550	AT	0	250	8.1	
131	bar	EN 10272	stainless steel, austenitic	X6CrNiMoNb17-12-2	1.4580	AT	0	250	8.1	
132	bar	EN 10272	stainless steel, austenitic	X2CrNiMoN17-13-3	1.4429	AT	0	250	8.1	
133	bar	EN 10272	stainless steel, austenitic	X3CrNiMo17-13-3	1.4436	AT	0	250	8.1	
134	bar	EN 10272	stainless steel, austenitic	X1NiCrMoCu31-27-4	1.4563	AT	0	250	8.2	
135	bar	EN 10272	stainless steel, austenitic	X1CrNiMoCuN20-18-7	1.4547	AT	0	250	8.2	

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
136	bar	EN 10272	stainless steel, austenitic	X1NiCrMoCuN25-20-7	1.4529	AT	0	250	8.2	
137	bar	EN 10272	stainless steel, austenitic-ferritic	X2CrNiMoN22-5-3	1.4462	AT	0	160	10.1	c
138	bar	EN 10272	stainless steel, austenitic-ferritic	X2CrNiN23-4	1.4362	AT	0	160	10.1	c
139	bar	EN 10272	stainless steel, austenitic-ferritic	X2CrNiMoCuN25-6-3	1.4507	AT	0	160	10.2	c
140	bar	EN 10272	stainless steel, austenitic-ferritic	X2CrNiMoN25-7-4	1.4410	AT	0	160	10.2	c
141	bar	EN 10272	stainless steel, austenitic-ferritic	X2CrNiMoCuWN25-7-4	1.4501	AT	0	160	10.2	c
142	bar	EN 10273	elevated temperature properties	P235GH	1.0345	N	0	150	1.1	
143	bar	EN 10273	elevated temperature properties	P250GH	1.0460	N	0	150	1.1	
144	bar	EN 10273	elevated temperature properties	P265GH	1.0425	N	0	150	1.1	
145	bar	EN 10273	elevated temperature properties	P295GH	1.0481	N	0	150	1.2	
146	bar	EN 10273	elevated temperature properties	P355GH	1.0473	N	0	150	1.2	
147	bar	EN 10273	elevated temperature properties	P275NH	1.0487	N	0	150	1.1	
148	bar	EN 10273	elevated temperature properties	P355NH	1.0565	N	0	150	1.2	
149	bar	EN 10273	elevated temperature properties	P460NH	1.8935	N	0	150	1.3	
150	bar	EN 10273	elevated temperature properties	P355QH	1.8867	QT	0	150	1.2	
151	bar	EN 10273	elevated temperature properties	P460QH	1.8871	QT	0	150	3.1	
152	bar	EN 10273	elevated temperature properties	P500QH	1.8874	QT	0	150	3.1	

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
153	bar	EN 10273	elevated temperature properties	P690QH	1.8880	QT	0	150	3.1	
154	bar	EN 10273	elevated temperature properties	16Mo3	1.5415	N	0	150	1.2	e
155	Bar	EN 10273	elevated temperature properties	13CrMo4-5	1.7335	NT	0	16	5.1	
156	bar	EN 10273	elevated temperature properties	13CrMo4-5	1.7335	NT, QA, QL	16	150	5.1	
157	bar	EN 10273	elevated temperature properties	10CrMo9-10	1.7380	NT	0	60	5.2	
158	bar	EN 10273	elevated temperature properties	10CrMo9-10	1.7380	NT, QA, QL	60	150	5.2	
159	bar	EN 10273	elevated temperature properties	11CrMo9-10	1.7383	NT, QA, QL	0	60	5.2	
160	bar	EN 10273	elevated temperature properties	11CrMo9-10	1.7383	QL	60	100	5.2	
161	fastener	EN 10269	elevated temperature properties	C35E	1.1181	N	0	60	—	d
162	fastener	EN 10269	elevated temperature properties	C35E	1.1181	QT	0	150	—	d
163	fastener	EN 10269	elevated temperature properties	C45E	1.1191	N	0	60	—	d
164	fastener	EN 10269	elevated temperature properties	C45E	1.1191	QT	0	150	—	d
165	fastener	EN 10269	elevated temperature properties	35B2	1.5511	QT	0	150	—	d
166	fastener	EN 10269	elevated and low temperature properties	20Mn5	1.1133	N	0	150	—	d
167	fastener	EN 10269	elevated and low temperature properties	25CrMo4	1.7218	QT	0	150	—	d
168	fastener	EN 10269	elevated and low temperature properties	42CrMo4	1.7225	QT	0	60	—	d
169	fastener	EN 10269	elevated temperature properties	42CrMo5-6	1.7233	QT	0	150	—	d
170	fastener	EN 10269	elevated temperature properties	40CrMoV4-6	1.7711	QT	0	160	—	d
171	fastener	EN 10269	elevated temperature properties	21CrMoV5-7	1.7709	QT	0	160	—	d
172	fastener	EN 10269	elevated temperature properties	20CrMoVTiB4-10	1.7729	QT	0	160	—	d

