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BSI Standards Publication

Unfired pressure vessels

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

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National foreword

This British Standard is the UK implementation of EN 13445-8:2014+A1:2014. It supersedes BS EN 13445-8:2014 which is withdrawn.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.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Unfired pressure vessels - Part 8: Additional requirements for pressure vessels of aluminium and aluminium alloys

Récipients sous pression non soumis à la flamme - Partie 8: Exigences complémentaires pour les récipients sous pression en aluminium et alliages d'aluminium

Unbefeuerte Druckbehälter - Teil 8: Zusätzliche Anforderungen an Druckbehälter aus Aluminium und Aluminiumlegierungen

This European Standard was approved by CEN on 19 August 2014.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

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

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

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Contents

Page

Foreword

This document (EN 13445-8:2014) 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 13445-8:2009. 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, consolidating these Amendments and including other identified corrections. . Issue 2 (2015-07) includes the corrected pages listed in Annex Y.

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.

Foreword to amendment A1

This document (EN 13445-8:2014/A1:2014) has been prepared by Technical Committee CEN/TC 54 “Unfired pressure vessels”, the secretariat of which is held by BSI.

This Amendment to the European Standard EN 13445-8:2014 shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2015, and conflicting national standards shall be withdrawn at the latest by June 2015.

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 97/23/EC.

For relationship with EU Directive 97/23/EC, see informative Annex ZA, which is an integral part of this document.

This document includes the text of the amendment itself. The corrected pages of EN 13445-8 will be published in July 2015 as Issue 2 of the standard.

This document was submitted to the Formal Vote with the reference EN 13445-8:2009/FprA1.

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 European Standard specifies requirements for unfired pressure vessels and their parts made of aluminium and aluminium alloys in addition to the general requirements for unfired pressure vessels under EN 13445:2014 Parts 1 to 5. This European Standard specifies unfired pressure vessels for loads up to 500 full cycles.

NOTE Cast materials are not included in this version. Details regarding cast materials will be subject to an amendment to or a revision of this European Standard.

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 485-2:2013, *Aluminium and aluminium alloys — Sheet, strip and plate — Part 2: Mechanical properties*

EN 573-3:2013, *Aluminium and aluminium alloys — Chemical composition and form of wrought products — Part 3: Chemical composition and form of products*

EN 586-2:1994, *Aluminium and aluminium alloys — Forgings — Part 2: Mechanical properties and additional property requirements*

EN 754-2:2013, *Aluminium and aluminium alloys — Cold drawn rod/bar and tube — Part 2: Mechanical properties*

EN 755 (all parts), *Aluminium and aluminium alloys — Extruded rod/bar, tube and profiles*

EN 764-5:2002, *Pressure Equipment — Part 5: Compliance and Inspection Documentation of Materials*

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

EN 12392:2000, *Aluminium and aluminium alloys — Wrought products — Special requirements for products intended for the production of pressure equipment*

EN 13445-1:2009, *Unfired pressure vessels — Part 1: General*

EN 13445-2:2009, *Unfired pressure vessels — Part 2: Materials*

EN 13445-3:2009, *Unfired pressure vessels — Part 3: Design*

EN 13445-4:2009, *Unfired pressure vessels — Part 4: Fabrication*

EN 13445-5:2009, *Unfired pressure vessels — Part 5: Inspection and testing*

EN ISO 3452-1:2013, *Non-destructive testing — Penetrant testing — Part 1: General principles (ISO 3452-1:2013)*

EN ISO 3834-2:2005, *Quality requirements for fusion welding of metallic materials — Part 2: Comprehensive quality requirements (ISO 3834-2:2005)*

EN ISO 3834-3:2005, *Quality requirements for fusion welding of metallic materials — Part 3: Standard quality requirements (ISO 3834-3:2005)*

EN ISO 4063:2010, *Welding and allied processes — Nomenclature of processes and reference numbers (ISO 4063:2009, Corrected version 2010-03-01)*

EN ISO 6520-1:2007, *Welding and allied processes — Classification of geometric imperfections in metallic materials — Part 1: Fusion welding (ISO 6520-1:2007)*

EN ISO 9606-2:2004, *Qualification test of welders — Fusion welding — Part 2: Aluminium and aluminium alloys (ISO 9606-2:2004)*

EN ISO 10042:2005, *Welding — Arc-welded joints in aluminium and its alloys — Quality levels for imperfections* (ISO 10042:2005)

EN ISO 11666:2010, *Non-destructive testing of welds — Ultrasonic testing — Acceptance levels* (ISO 11666:2010)

EN ISO 15614-2:2005, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 2: Arc welding of aluminium and its alloys* (ISO 15614-2:2005)

EN ISO 16826:2014, *Non-destructive testing — Ultrasonic testing — Examination for discontinuities perpendicular to the surface (ISO 16826:2012)*

EN ISO 17635:2010, *Non-destructive testing of welds — General rules for metallic materials* (ISO 17635:2010)

EN ISO 17636-1:2013, Non-destructive testing of welds — Radiographic testing — Part 1: X- and gamma-ray techniques with film (ISO 17636-1:2013)

EN ISO 17636-2:2013, Non-destructive testing of welds — Radiographic testing — Part 2: X- and gamma-ray techniques with digital detectors (ISO 17636-2:2013)

EN ISO 17637:2011, *Non-destructive testing of welds — Visual testing of fusion-welded joints (ISO 17637:2003)*

EN ISO 17640:2010, *Non-destructive testing of welds — Ultrasonic testing — Techniques, testing levels, and assessment* (ISO 17640:2010)

EN ISO 23277:2009, *Non-destructive testing of welds — Penetrant testing of welds — Acceptance levels* (ISO 23277:2006)

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

ISO 857-1:1998, *Welding and allied processes — Vocabulary — Part 1: Metal welding processes*

3 Terms, definitions, symbols and units

For the purposes of this document, the terms, definitions, symbols and units given in EN 13445:2014 Parts 1 to 5 apply.

NOTE Further symbols are listed in 8.2.3.

4 General requirements

The general requirements of EN 13445-1:2014 shall apply.

5 Materials

5.1 General

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.

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

The requirements of EN 13445-2:2014 shall apply with the following additions/exclusions.

5.2 Elongation after fracture

NOTE Also see 4.1.4 of EN 13445-2:2014.

Aluminium and aluminium alloys used for welded parts of pressure vessels that are subjected to cold forming (e.g. rolled shells and heads) shall have a specified minimum elongation after fracture measured on a gauge length

$$L_o = 5{,}65\sqrt{S_o} \qquad (5.2\text{-}1)$$

that is ≥ 14 % in the longitudinal or transverse direction as defined by the material specification.

Aluminium and aluminium alloys used for parts of pressure vessels that are not subject to cold forming (e.g. straight flanges and nozzles) shall have a specified minimum elongation after fracture of ≥ 10 % in the longitudinal or transverse direction as defined by the material specification, measured on a gauge length as defined in Formula (5.2-1).

5.3 Prevention of brittle fracture

EN 13445-2:2009, Annex B, is not applicable. All materials of Table 5.6-1 are suitable for any minimum metal temperature without impact testing.

NOTE See also EN 1252-1 and EN 12392:2000, 8.4.

5.4 Lamellar tearing

NOTE Also see EN 13445-2:2014, 4.2.1.2.

Specific requirements of lamellar tearing for pressure vessels of aluminium and its alloys are not applicable.

5.5 Chemical composition

The chemical composition shall be in accordance with the material specification.

It is recommended that the material to be used for welded components be produced from rolling or extrusion ingots with hydrogen level no greater than 0,2 ml per 100 g aluminium, measured on liquid metal during casting (see EN 12392:2000, 5.1.3).

EN 12392:2000, 4.1, recommends a maximum lead content not exceeding 150 µg/g.

5.6 Material grouping system

Annex A of EN 13445-2:2009 is not applicable for pressure vessels of aluminium and its alloys. The allowable materials for the construction of aluminium alloy pressure vessels shall be according to Table 5.6-1 below.

Any product form available in EN 12392:2000 for a material in Table 5.6-1 at an acceptable temper is acceptable for construction to this European Standard, as long as the requirements of 5.2 and 5.5 are fulfilled. Other materials not defined here may be used by agreement by the parties concerned (see EN 13445-2:2009, 4.1.4) if they meet the requirements of 5.2 and 5.5 and a particular material appraisal is produced (see EN 764-4:2002).

Table 5.6-1 — Grouping system based on CR ISO/TR 15608:2013 and allowable materials of construction based on EN 12392:2000 using the EN AW numbers according to EN 573-3:2013

Group	Sub group	Type of aluminium and aluminium alloys	Designation		
			EN AW number	Chemical symbol	Temper
21		Pure aluminium with ≤ 1 % impurities or alloy content	EN AW — 1050A EN AW — 1070A EN AW — 1080A	EN AW-Al 99,5 EN AW-Al 99,7 EN AW-Al 99,8(A)	O, H111, H112 O, H111, H112 O, H111, H112
22	Non heat treatable alloys				
	22.1	Aluminium-manganese alloys	EN AW — 3003 EN AW — 3103 EN AW — 3105	EN AW-Al Mn1Cu EN AW-Al Mn1 EN AW-Al Mn0,5Mg0,5	O, H111, H112 O, H111, H112 O, H111
	22.2	Aluminium-magnesium alloys with Mg ≤ 1,5 %	EN AW — 5005 EN AW — 5005A EN AW — 5050	EN AW-Al Mg1(B) EN AW-Al Mg1(C) EN AW-Al Mg1,5(C)	O, H111, H112 O, H111, H112 O, H111
	22.3	Aluminium-magnesium alloys with 1,5 % < Mg ≤ 3,5 %	EN AW — 5049 EN AW — 5052 EN AW — 5154A EN AW — 5251 EN AW — 5454 EN AW — 5754	EN AW-Al Mg2Mn0,8 EN AW-Al Mg2,5 EN AW-Al Mg3,5(A) EN AW-Al Mg2 EN AW-Al Mg3Mn(A) EN AW-Al Mg3	O, H111, H112 O, H111, H112 O, H111, H112 O, H111, H112 O, H111, H112 O, H111, H112
	22.4	Aluminium-magnesium alloys with Mg > 3,5 %	EN AW — 5083 EN AW — 5086	EN AW-Al Mg4,5Mn0,7 EN AW-Al Mg4	O, H111, H112 O, H111
23	Heat treatable alloys				
	23.1	Aluminium-magnesium-silicon alloys	EN AW — 6060 EN AW — 6061	EN AW-Al MgSi EN AW-Al Mg1SiCu	T4 [a] T4 [b], T6 [c]

[a] for profiles only

[b] for seamless pipes and flanges only

[c] for flanges only

6 Design

6.1 General

The requirements of EN 13445-3:2014 shall apply with the following additions/exclusions.

6.2 Design temperature and properties

NOTE 1 Also see EN 13445-2:2009, 4.2.2.

EN 13445-2:2009, 4.2.2.1, 2nd paragraph, is not applicable for aluminium and its alloys.

Design strength values are given in Tables A.2 to A.5 in Annex A. Design temperatures that exceed the respective temperature limit in Annex A are not permitted.

For materials of group 22.4 temperatures above 80 °C may result in grain boundary precipitation of Al_3-Mg_2. These materials may be used at temperatures above 80 °C up to 200 °C only for non-corrosive service.

NOTE 2 For further material properties see EN 12392:2000.

For welded parts and heat treated parts after forming only the values equivalent to the O temper shall be used for design when 6 000 series flanges, etc. are welded. These values are not quoted in EN 12392:2000 and so the tabulated values for f shown in Table 6.3-2 shall be used for design. The weld area shall be based on the O temper but the flange strength away from the weld (2t) may be based on the actual temper (T4 or T6).

For aluminium and aluminium alloys values of 0,2 % proof stress (or 1 % proof stress for material group 21-1 000 series aluminium) for temperatures above 20 °C shall be established by linear interpolation between two adjacent values in Annex A or in EN 12392:2000 except that for alloys 5083 and 5086 the respective value at 50 °C may be used for 65 °C.

For material of group 22.4: For short periods, higher temperatures (e.g. when defrosting refrigerating plant) up to 150 °C are permissible provided that the pressure is reduced to half the working pressure for a period up to 8 h and to atmospheric pressure for a period up to 24 h.

6.3 Time-independent nominal design stress

The design stress for aluminium and aluminium alloy materials shall be in accordance with the Table 6.3-1.

Table 6.3-1 — Design Stresses for aluminium and aluminium alloy material

Group according to Table 5.6-1	Design stresses at design condition	Design stresses at test condition
21	$f = [R_{p1,0,T} / 1,5]$	$f_{test} = [R_{p1,0,20} / 1,05]$
22	f = min ($[R_{p0,2,T} / 1,5]$; $[R_{m,20} / 2,4]$)	$f_{test} = [R_{p0,2,20} / 1,05]$
23	f = min ($[R_{p0,2,T} / 1,5]$; $[R_{m,20} / 3]$	$f_{test} = [R_{p0,2,20} / 1,05]$

Table 6.3-2 — Allowable Design Stress values for 6000 series aluminium alloys in the welded condition (see 6.2)

Material designation to EN 12392:2000	Value of f for design temperature (°C) not exceeding						
	50	75	100	125	150	175	200
EN AW 6060	40	40	40	38	36	22	14
EN AW 6061	55	55	55	54	51	43	32

6.4 Thick walled, small bore piping for shells

Equations (6.4-1) and (6.4-2) may be used as an alternative to Annex B and C in EN 13445-3:2014 for thick-walled piping of aluminium and aluminium alloy materials, i.e. for piping with $e/D_e > 0,16$ and DN ≤ 50. The maximum allowable pressure shall be used for design.

Limit Load Procedure

$$p_d < PS \quad (6.4\text{-}1)$$

This maximum allowable pressure can be determined as follows:

$$PS = \left(\frac{2}{\sqrt{3}} \cdot R_{p0,2} \cdot \ln\left[\frac{D_O}{D_i} \right] \right) / 1,5 \quad (6.4\text{-}2)$$

NOTE The method proposed is the standard design method for vaporisers upstream a cryogenic pressure tank. These vaporisers are small bore piping (DN ≤ 50) with comparable thick wall thickness (e/D_e typically ranges from 0,23 to 0,33 or D_e/D_i from 2,7 to 1,8).

6.5 Fatigue design

Fatigue design for over 500 full equivalent pressure cycles is not covered by this Part 8 for aluminium and aluminium alloy pressure vessels. For the determination of 500 full equivalent pressure cycles see EN 13445-3:2009, 5.4.2

NOTE This will be subject to a future revision of or an amendment to this Part 8.

6.6 Lapped joints, joggle joints, permanent backing strips

6.6.1 General

The requirements of 5.7.4 in EN 13445-3:2014 are not applicable for pressure vessels of aluminium and aluminium alloys, and 5.7.4.1, 5.7.4.2, and 5.7.4.3.1 shall be replaced with the following 6.6.2, 6.6.3, and 6.6.4, respectively.

6.6.2 Lapped joints

Lapped joints with fillet welds shall be used only when all of the following conditions are fulfilled:

a) only testing group 4 is permitted;

b) the materials are limited to material groups 21, 22.1, 22.2, 22.3, 22.4;

c) for circumferential joints of shell to head only;

d) the nominal wall thickness of the thickest pressure part does not exceed 8 mm;

e) the overlap shall be minimum 4e, where e represents the nominal thickness of the thickest pressure part;

f) both sides of the lap are welded;

g) the maximum vessel diameter does not exceed 1 600 mm;

h) non-corrosive conditions only are permitted.

6.6.3 Joggle joints

Joggle joints shall be used only when all of the following conditions are fulfilled:

a) the materials are limited to material groups 21, 22.1, 22.2, 22.3, and 22.4 (except 5454);

b) for circumferential joints of shell to head only;

c) the nominal wall thickness of the thickest pressure part does not exceed 12 mm;

d) the inside of the vessel is not subject to corrosion;

e) the intersections between longitudinal and circumferential joints shall be radiographed and found to be free of unacceptable imperfections;

f) the maximum vessel diameter does not exceed 1 600 mm.

6.6.4 Joints with permanent backing strips

Permanent backing strips shall not be used for longitudinal seams.