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
173	fastener	EN 10269	elevated temperature properties	X15CrMo5-1	1.7390	NT, QT	0	160	—	d
174	fastener	EN 10269	elevated temperature properties	X22CrMoV12-1	1.4923	QT1, QT2	0	160	—	d
175	fastener	EN 10269	elevated temperature properties	X12CrNiMoV12-3	1.4938	QT	0	160	—	d
176	fastener	EN 10269	elevated temperature properties	X19CrMoNbVN11-1	1.4913	QT	0	160	—	d
177	fastener	EN 10269	elevated temperature properties	X2CrNi18-9	1.4307	AT	0	160	—	d
178	fastener	EN 10269	elevated and low temperature properties	X2CrNi18-9	1.4307	C700, C800	0	25	—	d
179	fastener	EN 10269	elevated and low temperature properties	X2CrNi18-9	1.4307	C700	25	35	—	d
180	fastener	EN 10269	elevated and low temperature properties	X5CrNi18-10	1.4301	AT	0	160	—	d
181	fastener	EN 10269	elevated and low temperature properties	X5CrNi18-10	1.4301	C700	0	35	—	d
182	fastener	EN 10269	elevated and low temperature properties	X4CrNi18-12	1.4303	AT	0	160	—	d
183	fastener	EN 10269	elevated and low temperature properties	X4CrNi18-12	1.4303	C700, C800	0	25	—	d
184	fastener	EN 10269	elevated and low temperature properties	X4CrNi18-12	1.4303	C700	25	35	—	d
185	fastener	EN 10269	elevated temperature properties	X2CrNiMo17-12-2	1.4404	AT	0	160	—	d
186	fastener	EN 10269	elevated and low temperature properties	X2CrNiMo17-12-2	1.4404	C700, C800	0	25	—	d
187	fastener	EN 10269	elevated and low temperature properties	X2CrNiMo17-12-2	1.4404	C 700	25	35	—	d
188	fastener	EN 10269	elevated temperature properties	X5CrNiMo17-12-2	1.4401	AT	0	160	—	d
189	fastener	EN 10269	elevated and low temperature properties	X5CrNiMo17-12-2	1.4401	C700, C800	0	25	—	d

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
190	fastener	EN 10269	elevated and low temperature properties	X5CrNiMo17-12-2	1.4401	C700	25	35	—	d
191	fastener	EN 10269	elevated and low temperature properties	X2CrNiMoN17-13-3	1.4429	AT	0	160	—	d
192	fastener	EN 10269	room temperature properties	X3CrNiCu18-9-4	1.4567	AT	0	160	—	d
193	fastener	EN 10269	room temperature properties	X3CrNiCu18-9-4	1.4567	C700	0	35	—	d
194	fastener	EN 10269	elevated and low temperature properties	X6CrNi18-10	1.4948	AT	0	160	—	d
195	fastener	EN 10269	elevated temperature properties	X10CrNiMoMnNbVB15-10-1	1.4982	AT + WW	0	100	—	d
196	fastener	EN 10269	elevated and low temperature properties	3CrNiMoBN17-13-3	1.4910	AT	0	160	—	d
197	fastener	EN 10269	elevated and low temperature properties	X6CrNiMoB17-12-2	1.4919	AT	0	160	—	d
198	fastener	EN 10269	elevated and low temperature properties	X6CrNiTiB18-10	1.4941	AT	0	160	—	d
199	fastener	EN 10269	elevated and low temperature properties	X6NiCrTiMoVB25-15-2	1.4980	AT + P	0	160	—	d
200	fastener	EN 10269	elevated temperature properties	X7CrNiMoBNb16-16	1.4986	WW + P	0	100	—	d
201	fastener	EN 10269	low temperature properties	19MnB4	1.5523	QT	0	16	—	d
202	fastener	EN 10269	low temperature properties	41NiCrMo7-3-2	1.6563	QT	0	160	—	d
203	fastener	EN 10269	low temperature properties	34CrNiMo6	1.6582	QT	0	100	—	d
204	fastener	EN 10269	low temperature properties	30CrNiMo8	1.6580	QT	0	100	—	d
205	fastener	EN 10269	low temperature properties	X12Ni5	1.5680	N, NT, QT	0	75	—	d
206	fastener	EN 10269	low temperature properties	X8Ni9	1.5662	N, NT, QT	0	75	—	d