Permanent backing strips are permitted for circumferential seams and for shell or head closure plates (see EN 13445-3:2009, Table A, reference E 7) only under the following conditions:

a) materials are limited to material groups 21, 22.1 to 22.4 and 23.1;

b) non–destructive examination is carried out in accordance with the design/joint efficiency to the same quality and acceptance criteria as a single-sided butt weld;

c) the inside of the vessel is not subject to corrosion;

d) backing strip material shall be of the same aluminium sub group as the vessel unless the combination of other backing strip material has been proven by a WPQR according to EN ISO 15614-2:2005.

6.7 Flat ends

The requirements of Clause 10 of EN 13445-3:2009 shall apply with the following additions/exclusions:

— Joint types E 5 and E 14 in Table A-3 of EN 13445-3:2009:
Only the first term of equation (10.4-10) shall be considered.

— Joint types E 6, E 7, and E 15 in Table A-3 of EN 13445-3:2009:
For values of C_1 and C_2 higher than 0,45 in equation (10.4-10) the value of 0,45 may be taken.

— Joint types E 10, E 11, E 17, and E 19 in Table A-3 of EN 13445-3:2009:
For values of C_1 and C_2 higher than 0,5 in equation (10.4-10) the value of 0,5 may be taken.

6.8 Design by experiment

— When a plate-and-fin structure is to be designed by experimental method, the procedure shall be based on the principles laid down in Annex T of EN 13445-3:2009, however, with the following modifications:

— A test piece shall be subject to a pressure load until the required pressure P_B is reached or the test piece is destroyed.

— PS shall be determined by P_B, divided by 4.

6.9 Port-hole-extruded tubes

Port-hole-extruded tubes in accordance with the EN 755-series may be used up to and including DN 25, provided that a joint efficiency of 0,7 is applied. When these tubes are subject to a combined pressure-leak-test for the entire length the joint efficiency may be set to a factor of 1. If this test is carried out:

by the tube manufacturer, the test pressure shall be

$$P_T = \frac{e_n}{D_e} \cdot 0{,}95 \cdot R_{px} \quad (6.9\text{-}1)$$

by the pressure vessel manufacturer, the test pressure shall be

$$P_T = 1{,}43 \cdot PS \quad (6.9\text{-}2)$$

The combined pressure-leak test for achieving a joint efficiency factor of 1 is to be carried out before integration in the piping system either using helium or a gas mixture containing helium, depending on the application. It does not replace the pressure test as specified in Clauses 8.6 and 8.7.

7 Manufacture

7.1 General

The requirements of EN 13445-4:2014 shall apply with the following additions/exclusions.

7.2 Materials

Aluminium and aluminium alloy materials and their grouping shall be in accordance with 5.6.

7.3 Tolerances

The requirements of EN 13445-4:2009, 5.4, shall apply with the following modification:

For the dished end tolerances of the circumference *C* the following limit deviations are applicable:

— for outer diameters $D_e \leq 300$ mm: +/- 4 mm;

— for outer diameters D_e with 300 mm < $D_e \leq 4000$ mm: +/- 10 mm;

— for outer diameters $D_e > 4000$ mm the tolerance shall be +/- 10 mm or more if agreed before fabrication commences.

7.4 Welding procedure specification (WPS)

NOTE Also see 7.2 of EN 13445-4:2014.

Gas welding according to EN ISO 4063:2010 is not permitted.

7.5 Qualification of welding procedure specifications (WPQR)

The requirements in 7.3 of EN 13445-4:2014 shall apply with the following modifications:

a) replace reference to EN ISO 15614-1 with EN ISO 15614-2:2005, except for radiographic acceptance which shall be in accordance with Clause 8;

b) furthermore, impact testing is not applicable for pressure vessels of aluminium and aluminium alloys.

7.6 Qualification of welders and welding operators

The requirements in 7.4 of EN 13445-4:2014 shall apply with the following modification:

Replace reference to EN 287-1[1)] with EN ISO 9606-2:2004.

7.7 Joint preparation

In addition to the requirements of 7.6 in EN 13445-4:2014 the following shall apply for pressure vessels of aluminium and its alloys:

a) aluminium and its alloys shall be cut to size and shape preferably by machining or by thermal cutting process, e.g. plasma arc cutting, or by a combination of both. Additionally, hydro-mechanical methods of edge preparation are acceptable;

b) for plates of ≤ 25 mm thickness cold shearing is permissible. Edges that are cut by thermal process or by cold shearing shall be dressed back by machining unless the manufacturer can demonstrate that the material and the weldability have not been adversely affected by the cutting process;

c) the aluminium surface to be welded shall be thoroughly cleaned of aluminium oxide traces and greases by mechanical means or by pickling. Chloride-containing detergents are prohibited (also see Clause 4 of EN 13445-4:2014).

7.8 Preheat

In addition to the requirements of 7.9 in EN 13445-4:2014 the following shall apply for pressure vessels of aluminium and its alloys:

a) preheating of aluminium and aluminium alloys is not required for metallurgical reasons and is therefore not mandatory. Preheating may be applied by the manufacturer for practical reasons, e.g. a heating at about 50 °C may facilitate the elimination of traces of water;

b) for aluminium alloys containing 3,0 % or more magnesium an extended preheating and interpass time at temperatures of 150 °C and above shall not be permitted as it may result in grain boundary precipitation of Al_3-Mg_2 and disintegration in weld areas.

7.9 Production test, reference criteria

The requirements in 8.2 of EN 13445-4:2009 are not applicable.

Production test plates are required for pressure vessels manufactured according to this European Standard in the case of a joint coefficient z of $0,85 < z \leq 1,0$. If a joint coefficient of 0,85 or less is specified by the designer no production test plates are required.

Requirements for impact testing are not relevant to aluminium materials.

a) There is a strict relationship between the WPS and the mechanical properties obtained in the procedure approval test for aluminium materials 21, 22.1, 22.3 and 22.4. Because of the tolerance of these aforementioned aluminium materials to weld procedural variables, production tests are not required if all of the following conditions are met:

   — The quality requirements for welding according to EN ISO 3834-2:2005 or EN ISO 3834-3:2005 are fulfilled.

1) EN ISO 9606-1 has been published in 2013 replaces EN 287-1. CEN has decided to have a transition period for EN 287-1. As a consequence, EN 287-1 is valid until October 2015.

— The welding process is fully mechanised (see ISO 857-1) ensuring that the welding procedure is applied consistently.

— There is no requirement in the WPS for preheating or post weld heat treatment (PWHT).

— The wall thickness $e_n \leq 30$ mm.

b) Otherwise, for vessels made of aluminium permitted by Clause 5 of this standard, the following shall apply:

1) for longitudinal welds, one test plate per vessel in the case of joint coefficient 1,0;

2) one test plate per 200 m of longitudinal welds in hemispherical heads in the case of joint coefficient 1,0;

3) one test plate per year where the circumferential welds are welded to a procedure involving joggle joints or permanent backing strips.

After 10 consecutive test plates have successfully passed the tests, testing may be reduced to the following:

4) one test plate per 200 m of longitudinal welds in the case of joint coefficient 1,0;

5) one test plate per 1500 m of longitudinal welds in hemispherical heads in the case of joint coefficient 1,0;

6) one test plate per year where the circumferential welds are welded to a procedure involving joggle joints or permanent backing strips.

The testing of the production test plate shall consider the parameters for the post-weld heat treatment(s) of the pressure vessel.

7.10 Extent of testing

Table 8.3-1 of EN 13445-4:2014 is not applicable for pressure vessels of aluminium and its alloys. For aluminium materials the following Table 7.10-1 shall apply:

Table 7.10-1 — Testing of production test plates

Material group	Nominal thickness e_n [a] (mm)	Test specimens [b]
21, 22.1, 22.2, 22.3, 22.4, 23.1	≤ 35	1 FB, 1 RB (or 2 SB for e > 12 mm), 1 TT, 1 Ma
	> 35	2 SB, 1 TT, 1 Ma, 1 LT[c]

[a] Thinner plate thickness.

[b] For symbols see Table 8.3-2 of EN 13445-4:2014.

[c] For information for LT see 8.4.3 of EN 13445-4:2014.

7.11 Performance of test and acceptance criteria

The requirements in 8.4.2, 8.4.3, 8.4.5 and 8.4.6 of EN 13445-4:2014 shall apply subject to the replacement of reference to EN ISO 15614-1 with EN ISO 15614-2:2005. The requirements in 8.4.1, 8.4.9 and 8.4.10 of EN 13445-4:2014 shall apply, the requirements in 8.4.7 and 8.4.8 of EN 13445-4:2014 shall not apply.

7.12 Forming procedures

7.12.1 As to cold forming the requirements in 9.3.1 of EN 13445-4:2014 shall apply with the following modification:

a) cold forming of material groups 21 and 22.1 to 22.4 shall be carried out at temperatures below 200 °C;

b) cold forming of material 23.1 is not allowed (T4 and T6).

7.12.2 As to hot forming the requirements in 9.3.2 of EN 13445-4:2014 are not applicable for pressure vessels of aluminium and its alloys.

Hot forming of aluminium and its alloys shall be carried out in a temperature range of 320 °C to 420 °C. The last stage of the hot forming process shall be completed above 300 °C, otherwise a subsequent heat treatment to achieve the O Temper is required.

7.13 Heat treatment after forming

7.13.1 For heat treatment of flat products after cold forming the requirements in 9.4.2 of EN 13445-4:2014 are not applicable for pressure vessels of aluminium and its alloys. For aluminium and its alloys the heat treatment shall be carried out in accordance with Table 7.13-1.

Table 7.13-1 — Heat treatment of flat products after cold forming

Material group	Ratio of deformation	Heat treatment
21	≤ 15 %	no
21	> 15 %	yes [a], annealing
22.1 [b], 22.2 [b], 22.3 [b], 22.4 [b]	≤ 5 %	no
22.1 [b], 22.2 [b], 22.3 [b], 22.4 [b]	> 5 %	yes [c], annealing

[a] With levels of cold forming and a ratio of deformation above 15 % for materials of group 21 or above, if proof can be furnished in specific cases that the residual elongation after fracture after cold forming remains at least 10 %, then in these cases annealing is not required.

[b] Elongation prior to forming ≥ 14 %.

[c] With levels of cold forming and a ratio of deformation above 5 % for materials of group 22 or above, if proof can be furnished in specific cases that the residual elongation after fracture after cold forming remains at least 10 %, then in these cases annealing is not required.

The heat treatment parameters shall be in accordance with the material specification of the material manufacturer. The general heat treatment parameters shall be:

a) the heating rate shall be as rapid as possible;

b) the holding temperature shall be in the range between 320 °C and 380 °C depending on the alloy type;

c) the holding time at the holding temperature shall be between 10 min and 60 min depending on the ratio of cold forming and the thickness of the material;

d) the cooling shall be performed in still air, the cooling rate needs not to be controlled.

7.13.2 For heat treatment of tubular products after cold forming the requirements in 9.4.3 of EN 13445-4:2014 are not applicable for pressure vessels of aluminium and its alloy. For aluminium and its alloys heat treatment shall be carried out in accordance with Table 7.13-2.

Table 7.13-2 — Heat treatment of tubular products after cold forming

Material group	Bending radius for the tube R	External diameter of the tube D_e	Heat treatment
21	≥ 1,3 D_e	all diameters	no
21	< 1,3 D_e	all diameters	yes, annealing
22.1 [a], 22.2 [a], 22.3 [a], 22.4 [a]	≥ 2.5 D_e	all diameters	no
22.1 [a], 22.2 [a], 22.3 [a], 22.4 [a]	< 2.5 D_e	all diameters	yes, annealing

[a] Elongation prior to forming ≥ 14 %.

The heat treatment parameters (annealing) shall be in accordance with the material specification of the material manufacturer. The general heat treatment parameters shall be:

a) the heating rate shall be as rapid as possible;

b) the holding temperature shall be in the range between 320 °C and 380 °C depending on the alloy type;

c) the holding time at the holding temperature shall be between 5 min and 60 min depending on the ratio of cold forming and the thickness of the material;

d) the cooling shall be performed in still air, the cooling rate needs not to be controlled.

7.13.3 For the heat treatment after hot forming the requirements in 9.4.5 of EN 13445-4:2014 are not applicable for pressure vessels of aluminium and its alloys. For aluminium and its alloys heat treatments shall be carried out in accordance with Table 7.13-3.

Table 7.13-3 — Heat treatment after hot forming

Material group	Hot forming conditions	Heat treatment
21, 22.1, 22.2, 22.3, 22.4	No subsequent heat treatment should be applied if the forming process of the last forming stage is completed above 300 °C.	no

7.13.4 The requirements in 9.4.4 and 9.4.6 of EN 13445-4:2014 are not applicable for pressure vessels of aluminium and its alloys.

7.14 Sampling of formed products

7.14.1 The requirements in 9.5.1 of EN 13445-4:2009 are not applicable for pressure vessels of aluminium and its alloys.

No mechanical tests with respect to forming are required for

— cold-formed plates and tubes for which heat treatment is not required by Table 7.13-1 and Table 7.13-2;

— cold-formed and heat-treated cylindrical and conical shell sections.

7.14.2 The requirements in 9.5.2 of EN 13445-4:2014 are not applicable for pressure vessels of aluminium and its alloys.

For all material groups allowed by Clause 5 a test plate shall be subjected to heat treatment together with the formed products or be subjected to a similar heat treatment separately. The following number of test coupons shall be taken:

a) one test coupon from a batch of up to 10 parts;

b) two test coupons from a batch of up to 25 parts;

c) three test coupon from a batch of up to 100 parts;

d) one test coupon for every further 100 parts.

7.15 Tests

7.15.1 Base material

The requirements in 9.6.1 of EN 13445-4:2014 are not applicable for pressure vessels of aluminium and its alloys.

For pressure vessels of aluminium and its alloys one tensile test shall be taken from each test coupon required in 7.14.2. The test specimens shall be taken transverse to the rolling direction with a deviation not greater than 20°.

7.15.2 Butt welds

The requirements in 9.6.2 of EN 13445-4:2014 are not applicable for pressure vessels of aluminium and its alloys.

NOTE This does not decrease the need to have a PQR test in the heat treated condition as required by 7.4.

7.16 Post weld heat treatment (PWHT)

The requirements in Clause 10 of EN 13445-4:2014 are not applicable for pressure vessels of aluminium and its alloys. However, the following shall apply for pressure vessels of aluminium and its alloys:

a) stress relieving heat treatment is normally not necessary or desirable for welded aluminium vessels except if there is a risk of stress corrosion due to the service media. Annealing heat treatment carried out for obtaining the delivery state O is the only usable heat treatment;

b) for material group 23.1 PWHT is not permitted;

c) the heat treatment parameters (annealing) shall be in accordance with the material specification of the material manufacturer or those as stated in Table 7.13-3.

8 Inspection and testing

8.1 General

The requirements in EN 13445-5:2014 shall apply with the following additions/exclusions.

8.2 Non-destructive testing of welded joints

8.2.1 General

The testing of vessels of aluminium and aluminium alloys shall be according the testing groups according to Table 8.2-1.

All testing groups shall require 100 % visual inspection to the maximum extent possible.

Testing group 4 shall be applicable only for:

— PS ≤ 20 bar; and

— maximum number of full pressure cycles ≤ 500; and

— lower level of nominal design stress (according to EN 13445-3:2014).

Table 8.2-1 — Testing groups for aluminium pressure vessels

	Testing group			
	1	2 [a]	3	4
Permitted materials [e]	21, 22.1 to 22.4	21, 22.1 to 22.4, 23.1 [g]	21, 22.1 to 22.4, 23.1 [g]	21, 22.1 to 22.4 (except EN AW 5454)
Extent of NDT of governing welded joints [c f]	100 %	100 % – 10 % [b]	10 %	0 %
NDT of other welds	Defined for each type of weld in Table 6.6.2-1 of EN 13445-5:2014.			
Joint coefficient	1	1	0,85	0,7
Maximum thickness for which specific materials are permitted	Unlimited [d]	40 mm	40 mm	20 mm
Welding process	Unlimited [d]	Fully mechanical welding only [a]	Unlimited [d]	Unlimited [d]
Service temperature range	Unlimited [d]	Unlimited [d]	Unlimited [d]	Unlimited [d]

[A] Fully mechanised and/or automatic welding process (see EN 1418)

[b] First figure: initially; second figure: after satisfactory experience. For definition of "satisfactory experience", see 8.2.2.