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
207	seamless tube	EN 10216-1	room temperature properties	P195TR2	1.0108	N	0	60	1.1	
208	seamless tube	EN 10216-1	room temperature properties	P235TR2	1.0255	N	0	60	1.1	
209	seamless tube	EN 10216-1	room temperature properties	P265TR2	1.0259	N	0	60	1.1	
210	seamless tube	EN 10216-2	elevated temperature properties	P195GH	1.0348	N	0	16	1.1	
211	seamless tube	EN 10216-2	elevated temperature properties	P235GH	1.0345	N	0	60	1.1	
212	seamless tube	EN 10216-2	elevated temperature properties	P265GH	1.0425	N	0	60	1.1	
213	seamless tube	EN 10216-2	elevated temperature properties	20MnNb6	1.0471	N	0	60	1.2	
214	seamless tube	EN 10216-2	elevated temperature properties	16Mo3	1.5415	N	0	60	1.2	e
215	seamless tube	EN 10216-2	elevated temperature properties	8MoB5-4	1.5450	N	0	16	1.3	
216	seamless tube	EN 10216-2	elevated temperature properties	14MoV6-3	1.7715	NT, QT [b]	0	60	6.1	
217	seamless tube	EN 10216-2	elevated temperature properties	10CrMo5-5	1.7338	NT, QT [b]	0	60	5.1	
218	seamless tube	EN 10216-2	elevated temperature properties	13CrMo4-5	1.7335	NT, QT [b]	0	60	5.1	
219	seamless tube	EN 10216-2	elevated temperature properties	10CrMo9-10	1.7380	NT, QT [b]	0	60	5.2	
220	seamless tube	EN 10216-2	elevated temperature properties	11CrMo9-10	1.7383	QT	0	60	5.2	
221	seamless tube	EN 10216-2	elevated temperature properties	25CrMo4	1.7218	QT	0	60	5.1	a
222	seamless tube	EN 10216-2	elevated temperature properties	20CrMoV13-5-5	1.7779	QT	0	60	6.3	
223	seamless tube	EN 10216-2	elevated temperature properties	15NiCuMoNb5-6-4	1.6368	NT, QT [b]	0	80	3.1	
223-2	seamless tube	EN 10216-2	elevated temperature properties	7CrWVMoNb9-6	1.8201	NT	0	60	6.2	
223-2	seamless tube	EN 10216-2	elevated temperature properties	7CrMoVTiB10-10	1.7378	NT	0	60	6.2	
224	seamless tube	EN 10216-2	elevated temperature properties	X11CrMo5 + I [g]	1.7362 + I	I	0	100	5.3	

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
225	seamless tube	EN 10216-2	elevated temperature properties	X11CrMo5 + NT1 [g]	1.7362 + N1	NT	0	100	5.3	
226	seamless tube	EN 10216-2	elevated temperature properties	X11CrMo5 + NT2 [g]	1.7362 + N2	NT, QT [b]	0	100	5.3	
227	seamless tube	EN 10216-2	elevated temperature properties	X11CrMo9-1 + I [g]	1.7386 + I	I	0	60	5.4	
228	seamless tube	EN 10216-2	elevated temperature properties	X11CrMo9-1 + NT [g]	1.7386 + NT	NT, QT [b]	0	60	5.4	
229	seamless tube	EN 10216-2	elevated temperature properties	X10CrMoVNb9-1	1.4903	NT, QT [b]	0	100	6.4	
229-2	seamless tube	EN 10216-2	elevated temperature properties	X10CrWMoVNb9-2	1.4901	NT	0	100	6.4	
229-2	seamless tube	EN 10216-2	elevated temperature properties	X11CrMoWVNb9-1-1	1.4905	NT	0	100	6.4	
230	seamless tube	EN 10216-2	elevated temperature properties	X20CrMoV11-1	1.4922	NT, QT [b]	0	100	6.4	
231	seamless tube	EN 10216-3	fine grain steel	P275NL1	1.0488	N	0	100	1.1	
232	seamless tube	EN 10216-3	fine grain steel	P275NL2	1.1104	N	0	100	1.1	
233	seamless tube	EN 10216-3	fine grain steel	P355N	1.0562	N	0	100	1.2	
234	seamless tube	EN 10216-3	fine grain steel	P355NH	1.0565	N	0	100	1.2	
235	seamless tube	EN 10216-3	fine grain steel	P355NL1	1.0566	N	0	100	1.2	
236	seamless tube	EN 10216-3	fine grain steel	P355NL2	1.1106	N	0	100	1.2	
237	seamless tube	EN 10216-3	fine grain steel	P460N	1.8905	N [b]	0	100	1.3	
238	seamless tube	EN 10216-3	fine grain steel	P460NH	1.8935	N [b]	0	100	1.3	
239	seamless tube	EN 10216-3	fine grain steel	P460NL1	1.8915	N [b]	0	100	1.3	
240	seamless tube	EN 10216-3	fine grain steel	P460NL2	1.8918	N [b]	0	100	1.1	
241	seamless tube	EN 10216-3	fine grain steel	P620Q	1.8876	Q	0	65	3.1	
242	seamless tube	EN 10216-3	fine grain steel	P620QH	1.8877	Q	0	65	3.1	
243	seamless tube	EN 10216-3	fine grain steel	P620QL	1.8890	Q	0	65	3.1	
244	seamless tube	EN 10216-3	fine grain steel	P690Q	1.8879	Q	0	100	3.1	
245	seamless tube	EN 10216-3	fine grain steel	P690QH	1.8880	Q	0	100	3.1	

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
246	seamless tube	EN 10216-3	fine grain steel	P690QL1	1.8881	Q	0	100	3.1	
247	seamless tube	EN 10216-3	fine grain steel	P690QL2	1.8888	Q	0	100	3.1	
248	seamless tube	EN 10216-4	low temperature properties	P215NL	1.0451	N	0	10	1.1	
249	seamless tube	EN 10216-4	low temperature properties	P255QL	1.0452	QT	0	40	1.1	e
250	seamless tube	EN 10216-4	low temperature properties	P265NL	1.0453	N	0	25	1.1	
251	seamless tube	EN 10216-4	low temperature properties	26CrMo4-2	1.7219	QT	0	40	5.1	a
252	seamless tube	EN 10216-4	low temperature properties	11MnNi5-3	1.6212	N, NT [b]	0	40	9.1	
253	seamless tube	EN 10216-4	low temperature properties	13MnNi6-3	1.6217	N, NT [b]	0	40	9.1	
254	seamless tube	EN 10216-4	low temperature properties	12Ni14	1.5637	NT	0	40	9.2	
255	seamless tube	EN 10216-4	low temperature properties	12Ni14 + QT	1.5637	QT	0	40	9.2	
256	seamless tube	EN 10216-4	low temperature properties	X12Ni5	1.5680	N	0	40	9.2	
257	seamless tube	EN 10216-4	low temperature properties	X12Ni5 + QT	1.5680	QT	0	40	9.2	
258	seamless tube	EN 10216-4	low temperature properties	X10Ni9	1.5682	N, NT	0	40	9.3	
259	seamless tube	EN 10216-4	low temperature properties	X10Ni9 + QT	1.5682	QT [b]	0	40	9.3	
260	seamless tube	EN 10216-5	stainless steel, austenitic	X2CrNi18-9	1.4307	AT	0	60	8.1	
261	seamless tube	EN 10216-5	stainless steel, austenitic	X2CrNi19-11	1.4306	AT	0	60	8.1	
262	seamless tube	EN 10216-5	stainless steel, austenitic	X2CrNiN18-10	1.4311	AT	0	60	8.1	
263	seamless tube	EN 10216-5	stainless steel, austenitic	X5CrNi18-10	1.4301	AT	0	60	8.1	
264	seamless tube	EN 10216-5	stainless steel, austenitic	X6CrNiTI18-10	1.4541	AT	0	60	8.1	
265	seamless tube	EN 10216-5	stainless steel, austenitic	X6CrNiNb18-10	1.4550	AT	0	60	8.1	
266	seamless tube	EN 10216-5	stainless steel, austenitic	X2CrNiMo18-14-3	1.4435	AT	0	60	8.1	
267	seamless tube	EN 10216-5	stainless steel, austenitic	X2CrNiMo17-12-2	1.4404	AT	0	60	8.1	

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
268	seamless tube	EN 10216-5	stainless steel, austenitic	X5CrNiMo17-12-2	1.4401	AT	0	60	8.1	
269	seamless tube	EN 10216-5	stainless steel, austenitic	X1CrNiMoN25-22-2	1.4466	AT	0	60	8.2	
270	seamless tube	EN 10216-5	stainless steel, austenitic	X6CrNiMoTi17-12-2	1.4571	AT	0	60	8.1	
271	seamless tube	EN 10216-5	stainless steel, austenitic	X6CrNiMoNb17-12-2	1.4580	AT	0	60	8.1	
272	seamless tube	EN 10216-5	stainless steel, austenitic	X2CrNiMoN17-13-3	1.4429	AT	0	60	8.1	
273	seamless tube	EN 10216-5	stainless steel, austenitic	X3CrNiMo17-13-3	1.4436	AT	0	60	8.1	
274	seamless tube	EN 10216-5	stainless steel, austenitic	X1CrNi25-21	1.4335	AT	0	60	8.2	
275	seamless tube	EN 10216-5	stainless steel, austenitic	X2CrNiMoN17-13-5	1.4439	AT	0	60	8.1	
276	seamless tube	EN 10216-5	stainless steel, austenitic	X1NiCrMoCu31-27-4	1.4563	AT	0	60	8.2	
277	seamless tube	EN 10216-5	stainless steel, austenitic	X1NiCrMoCu25-20-5	1.4539	AT	0	60	8.2	
278	seamless tube	EN 10216-5	stainless steel, austenitic	X1CrNiMoCuN20-18-7	1.4547	AT	0	60	8.2	
279	seamless tube	EN 10216-5	stainless steel, austenitic	X1NiCrMoCuN25-20-7	1.4529	AT	0	60	8.2	
280	seamless tube	EN 10216-5	stainless steel, austenitic	X2NiCrAlTi32-20	1.4558	AT	0	60	8.2	
281	seamless tube	EN 10216-5	stainless steel, austenitic	X6CrNi18-10	1.4948	AT	0	50	8.1	
282	seamless tube	EN 10216-5	stainless steel, austenitic	X7CrNiTi18-10	1.4940	AT	0	50	8.1	
283	seamless tube	EN 10216-5	stainless steel, austenitic	X7CrNiNb18-10	1.4912	AT	0	50	8.1	
284	seamless tube	EN 10216-5	stainless steel, austenitic	X7CrNiTiB18-10	1.4941	AT	0	50	8.1	
285	seamless tube	EN 10216-5	stainless steel, austenitic	X6CrNiMo17-13-2	1.4918	AT	0	50	8.1	
286	seamless tube	EN 10216-5	stainless steel, austenitic	X5NiCrAlTi31-20	1.4958	AT	0	50	8.2	
287	seamless tube	EN 10216-5	stainless steel, austenitic	X8NiCrAlTi32-21	1.4959	AT	0	50	8.2	
288	seamless tube	EN 10216-5	stainless steel, austenitic	X3CrNiMoNB17-13-3	1.4910	AT	0	50	8.1	
289	seamless tube	EN 10216-5	stainless steel, austenitic	X8CrNiNb16-13	1.4961	AT	0	50	8.1	
290	seamless tube	EN 10216-5	stainless steel, austenitic	X8CrNiMoVNb16-13	1.4988	AT	0	50	8.1	
291	seamless tube	EN 10216-5	stainless steel, austenitic	X8CrNiMoNb16-16	1.4981	AT	0	50	8.1	