[c] See testing details in Table 8.3-1 of this Part 8.

[d] "Unlimited" means no additional restriction due to testing. The limitations mentioned in this table are limitations imposed by testing. Other limitations given in the various clauses of this European Standard (such as design, or material limitations etc.) shall also be taken into account.

[e] See Clause 5 for permitted materials.

[f] The percentage relates to the percentage of welds of each individual vessel.

[g] It is intended that material group 23.1 is only used in a seamless condition (i.e. as seamless vessel shell, nozzle connection, end cap or flange) and only circumferential welding will be applied. Also because of the lower minimum elongation cold forming of material group 23.1 is not permitted.

8.2.2 Demonstration of satisfactory experience for testing group 2

The requirements in 6.6.1.1.4 of EN 13445-5:2014 shall apply with the following modifications:

— in case of groups 21, 22.1 to 22.4, except EN AW 5454, the successful production is 25 consecutive pressure vessels or 50 consecutive metres of governing welded joints;

— in case of materials of group 23.1 and EN AW 5454, it is 50 consecutive pressure vessels or consecutive 100 m of governing welded joints;

— experience in material group 22.4 covers experience in material groups 21, 22.1, 22.2 and 22.3;

— experience is accepted as long as there is a valid welding procedure approval test for a more critical or at least a comparable material.

8.2.3 Symbols

The following symbols are used in the tables of Clause 8:

A area surrounding the gas pores

a nominal throat thickness of the fillet weld (see also ISO 2553:1992)

b width of weld reinforcement

d diameter of gas pore

d_A diameter of area surrounding the gas pores

d_i inner diameter

d_n nominal diameter

e, t wall or plate thickness (nominal size)

h height or width of imperfection

L length of projected or cross section area

l length of imperfection in longitudinal direction of the weld

s nominal butt weld thickness (see also ISO 2553:1992)

w width of the weld or width or height of the cross section area

8.3 Determination of extent of non destructive testing

The requirements in 6.6.2 of EN 13445-5:2014 shall apply with the following modification:

Table 6.6.2-1 of EN 13445-5:2014 shall be replaced by Table 8.3-1, and NOTE 2 shall be replaced by:

a) multilayer welds;

b) performed by Metal Inert Gas (MIG 131) or Tungsten Inert Gas (TIG 141).

Special problems arising from elements such as those described below shall be considered especially for longitudinal joints:

c) other process, e.g. plasma 15, electron beam (EB) 76, friction welding 42;

d) single run weld, single run from one side or both sides;

e) automatic welding processes.

Table 8.3-1 — Extent of non-destructive testing

			Testing group	1	2	3	4
			Parent materials l m n	21, 22.1 to 22.4	21, 22.1 to 22.4 except 23.1	21, 22.1 to 22.4, and 23.1 [o]	21, 22.1 to 22.4 (except EN AW 5454)
Type of weld [a]			Testing [b]	Extent	Extent	Extent	Extent
Full penetration butt weld	1	Longitudinal joint	RT or UT PT	100 % 0	(100–10) % [p] 0	10 % [p] 0	0 [p] 0
	2a	Circumferential joint on a shell	RT or UT PT	25 % 0	(25–10) % 0	10% [c] 0	0 0
	2b	Circumferential joint on a shell with backing strip [k]	RT or UT PT	25 % 0	(25–10) % 0	10 % 0	0 0
	2c	Circumferential joggle joint [k]	RT or UT PT	25 % 0	(25–10) % 0	10 % 0	0 0
	3a	Circumferential joint on a nozzle with d_i > 150 mm and e > 16 mm	RT or UT PT	25% 0	(25–10)% 0	10% [c] 0	0 0
	3b	Circumferential joint on a nozzle with d_i > 150 mm and e > 16 mm with backing strip [k]	RT or UT PT	25 % 0	(25–10) % 0	10 % 0	0 0
	4	Circumferential joint on a nozzle with d_i < 150 mm or e < 16 mm	RT or UT PT	0 50 %	0 (50–10) %	0 10 % [d]	0 0
	5	All welds in shells, heads and in hemispherical heads to shells	RT or UT PT	100 % 0	100 % 0	10 % [p] 0	0 [p] 0
	6	Assembly of a conical shell with a cylindrical shell angle ≤ 30°	RT or UT PT	25 % 0	(25–10) % 0	10 % 0	0 [p] 0
	7	Assembly of a conical shell with a cylindrical shell angle > 30°	RT or UT PT	100 % 0	(100–25) % 0	10 % 10% [d]	10 % 0
Fillet weld, lapped joints [k]	8	Circumferential lapped joint head to shell	RT or UT PT	NP NP	NP NP	NP NP	0 [p] 0
Assembly of a flat head or tubesheet, with a cylindrical shell; assembly of a flange or a collar with a shell	9	With full penetration	RT or UT PT	25 % 0	(25–10) % 0	10 % 0 [p]	0 [p] 0 [p]
	10	With partial penetration, if a > 16 mm (as defined in Figure 6.6.2–1 of EN 13445-5:2014) [j]	RT or UT PT	NP NP	NP NP	10 % 0	0 0
	11	With partial penetration, if a ≤ 16 mm (as defined in Figure 6.6.2–2 of EN 13445-5:2014) [j]	RT or UT PT	NP NP	NP NP	NA 10 %	0 0
Assembly of a flange or a collar with a nozzle with d_n > 200 mm and ≥ 25 a	12	With full penetration	RT or UT PT	NA 25 % [g]	NA (25–10) %	NA 10 %	0 0
	13, 14	With partial penetration [j]	RT or UT PT	NP NP	NP NP	0 10 % [d p]	0 0 [p]

Table 8.3-1 (*concluded*)

			Testing group	1	2	3	4
			Parent materials l m n	21, 22.1 to 22.4	21, 22.1 to 22.4 except 23.1	21, 22.1 to 22.4, and 23.1 [o]	21, 22.1 to 22.4 (except EN AW 5454)
Type of weld [a]			Testing [b]	Extent	Extent	Extent	Extent
Nozzle or branch [e]	15	With full penetration if d_i > 200 mm and e > 25 mm	RT or UT PT	25 % [g] 0 [p]	(100–10) % 0 [p]	10 % 0 [p]	0 0 [p]
	16	With full penetration if d_i ≤ 200 mm or e ≤ 25 mm	RT or UT PT	NA 25 % [g p]	NA (25–10) % [p]	NA 10 % [d p]	0 0 [p]
	17, 18, 19	With partial penetration for any d_i and a > 16 mm	RT or UT PT[j]	NA 25 % [g p]	NA (25–10) % [p]	NA 10 % [d p]	0 0 [p]
Tube ends into tube sheet	20		PT or leak test [q]	100 %	100 %	10 %	0
Permanent attachments	21	With full penetration or partial penetration	RT or UT PT	0 25 % [p]	0 25 % [p]	0 25 % [p]	0 0 [p]
Pressure retaining areas after removal of temporary attachments	22		PT	100 %	100 %	100 %	0 [p]
Cladding by welding [h]	23		PT	NA	NA	NA	NA
Repairs	24	RT or UT PT	NDT of repairs shall be 100 % of the area of repair by NDT methods as stated on the type of weld above.				

[a] See Figure 6.6.2-3 of EN 13445-5:2014.

[b] RT = Radiographic testing; UT = Ultrasonic testing; MT = Magnetic particle testing; PT = Penetrant testing.

[c] 2 % if e ≤ 30 mm and same WPS as longitudinal, for aluminium groups 21, 22.1 to 22.4 (except EN AW 5454).

[d] 10 % if e > 30 mm or 23.1, 0 % if e ≤ 30 mm (except 23.1).

[e] Percentage in the table refers to the aggregate weld length of all the nozzles, see 6.6.2.5 b) in EN 13445-5:2014.

[f] (deleted)

[g] 10 % for aluminium group 21.