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
292	seamless tube	EN 10216-5	stainless steel, austenitic	X10CrNiMoMnNbVB15-10-1	1.4982	AT	0	50	8.1	
293	seamless tube	EN 10216-5	stainless steel, austenitic-ferritic	X2CrNiMoN22-5-3	1.4462	AT	0	30	10.1	c
294	seamless tube	EN 10216-5	stainless steel, austenitic-ferritic	X2CrNiMoSi18-5-3	1.4424	AT	0	30	10.1	c
295	seamless tube	EN 10216-5	stainless steel, austenitic-ferritic	X2CrNiN23-4	1.4362	AT	0	30	10.1	c
296	seamless tube	EN 10216-5	stainless steel, austenitic-ferritic	X2CrNiMoN25-7-4	1.4410	AT	0	30	10.2	c
297	seamless tube	EN 10216-5	stainless steel, austenitic-ferritic	X2CrNiMoCuN25-6-3	1.4507	AT	0	30	10.2	c
298	seamless tube	EN 10216-5	stainless steel, austenitic-ferritic	X2CrNiMoCuWN25-7-4	1.4501	AT	0	30	10.2	c
299	welded tube	EN 10217-1	room temperature properties	P195TR2	1.0108	N	0	40	1.1	
300	welded tube	EN 10217-1	room temperature properties	P235TR2	1.0255	N	0	40	1.1	
301	welded tube	EN 10217-1	room temperature properties	P265TR2	1.0259	N	0	40	1.1	
302	welded tube	EN 10217-2	elevated temperature properties	P195GH	1.0348	N	0	16	1.1	
303	welded tube	EN 10217-2	elevated temperature properties	P235GH	1.0345	N	0	16	1.1	
304	welded tube	EN 10217-2	elevated temperature properties	P265GH	1.0425	N	0	16	1.1	
305	welded tube	EN 10217-2	elevated temperature properties	16Mo3	1.5415	N	0	16	1.2	e
306	welded tube	EN 10217-3	fine grain steel	P275NL1	1.0488	N	0	40	1.1	
307	welded tube	EN 10217-3	fine grain steel	P275NL2	1.1104	N	0	40	1.1	
308	welded tube	EN 10217-3	fine grain steel	P355N	1.0562	N	0	40	1.2	
309	welded tube	EN 10217-3	fine grain steel	P355NH	1.0565	N	0	40	1.2	

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
310	welded tube	EN 10217-3	fine grain steel	P355NL1	1.0566	N	0	40	1.2	
311	welded tube	EN 10217-3	fine grain steel	P355NL2	1.1106	N	0	40	1.2	
312	welded tube	EN 10217-3	fine grain steel	P460N	1.8905	N	0	40	1.3	
313	welded tube	EN 10217-3	fine grain steel	P460NH	1.8935	N	0	40	1.3	
314	welded tube	EN 10217-3	fine grain steel	P460NL1	1.8915	N	0	40	1.3	
315	welded tube	EN 10217-3	fine grain steel	P460NL2	1.8918	N	0	40	1.3	
316	welded tube	EN 10217-4	low temperature properties	P215NL	1.0451	N	0	10	1.1	
317	welded tube	EN 10217-4	low temperature properties	P265NL	1.0453	N	0	16	1.1	
318	welded tube	EN 10217-5	elevated temperature properties	P235GH	1.0345	N	0	40	1.1	
319	welded tube	EN 10217-5	elevated temperature properties	P265GH	1.0425	N	0	40	1.1	
320	welded tube	EN 10217-5	elevated temperature properties	16Mo3	1.5415	N	0	40	1.2	[e]
321	welded tube	EN 10217-6	low temperature properties	P215NL	1.0451	N	0	10	1.1	
322	welded tube	EN 10217-6	low temperature properties	P265NL	1.0453	N	0	25	1.1	
323	welded tube	EN 10217-7	stainless steel, austenitic	X2CrNi18-9	1.4307	AT	0	60	8.1	
324	welded tube	EN 10217-7	stainless steel, austenitic	X2CrNi19-11	1.4306	AT	0	60	8.1	
325	welded tube	EN 10217-7	stainless steel, austenitic	X2CrNiN18-10	1.4311	AT	0	60	8.1	
326	welded tube	EN 10217-7	stainless steel, austenitic	X5CrNi18-10	1.4301	AT	0	60	8.1	
327	welded tube	EN 10217-7	stainless steel, austenitic	X6CrNiTi18-10	1.4541	AT	0	60	8.1	