[h] Weld cladding is not applicable for aluminium and aluminium alloys.

[i] For explanation of the reduction in NDT in testing group 2, also see 6.6.2.4 of EN 13445-5:2014.

[j] In exceptional cases or where the design or load bearing on the joint is critical, it may be necessary to employ both techniques (i.e. volumetric testing (RT or UT) and surface testing (PT)).

[k] For limitations of application see 6.6.

[l] The percentage of surface examination refers to the percentage of length of the welds both on the inside (where accessible) and the outside.

[m] RT and UT are volumetric while PT is surface testing. When referenced in this table both volumetric and surface are necessary to the extent shown.

[n] NA means "testing not applicable", NP means "type of joint not permitted".

[o] It is intended that material group 23.1 is only used in a seamless condition (i.e. as seamless vessel shell, nozzle connection, end cap or flange), and only circumferential welding will be applied.

[p] Where pneumatic testing is carried out in accordance with 8.7 the additional NDT requirements shall take precedence over this table. The NDT requirements shall, however, not be less than those specified in this table.

[q] Leak testing at a sensitivity of 10^{-3} atm·ml/s or better (e.g. gas and bubble test method or better).

8.4 Applicable non-destructive testing techniques

8.4.1 NDT methods

The requirements in Table 6.6.3-1 of EN 13445-5:2014 shall be replaced by Table 8.4-1.

Table 8.4-1 shows the method characterisation and acceptance criteria to be applied to aluminium weldments. The table is based on EN ISO 17635:2010 and EN ISO 10042:2005.

Table 8.4-1 — NDT methods, techniques, characterisation, acceptance criteria

NDT Methods (abbreviations)	Techniques	Characterisation	Acceptance criteria
Visual inspection (VT)	EN ISO 17637:2011	EN ISO 10042:2005 (surface imperfections)	EN ISO 10042:2005; for acceptance level and -criteria see Table 8.4.3-1 [c]
Radiography (RT)	EN ISO 17636-1:2013 and EN ISO 17636-2:2013, class B [a]	EN ISO 10042:2005 (internal imperfections)	EN ISO 10042:2005; for acceptance level and -criteria see Table 8.4.2-1
Ultrasonic Testing (UT)	EN ISO 17640:2010 for thickness t (mm): t < 40: class A 40 ≤ t < 100: class B t ≥ 100: class C	EN ISO 23279:2010 [b]	EN ISO 11666:2010; for acceptance level 2 and no planar imperfections accepted
Penetrant Testing (PT)	EN ISO 3452:2013 and testing parameters of EN ISO 23277:2009, Table A.1	EN ISO 23277:2009	EN ISO 23277:2009 For acceptance level and -criteria see Table 8.4.4-1

[a] However, the maximum area for single exposure shall correspond to the requirements of Class A of EN ISO 17636-1:2013 and EN ISO 17636-2:2013.

[b] EN ISO 23279:2010 is a recommendation only.

[c] Additional requirements for the following imperfections:

— stray arc (601) — removal plus 100 % PT to ensure no imperfection;

— spatter (602) — weld spatter shall be removed from all pressure parts and load carrying attachment welds;

— isolated non systematic spatter is permitted;

— torn surface (603), grinding mark (603), chipping mark (605) shall be ground to provide a smooth transition;

— underflushing (606) shall not be permitted. Any local underflushing shall be related to design characteristics.

8.4.2 Acceptance criteria for radiographic testing (RT)

The acceptance criteria for radiographic testing shall be in accordance with Table 8.4.2-1, and not Table 6.6.4-1 in EN 13445-5:2014.

Where Table 8.4.2-1 does not give acceptance criteria then the criteria according to EN ISO 10042:2005 Level B shall be used.

Table 8.4.2-1 — Acceptance criteria for radiographic testing (RT)

EN ISO 6520-1:2007 imperfection reference n°	Type of imperfection Designation	Maximum permitted
2016	Worm-hole isolated	EN ISO 10042:2005, level C
	Worm-hole aligned	Not permitted
303	Oxide inclusion	EN ISO 10042:2005, level C
3041	Tungsten inclusion	EN ISO 10042:2005, level C
2011	Gas pore	EN ISO 10042:2005, level C
2013	Clustered (localised) porosity	EN ISO 10042:2005, level C

8.4.3 Acceptance criteria for visual and surface penetrant testing

The acceptance criteria for visual and surface penetrant testing shall be in accordance with Tables 8.4.3-1 and 8.4.4-1.

Where Table 8.4.3-1 does not give acceptance criteria then the criteria according to EN ISO 10042:2005, level B shall be used.

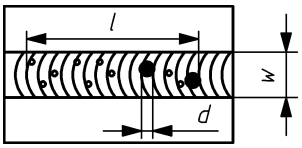
Table 8.4.3-1 — Acceptance criteria for visual testing (VT)

EN ISO 6520-1:2007 imperfection reference n°	Type of Imperfection Designation	Maximum permitted
502	Excess weld metal (butt weld)	EN ISO 10042:2005, level C
503	Excessive convexity (fillet weld)	EN ISO 10042:2005, level C
504	Excessive penetration	EN ISO 10042:2005, level C
507	Linear misalignment	See requirements of 5.2 and 5.3 of EN 13445-4:2014; “middle line - and surface alignment”

8.4.4 Acceptance criteria for penetrant testing (PT)

Table 8.4.4-1 includes acceptance criteria according to EN ISO 23277:2009 and additional requirements.

Table 8.4.4-1 Acceptance criteria for penetrant testing (PT)

Type of Imperfection Designation	Definition of maximum permitted	
	t = ≤ 10 mm	t > 10 mm
Linear indication	EN ISO 23277:2009, level 1	EN ISO 23277:2009, level 1
Rounded indication	EN ISO 23277:2009, level 1	EN ISO 23277:2009, level 2
Summation of linear- and rounded indications 	Permitted if the summation of the indication area is ≤ 0,5 % of the considered area of weld ($L \times w$). Clustered indications are not permitted.	

8.5 Selection of non-destructive testing methods for internal imperfections

The requirements in 6.6.3.3 of EN 13445-5:2014 shall apply with the following modification: Table 6.6.3-2 in EN 13445-5:2014 shall be replaced by Table 8.5-1.

Table 8.5-1 — Selection of non-destructive testing method[a] for determining internal imperfections, in accordance with EN ISO 17635:2010, Table 3

Material: Aluminium and its alloys	Parent material nominal thickness (e in millimetres)			
type of joint	$e \leq 8$	$8 < e \leq 40$	$40 < e \leq 100$	$e > 100$
Butt joints, full penetration	RT class B or (UT class A)	RT class B or UT class A	RT class B or UT [b] class B	UT [b] class C
T-joints, full penetration	RT class B or UT class A	UT class A or (RT class B)	UT class B or (RT class B)	UT class C
Butt joints or T-joints, partial penetration	Throat thickness of weld (a in millimetres) a > 16 mm RT class B or UT class A			

[a] RT and UT mean radiographic and ultrasonic testing in accordance with the standards mentioned in Table 8.3-1.

[b] For $e \geq 60$ mm UT shall include examination for imperfections perpendicular to the surface in accordance with EN 583-4:2002.

For surface condition and preparation for non-destructive testing the requirements in 6.6.3.5 of EN 13445-5:2014 shall apply with the following modification:

The last sentence in EN 13445-5:2014, 6.6.3.5, about cyclic loading is not applicable to aluminium pressure vessels.

8.6 Standard hydrostatic test

The requirements in 10.2.3.3 of EN 13445-5:2014 shall apply with the following modification:

For a vessel according to testing group 1, 2, 3 and 4 the test pressure shall be not less than that determined by 10.2.3.3.1 in EN 13445-5:2014.

10.2.3.3.2 in EN 13445-5:2014, testing group 4, is not applicable to aluminium pressure vessels.

8.7 Pneumatic testing

The requirement in 10.2.3.4.1 of EN 13445-5:2014 shall be followed. 10.2.3.4.2 shall be replaced with the following.