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
328	welded tube	EN 10217-7	stainless steel, austenitic	X6CrNiNb18-10	1.4550	AT	0	60	8.1	
329	welded tube	EN 10217-7	stainless steel, austenitic	X2CrNiMo17-12-2	1.4404	AT	0	60	8.1	
330	welded tube	EN 10217-7	stainless steel, austenitic	X5CrNiMo17-12-2	1.4401	AT	0	60	8.1	
331	welded tube	EN 10217-7	stainless steel, austenitic	X6CrNiMoTi17-12-2	1.4571	AT	0	60	8.1	
332	welded tube	EN 10217-7	stainless steel, austenitic	X2CrNiMo17-12-3	1.4432	AT	0	60	8.1	
333	welded tube	EN 10217-7	stainless steel, austenitic	X2CrNiMoN17-13-3	1.4429	AT	0	60	8.1	
334	welded tube	EN 10217-7	stainless steel, austenitic	X3CrNiMo17-13-3	1.4436	AT	0	60	8.1	
335	welded tube	EN 10217-7	stainless steel, austenitic	X2CrNiMo18-14-3	1.4435	AT	0	60	8.1	
336	welded tube	EN 10217-7	stainless steel, austenitic	X2CrNiMoN17-13-5	1.4439	AT	0	60	8.1	
337	welded tube	EN 10217-7	stainless steel, austenitic	X2CrNiMo18-15-4	1.4438	AT	0	60	8.1	
338	welded tube	EN 10217-7	stainless steel, austenitic	X1NiCrMoCu31-27-7	1.4563	AT	0	60	8.2	
339	welded tube	EN 10217-7	stainless steel, austenitic	X1NiCrMoCu25-20-5	1.4539	AT	0	60	8.2	
340	welded tube	EN 10217-7	stainless steel, austenitic	X1CrNiMoCuN20-18-7	1.4547	AT	0	60	8.2	
341	welded tube	EN 10217-7	stainless steel, austenitic	X1NiCrMoCuN25-20-7	1.4529	AT	0	60	8.2	
342	welded tube	EN 10217-7	stainless steel, austenitic-ferritic	X2CrNiMoN22-5-3	1.4462	AT	0	30	10.1	c
343	welded tube	EN 10217-7	stainless steel, austenitic-ferritic	X2CrNiN23-4	1.4362	AT	0	30	10.1	c
344	welded tube	EN 10217-7	stainless steel, austenitic-ferritic	X2CrNiMoN25-7-4	1.4410	AT	0	30	10.2	c
345	welded tube	EN 10217-7	stainless steel, austenitic-ferritic	X2CrNiMoCuWN25-7-4	1.4501	AT	0	30	10.2	c

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
346	forging	EN 10222-2	elevated temperature properties	P245GH	1.0352	A	0	35	1.1	
347	forging	EN 10222-2	elevated temperature properties	P245GH	1.0352	N, NT, QT	35	160	1.1	
348	forging	EN 10222-2	elevated temperature properties	P280GH	1.0426	N	0	35	1.2	
349	forging	EN 10222-2	elevated temperature properties	P280GH	1.0426	NT, QT	35	160	1.2	
350	forging	EN 10222-2	elevated temperature properties	P305GH	1.0436	N	0	35	1.2	
351	forging	EN 10222-2	elevated temperature properties	P305GH	1.0436	NT	35	160	1.2	
352	forging	EN 10222-2	elevated temperature properties	P305GH	1.0436	QT	0	70	1.2	e
353	forging	EN 10222-2	elevated temperature properties	16Mo3	1.5415	N	0	35	1.2	e
354	forging	EN 10222-2	elevated temperature properties	16Mo3	1.5415	QT	35	500	1.2	e
355	forging	EN 10222-2	elevated temperature properties	13CrMo4-5	1.7335	NT	0	70	5.1	
356	forging	EN 10222-2	elevated temperature properties	13CrMo4-5	1.7335	NT, QT	70	500	5.1	
357	forging	EN 10222-2	elevated temperature properties	15MnMoV4-5	1.5402	NT, QT	0	250	1.2	
358	forging	EN 10222-2	elevated temperature properties	18MnMoNi5-5	1.6308	QT	0	200	4.1	
359	forging	EN 10222-2	elevated temperature properties	14MoV6-3	1.7715	NT, QT	0	500	6.1	
360	forging	EN 10222-2	elevated temperature properties	15MnCrMoNiV5-3	1.6920	NT, QT	0	100	4.1	
361	forging	EN 10222-2	elevated temperature properties	11CrMo9-10	1.7383	NT	0	200	5.2	
362	forging	EN 10222-2	elevated temperature properties	11CrMo9-10	1.7383	NT, QT	200	500	5.2	
363	forging	EN 10222-2	elevated temperature properties	X16CrMo5-1	1.7366	A	0	300	5.3	
364	forging	EN 10222-2	elevated temperature properties	X16CrMo5-1	1.7366	NT	0	300	5.3	

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
365	forging	EN 10222-2	elevated temperature properties	X10CrMoVNb9-1	1.4903	NT	0	130	6.4	
366	forging	EN 10222-2	elevated temperature properties	X20CrMoV11-1	1.4922	QT	0	330	6.4	
367	forging	EN 10222-3	low temperature properties	13MnNi6-3	1.6217	NT	0	70	9.1	
368	forging	EN 10222-3	low temperature properties	15NiMn6	1.6228	N	0	35	9.1	
369	forging	EN 10222-3	low temperature properties	15NiMn6	1.6228	NT, QT	35	50	9.1	
370	forging	EN 10222-3	low temperature properties	12Ni14	1.5637	N	0	35	9.2	
371	forging	EN 10222-3	low temperature properties	12Ni14	1.5637	NT	35	50	9.2	
372	forging	EN 10222-3	low temperature properties	12Ni14	1.5637	QT	50	70	9.2	
373	forging	EN 10222-3	low temperature properties	X12Ni5	1.5680	N	0	35	9.2	
374	forging	EN 10222-3	low temperature properties	X12Ni5	1.5680	NT, QT	35	50	9.2	
375	forging	EN 10222-3	low temperature properties	X8Ni9	1.5662	N, NT	0	50	9.3	
376	forging	EN 10222-3	low temperature properties	X8Ni9	1.5662	QT	50	70	9.3	
377	forging	EN 10222-4	fine grain steel, high proof strength	P285NH	1.0477	N	0	70	1.2	
378	forging	EN 10222-4	fine grain steel, high proof strength	P285QH	1.0478	QT	70	400	1.2	e
379	forging	EN 10222-4	fine grain steel, high proof strength	P355NH	1.0565	N	0	70	1.2	
380	forging	EN 10222-4	fine grain steel, high proof strength	P355QH	1.0571	QT	70	400	1.2	e
381	forging	EN 10222-4	fine grain steel, high proof strength	P420NH	1.8932	N	0	70	1.3	
382	forging	EN 10222-4	fine grain steel, high proof strength	P420QH	1.8936	QT	70	400	3.1	
383	forging	EN 10222-5	stainless steel, martensitic	X3CrNi13-4	1.4313	QT+T	0	350	7.2	e
384	forging	EN 10222-5	stainless steel, martensitic	X3CrNi13-4	1.4313	QT	0	250	7.2	e

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
385	forging	EN 10222-5	stainless steel, austenitic	X2CrNi18-9	1.4307	AT	0	250	8.1	
386	forging	EN 10222-5	stainless steel, austenitic	X2CrNiN18-10	1.4311	AT	0	250	8.1	
387	forging	EN 10222-5	stainless steel, austenitic	X5CrNi18-10	1.4301	AT	0	250	8.1	
388	forging	EN 10222-5	stainless steel, austenitic	X6CrNiTi18-10	1.4541	AT	0	450	8.1	
389	forging	EN 10222-5	stainless steel, austenitic	X6CrNiNb18-10	1.4550	AT	0	450	8.1	
390	forging	EN 10222-5	stainless steel, austenitic	X6CrNi18-10	1.4948	AT	0	250	8.1	
391	forging	EN 10222-5	stainless steel, austenitic	X6CrNiTiB18-10	1.4941	AT	0	450	8.1	
392	forging	EN 10222-5	stainless steel, austenitic	X7CrNiNb18-10	1.4912	AT	0	450	8.1	
393	forging	EN 10222-5	stainless steel, austenitic	X2CrNiMo17-12-2	1.4404	AT	0	250	8.1	
394	forging	EN 10222-5	stainless steel, austenitic	X2CrNiMoN17-11-2	1.4406	AT	0	160	8.1	
395	forging	EN 10222-5	stainless steel, austenitic	X5CrNiMo17-12-2	1.4401	AT	0	250	8.1	
396	forging	EN 10222-5	stainless steel, austenitic	X6CrNiMoTi17-12-2	1.4571	AT	0	450	8.1	
397	forging	EN 10222-5	stainless steel, austenitic	X2CrNiMo17-12-3	1.4432	AT	0	250	8.1	
398	forging	EN 10222-5	stainless steel, austenitic	X2CrNiMoN17-13-3	1.4429	AT	0	160	8.1	
399	forging	EN 10222-5	stainless steel, austenitic	X3CrNiMo17-13-3	1.4436	AT	0	250	8.1	
400	forging	EN 10222-5	stainless steel, austenitic	X2CrNiMo18-14-3	1.4435	AT	0	75	8.1	
401	forging	EN 10222-5	stainless steel, austenitic	X3CrNiMoN17-13-3	1.4910	AT	0	75	8.1	
402	forging	EN 10222-5	stainless steel, austenitic	X2CrNiCu19-10	1.4650	AT	0	450	8.1	
403	forging	EN 10222-5	stainless steel, austenitic	X3CrNiMo18-12-3	1.4449	AT	0	450	8.1	
404	forging	EN 10222-5	stainless steel, austenitic-ferritic	X2CrNiMoN22-5-3	1.4462	AT	0	350	10.1	[c]