The pneumatic test pressure shall be in accordance with 10.2.3.3.1 in EN 13445-5:2014. Vessels subjected to this pressure shall be located in an enclosed and restricted area, e.g. a special chamber (bunker) capable of withstanding explosion or being properly anchored in a water basin and adequate measures being taken to prevent parts shooting away in the case of explosion. Alternatively, the vessel shall be located in an area, a sufficient distance away from any individuals (public or manufacturer's employees) such that in the case of explosion people will not be affected by the blast. This does not include damage from projectiles.

Alternatively, a test may be performed at a test pressure that is 1.1 times the maximum allowable pressure.

When this lower test pressure is used for a pneumatic test as the initial pressure test then 100 % of the longitudinal welds shall be subject to volumetric non-destructive examination and at least 10 % of the main circumferential welds including all ‘T’ junctions and flat ends to shell shall be subject to volumetric examination. In addition, 100 % of nozzle to shell welds, full and partial penetration attachment welds to the pressure boundary, flat ends to shells and areas where temporary attachments have been removed shall be subjected to 100 % surface penetrant examination where the weld thickness exceeds 6,5 mm.

Where during pneumatic test a vessel has been subjected to the pressure in accordance with 10.2.3.3.1 of EN 13445-5:2014 then the requirements in 10.2.3.4.3 shall apply for the inspection pressure. Where the alternative 1.1 times the maximum allowable pressure has been used then the pressure shall be reduced to the maximum allowable pressure for inspection of the vessel.

9 Inspection and testing of serially produced pressure vessels — Model approval

9.1 General

The requirements in Annex A.2, a) of EN 13445-5:2014 shall apply with the following modification:

The design and construction of the vessels, except where otherwise specified in this clause, is limited to testing group 2 or 3 (Table 8.2-1) and material groups 21 and 22.1 to 22.4, except EN AW 5454 only.

9.2 Inspection and testing of pressure vessels subject to cyclic loads

The requirements in Annex G of EN 13445-5:2014 are not applicable for pressure vessels of aluminium and its alloys.

Annex A
(normative)

Allowable design strength values

A.1 General

The safety factors of Table 6.3-1 are used to establish the design strength values in Annex A.

Material properties given in EN 12392:2000, Tables 5 and 6, are considered when establishing the design strength values in Annex A.

Design strength values given in italics are time-dependent.

A.2 Extruded rod/bar, tube and profile

Mechanical properties for plates shall comply with EN 755-2.

Table A.2 — Extruded rod/bar, tube and profile

EN AW number	Temper	$R_{p,20°C}$ MPa	Value of *f* for design temperature[a] MPa							
			20°C	50°C	75°C	100°C	125°C	150°C	175°C	200°C
EN AW-1050A	O/H111	20	20,0	19,3	18,7	*16,7*	*13,3*	*10,0*	*8,0*	*6,3*
EN AW-1070A	H112	23	25,6	24,5	23,5	21,5	20,4	19,4	—	—
EN AW-3003	O/H111	35	23,3	23,3	22,0	21,3	20,7	19,3	*17,3*	*15,3*
EN AW-3103	O/H111	35	23,3	23,3	22,0	21,3	20,7	19,3	*17,3*	*15,3*
EN AW-5005	O/H111	40	26,7	26,7	25,9	25,1	*34,3*	*26,7*	*19,8*	*16,0*
EN AW-5005A	O/H111	40	26,7	26,7	26,0	25,3	*32,0*	*24,7*	*18,0*	*14,7*
	H112	40	26,7	26,7	26,0	25,3	*32,0*	*24,7*	*18,0*	*14,7*
EN AW-5052	O/H111	70	46,7	46,7	45,9	44,5	*36,8*	*29,1*	*21,5*	*14,4*
EN AW-5154A	O/H111	85	56,7	56,7	55,3	54,0	*46,7*	*29,3*	*18,7*	*12,0*
EN AW-5251	O/H111	60	40,0	40,0	39,3	38,0	*32,6*	*27,3*	*18,0*	*12,7*
EN AW-5454	O/H111	85	56,7	56,7	55,3	54,0	*45,3*	*31,3*	*21,3*	*15,3*
EN AW-5754	O/H111	80	53,3	53,3	52,0	50,7	*40,7*	*26,0*	*15,3*	*10,7*
EN AW-5083	O/H111	110	73,3	73,3	71,6	71,6	*42,8*	*25,2*	*14,1*	*8,8*
EN AW-5086	O/H111	95	63,3	63,3	62,1	62,1	*45,6*	*27,2*	*16,5*	*10,8*

[a] Italic numerical values are creep-range values.

A.3 Cold drawn rod/bar and tube

Mechanical properties for plates shall comply with EN 754-2:2013.

Table A.3 — Cold drawn rod/bar and tube

EN AW number	Temper	$R_{p,20°C}$ MPa	Value of *f* for design temperature[a] MPa							
			20°C	50°C	75°C	100°C	125°C	150°C	175°C	200°C
EN AW-3003	O/H111	35	23,3	23,3	22,0	21,3	20,7	19,3	*17,3*	*15,3*
EN AW-3103	O/H111	35	23,3	23,3	22,0	21,3	20,7	19,3	*17,3*	*15,3*
EN AW-5005	O/H111	40	26,7	26,7	25,9	25,1	*23,3*	*21,5*	*19,8*	*16,0*
EN AW-5005A	O/H111	40	26,7	26,7	26,0	25,3	*22,8*	*20,4*	*18,0*	*14,7*
EN AW-5049	O/H111	80	53,3	53,3	52,0	50,7	*44,0*	*30,7*	*22,0*	*16,0*
EN AW-5052	O/H111	65	43,3	43,3	42,7	41,3	*34,2*	*27,1*	*20,0*	*13,3*
EN AW-5154A	O/H111	85	56,7	56,7	55,3	54,0	*46,7*	*29,3*	*18,7*	*12,0*
EN AW-5754	O/H111	80	53,3	53,3	52,0	50,7	*40,7*	*26,0*	*15,3*	*10,7*
EN AW-5083	O/H111	110	73,3	73,3	71,6	71,6	*42,8*	*25,2*	*14,1*	*8,8*
EN AW-5086	O/H111	95	63,3	63,3	62,1	62,1	*45,6*	*27,2*	*16,5*	*10,8*

[a] Italic numerical values are creep-range values.

A.4 Forgings

Mechanical properties shall comply with EN 586-2:1994.

Table A.4 — Forgings

EN AW number	Test direction	Temper	$R_{p,20°C}$ MPa	Value of *f* for design temperature[a] MPa							
				20°C	50°C	75°C	100°C	125°C	150°C	175°C	200°C
EN AW-5754		H112	80	53,3	53,3	52,2	50,7	*23,2*	*14,9*	*8,8*	*6,1*
EN AW-5083	L (12%)	H112	120	80,0	80,0	80,0	76,2	*46,7*	*27,5*	*15,4*	*9,6*
	T (10%)	H112	110	73,3	73,3	73,3	69,8	*42,8*	*25,2*	*14,1*	*8,8*

[a] Italic numerical values are creep-range values.

A.5 Plate

Mechanical properties for plates shall comply with EN 485-2:2013.

Table A.5 — Plate

EN AW number	Temper	Wall thickness Mm	$R_{p,20°C}$ MPa	Value of *f* for design temperature[a] MPa							
				20°C	50°C	75°C	100°C	125°C	150°C	175°C	200°C
EN AW-1050A	O/H111		20	20,0	19,3	18,7	16,7	13,3	10,0	8,0	6,3
	H112	6 ≤ t ≤ 12,5	30	20,0	19,3	18,7	16,7	13,3	10,0	*8,0*	*6,4*
		12,5 < t ≤ 80	25	16,7	16,1	15,6	13,9	11,1	8,3	*6,7*	*5,3*
EN AW-1070A	O/H111		15	16,7	16,0	15,3	14,0	13,3	12,7	—	—
	H112	6 ≤ t ≤ 12,5	20	22,2	21,3	20,4	18,7	17,8	16,9	—	—
EN AW-1080A	O/H111		15	14,7	14,0	13,3	12,7	12,0	11,3	—	—
EN AW-3003	O/H111	t ≤ 50	35	23,3	23,3	22,0	21,3	20,7	19,3	*17,3*	*15,3*
	H112	6 ≤ t < 12,5	70	46,7	46,7	44,7	42,0	*34,7*	*26,0*	*19,3*	*15,3*
		12,5 ≤ t < 80	40	26,7	26,7	25,5	24,0	*19,8*	*14,9*	*11,0*	*8,8*
EN AW-3103	O/H111		35	23,3	23,3	22,0	21,3	20,7	19,3	*19,3*	*15,3*
	H112	6 ≤ t < 12,5	70	45,8	45,8	44,7	42,0	*34,7*	*26,0*	*19,3*	*15,3*
		12,5 ≤ t < 80	40	26,7	26,7	25,5	24,0	*19,8*	*14,9*	*11,0*	*8,8*
EN AW-3105	O/H111		40	26,7	26,7	25,3	24,0	*30,0*	*23,3*	*17,3*	*14,0*
EN AW-5005	O/H111		35	23,3	23,3	22,7	22,0	*20,4*	*18,8*	*17,3*	*14,0*
EN AW-5005A	O/H111		35	23,3	23,3	22,8	22,2	*20,0*	*17,9*	*15,8*	*12,8*

Table A.5 *(continued)*

EN AW number	Temper	Wall thickness mm	$R_{p,20°C}$ MPa	Value of *f* for design temperature MPa							
				20°C	50°C	75°C	100°C	125°C	150°C	175°C	200°C
EN AW-5050	O/H111		45	30,0	30,0	29,3	28,7	*25,8*	*22,9*	*20,0*	*14,7*
	H112		55	36,7	36,7	36,0	34,7	*29,8*	*24,9*	*20,0*	*14,7*
EN AW-5049	O/H111		80	53,3	53,3	52,0	50,7	*44,0*	*30,7*	*22,0*	*16,0*
	H112	6 < t ≤ 12,5	100	66,7	66,7	65,2	63,3	*31,4*	*21,9*	*15,7*	*11,4*
		12,5 < t ≤ 25	90	60,0	60,0	58,7	57,0	*28,3*	*19,7*	*14,1*	*10,3*
		25 < t ≤ 80	80	53,3	53,3	52,2	50,7	*25,1*	*17,5*	*12,6*	*9,1*
EN AW-5052	O/H111	0,2 < t ≤ 80	65	43,3	43,3	42,7	41,3	*34,2*	*27,1*	*20,0*	*13,3*
	H112	6 < t ≤ 12,5	80	53,3	53,3	52,4	50,9	*31,5*	*30,1*	*14,5*	*9,7*
		12,5 < t ≤ 80	70	46,7	46,7	45,8	44,5	*27,6*	*26,3*	*12,7*	*8,5*
EN AW-5154A	O/H111		85	56,7	56,7	55,3	54,0	*46,7*	*29,3*	*18,7*	*12,0*
	H112	6 < t ≤ 12,5	125	83,3	83,3	81,3	79,3	*46,7*	*29,3*	*18,7*	*12,0*
		12,5 < t ≤ 80	90	60,0	60,0	58,6	57,1	*33,6*	*21,1*	*13,4*	*8,6*
EN AW-5251	O/H111		60	40,0	40,0	39,3	38,0	*32,6*	*27,3*	*18,0*	*12,7*
EN AW-5454	O/H111		85	56,7	56,7	55,3	54,0	*45,3*	*31,3*	*21,3*	*15,3*
	H112	40 < t ≤ 120	90	60,0	60,0	58,6	57,1	*32,6*	*22,6*	*15,4*	*11,0*
EN AW-5754	O/H111		80	53,3	53,3	52,0	50,7	*40,7*	*26,0*	*15,3*	*10,7*
	H112	6 < t ≤ 12,5	100	66,7	66,7	65,2	63,3	*29,0*	*18,6*	*11,0*	*7,6*
		12,5 < t ≤ 25	90	60,0	60,0	58,7	57,0	*26,1*	*16,7*	*9,9*	*6,9*
		25 < t ≤ 80	80	53,3	53,3	52,2	50,7	*23,2*	*14,9*	*8,8*	*6,1*

Table A.5 *(continued)*

EN AW number	Temper	Wall thickness mm	$R_{p,20°C}$ MPa	Value of *f* for design temperature MPa							
				20°C	50°C	75°C	100°C	125°C	150°C	175°C	200°C
EN AW-5083	O/H111	t ≤ 50 [b]	125	83,3	83,3	83,3	79,3	*48,7*	*28,7*	*16,0*	*10,0*
		50 < t ≤ 80	115	76,7	76,7	76,7	73,0	*44,8*	*26,4*	*14,7*	*9,2*
		80 < t ≤ 120	110	73,3	73,3	73,3	69,8	*42,8*	*25,2*	*14,1*	*8,8*
		120 < t ≤ 200	105	70,0	70,0	70,0	66,6	*40,9*	*24,1*	*13,4*	*8,4*
		200 < t ≤ 250	95	63,3	63,3	63,3	60,3	*37,0*	*21,8*	*12,2*	*7,6*
		250 < t ≤ 300	90	60,0	60,0	60,0	57,1	*35,0*	*20,6*	*11,5*	*7,2*
	H112	6 < t ≤ 40	125	83,3	83,3	83,3	79,3	*48,7*	*28,7*	*16,0*	*10,0*
		40 < t ≤ 80	115	76,7	76,7	76,7	73,0	*44,8*	*26,4*	*14,7*	*9,2*
		80 < t ≤ 120	110	73,3	73,3	73,3	69,8	*42,8*	*25,2*	*14,1*	*8,8*
EN AW-5086	O/H111		100	66,7	66,7	66,7	63,3	*48,0*	*28,7*	*17,3*	*11,3*
	H112	40 < t ≤ 80	100	66,7	66,7	66,7	63,5	*38,4*	*22,9*	*13,9*	*9,1*

a Italic numerical values are creep-range values.

b Yield strength at room temperature of 125 MPa shall be guaranteed and verified by the plate manufacturer.

Annex Y
(informative)

History of EN 13445-8

Y.1 Differences between EN 13445-8:2009 and EN 13445-8:2014

The 2014 edition of EN 13445-8 contains the 2009 edition of the standard and all corrections issued in the meantime.

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

Y.2 List of corrected pages of Issue 2 (2015-07)

Pages 2, 3, 5, 6, 6a, 7, 8, 9, 10, 11, 11a, 12, 12a, 13, 14, 15, 16, 19, 20, 21, 24a to 24f, 25, 26, 27.

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
5, Annex A	2.2.3 (b), 5th indent	Provision and consideration of appropriate material properties
5.3	4.1 (a)	Prevention of brittle fracture
5.5	4.1 (d)	Material suitable for intended processing procedure
6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8	2.2	Design for adequate strength
6.3	7.1.2	Quantitative requirements
6.4, 6.6, 6.7	2.2.3 (a)	Calculation method — Design by Formula (DBF)
7.5, 7.9, 7.10, 7.11	3.1.2	Operating procedure to carry out permanent joints
7.6	3.1.2	Qualified personnel to carry out permanent joints
7.7	3.1.1	Preparation of component parts
7.8	3.1.2	Operating procedure to carry out permanent joints
7.12	3.1.1	Forming
7.13, 7.16	3.1.4	Heat treatment
8.2, 8.3, 8.4, 8.5	3.2.1	Internal and surface defect
8.6, 8.7	3.2.2	Proof test

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

Bibliography

[1] EN 287-1:2004, *Qualification test of welders — Fusion welding — Part 1: Steels*

[2] EN 764-4:2002, *Pressure equipment — Part 4: Establishment of technical delivery conditions for metallic materials*

[3] EN 1252-1:1998, *Cryogenic vessels — Materials — Part 1: Toughness requirements for temperatures below -80°C*

[4] EN 1418:1997, *Welding personnel — Approval testing of welding operators for fusion welding and resistance weld setters for fully mechanised and automatic welding of metallic materials*

[5] EN ISO 15614-1:2004, *Specification and qualification of welding procedures for metallic materials - Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys* (ISO 15614-1:2004)

[6] EN ISO 23279:2010, *Non-destructive testing of welds — Ultrasonic testing —Characterization of indications in welds* (ISO 23279:2010)

[7] ISO 2553:1992, *Welded, brazed and soldered joints — Symbolic representation on drawings*

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