Table E.2-1 (*continued*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
405	forging	EN 10222-5	stainless steel, austenitic-ferritic	X2CrNiMoN25-7-4	1.4410	AT	0	160	10.2	c
406	casting	EN 10213	elevated temperature properties	GP240GR	1.0621	N	0	100	1.1	h
407	casting	EN 10213	elevated temperature properties	GP240GH	1.0619	N, QT	0	100	1.1	e
408	casting	EN 10213	elevated temperature properties	GP280GH	1.0625	N, QT	0	100	1.2	e
409	casting	EN 10213	elevated temperature properties	G20Mo5	1.5419	QT	0	100	3.1	
410	casting	EN 10213	elevated temperature properties	G17CrMo5-5	1.7357	QT	0	100	5.1	
411	casting	EN 10213	elevated temperature properties	G17CrMo9-10	1.7379	QT	0	150	5.2	
412	casting	EN 10213	elevated temperature properties	G12MoCrV5-2	1.7720	QT	0	100	6.1	
413	casting	EN 10213	elevated temperature properties	G17CrMoV5-10	1.7706	QT	0	150	6.2	
414	casting	EN10213	elevated temperature properties	GX4CrNi 13-4	1.4317	QT	0	300	8.1	
415	casting	EN10213	elevated temperature properties	GX8CrNi 12	1.4107	QT	0	300	8.1	
416	casting	EN 10213	elevated temperature properties	GX15CrMo5	1.7365	QT	0	150	5.3	
417	casting	EN 10213	elevated temperature properties	GX23CrMoV12-1	1.4931	QT	0	150	6.4	
418	casting	EN 10213	low temperature properties	G17Mn5	1.1131	QT	0	50	1.1	
419	casting	EN 10213	low temperature properties	G20Mn5	1.6220	N	0	30	1.2	
420	casting	EN 10213	low temperature properties	G20Mn5	1.6220	QT	0	100	1.2	e
421	casting	EN 10213	low temperature properties	G18Mo5	1.5422	QT	0	100	1.2	e
422	casting	EN 10213	low temperature properties	G9Ni10	1.5636	QT	0	35	9.1	
423	casting	EN 10213	low temperature properties	G17NiCrMo13-6	1.6781	QT	0	200	9.2	
424	casting	EN 10213	low temperature properties	G9Ni14	1.5638	QT	0	35	9.2	
425	casting	EN 10213	low temperature properties	GX3CrNi13-4	1.6982	QT	0	300	8.1	
426	casting	EN 10213	stainless steel, austenitic	GX2CrNi19-11	1.4309	AT	0	150	8.1	

Table E.2-1 (*concluded*)

1	2	3	4	5	6	7	8		9	10
No	Product form	European Standard	Material description	Grade	Material number	Heat treatment [g]	Thickness mm		Material group to CEN ISO/TR 15608: 2013	Notes
427	casting	EN 10213	stainless steel, austenitic	GX5CrNi19-10	1.4308	AT	0	150	8.1	
428	casting	EN 10213	stainless steel, austenitic	GX5CrNiNb19-11	1.4552	AT	0	150	8.1	
429	casting	EN 10213	stainless steel, austenitic	GX2CrNiMo19-11-2	1.4409	AT	0	150	8.1	
430	casting	EN 10213	stainless steel, austenitic	GX5CrNiMo19-11-2	1.4408	AT	0	150	8.1	
431	casting	EN 10213	stainless steel, austenitic	GX5CrNiMoNb19-11-2	1.4581	AT	0	150	8.1	
432	casting	EN 10213	stainless steel, austenitic	GX2NiCrMo28-20-2	1.4458	AT	0	150	8.2	
433	casting	EN10213	stainless steel, austenitic-ferritic	GX2CrNiMoN25-7-3	1.4417	AT	0	150	10.2	c
434	casting	EN 10213	stainless steel, austenitic-ferritic	GX2CrNiMoN22-5-3	1.4470	AT	0	150	10.1	c
435	casting	EN 10213	stainless steel, austenitic-ferritic	GX2CrNiMoCuN25-6-3-3	1.4517	AT	0	150	10.2	c
436	casting	EN 10213	stainless steel, austenitic-ferritic	GX2CrNiMoN26-7-4	1.4469	AT	0	150	10.2	c

a Because of the carbon content special precautions are necessary when the material is welded.

b See EN 10216 series for details of heat treatment.

c See B.2.3, Figures B.2-9 to B.2-11.

d Welding on fasteners made of these materials is not permitted.

e Additional requirements for forming and welding should be considered on a case by case basis.

f Hot forming is not allowed for thermomechanically treated steels, see 9.3.2 of EN 13445-4:2014.

g Heat treatment conditions:

- A annealed
- AT solution annealed
- C cold worked
- I isothermally annealed
- M thermomechanically rolled
- N normalised
- NT normalised and tempered
- P precipitation hardened
- QT quenched and tempered
- RA recrystalised annealed
- WW warm worked

h steel grade deleted in EN 10213:2007.

Annex Y
(informative)

History of EN 13445-2

Y.1 Differences between EN 13445-2:2009 and EN 13445-2:2014

The 2014 edition of EN 13445-2 contains the 2009 edition of the standard and all Amendment(s) and/or correction(s) issued in the meantime.

Significant technical changes include:

— the modification of Annex B "the prevention of brittle fracture" to extend the method 2 and to adjust of calculation methods;

— the modification of the annex on the prevention of brittle fracture and methods 1 and 2. It introduces modifications on the temperature adjustment term T_s to calculate the reference design temperature values T_R.

NOTE The changes referred include the significant technical changes but is not an exhaustive list of all modifications.

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of the EU Pressure Equipment Directive 97/23/EC

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Pressure Equipment Directive 97/23/EC.

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard given in Table ZA.1 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

Table ZA.1 — Correspondence between this European Standard and Pressure Equipment Directive 97/23/EC

Clause(s)/subclause(s) of this EN	**Essential Requirements (ERs) of Pressure Equipment Directive 97/23/EC**	**Qualifying remarks/Notes**
4	2.2.3 (b), 5th indent	provision and consideration of appropriate material properties
4.1.6 and Annex B	4.1 (a)	prevention of brittle fracture
4.1.7	4.1 (d)	material suitable for intended processing procedure
4.1.1	4.2 (b)	compliance with the material specifications
4.1.5	7.5	detailed requirements on elongation after rupture for steel
4.1.6 and Annex B	7.5	detailed requirements on impact rupture energy for steel
4.2.4	2.2.3 (b), 7th indent	design properties in the creep range

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

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