



SLOVENSKI STANDARD

SIST EN 13445-4:2014

01-november-2014

Nadomešča:

SIST EN 13445-4:2009

SIST EN 13445-4:2009/A1:2012

SIST EN 13445-4:2009/A2:2014

Neogrevane tlačne posode - 4. del: Proizvodnja

Unfired pressure vessels - Part 4: Fabrication

Unbefeuerte Druckbehälter - Teil 4: Herstellung

Réceptifs sous pression non soumis à la flamme - Partie 4 : fabrication

<https://standards.iteh.ai/catalog/standards/sist/287304e9-cfb6-46ad-a7e7-dd0305aed9fb/sist-en-13445-4-2014>

Ta slovenski standard je istoveten z: **EN 13445-4:2014**

ICS:

23.020.30	Tlačne posode, plinske jeklenke	Pressure vessels, gas cylinders
-----------	---------------------------------	---------------------------------

SIST EN 13445-4:2014

en,fr,de

iTeh STANDARD PREVIEW
(standards.iteh.ai)

[SIST EN 13445-4:2014](#)

<https://standards.iteh.ai/catalog/standards/sist/287304e9-cfb6-46ad-a7e7-dd0305aed9fb/sist-en-13445-4-2014>

EUROPEAN STANDARD

EN 13445-4

NORME EUROPÉENNE

EUROPÄISCHE NORM

September 2014

ICS 23.020.30

Supersedes EN 13445-4:2009

English Version

Unfired pressure vessels - Part 4: Fabrication

Récipients sous pression non soumis à la flamme - Partie 4:
Fabrication

Unbefeuerte Druckbehälter - Teil 4: Herstellung

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.

CEN members are the national standards bodies of 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 United Kingdom.

SIST EN 13445-4:2014

<https://standards.iteh.ai/catalog/standards/sist/287304e9-cfb6-46ad-a7e7-dd0305aed9fb/sist-en-13445-4-2014>



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

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

Contents

Page

Foreword.....	5
1 Scope	7
2 Normative references	7
3 Requirements for manufacturing and subcontracting	9
3.1 Manufacturing	9
3.2 Subcontracting.....	9
4 Materials	10
4.1 General.....	10
4.2 Material traceability	10
4.2.1 General.....	10
4.2.2 Identification system	10
4.2.3 Visibility	11
4.2.4 Review of material certification and material identification	11
4.2.5 Transfer of markings	11
5 Manufacturing tolerances	11
5.1 Surface geometry of welds	11
5.2 Middle line alignment	11
5.3 Surface alignment.....	13
5.3.1 Surface misalignment between parts	13
5.3.2 Joining of parts of different thickness	13
5.4 Tolerances for vessels subjected to internal pressure	13
5.4.1 External diameter	13
5.4.2 Out of roundness.....	13
5.4.3 Deviation from the longitudinal axis.....	14
5.4.4 Irregularities in profile.....	14
5.4.5 Local thinning	16
5.4.6 Dished ends.....	17
5.5 Tolerances for vessels subjected to external pressure	19
5.6 Structural tolerances	19
6 Weld details	19
6.1 General.....	19
6.2 Vessels or parts made of more than one course	19
6.3 Lapped joints, joggle joints, permanent backing strips	19
7 Welding	19
7.1 General.....	19
7.2 Welding procedure specification (WPS)	20
7.3 Welding procedure qualification record (WPQR).....	20
7.4 Qualification of welders and welding operators.....	21
7.5 Filler metals and auxiliary materials.....	21
7.6 Joint preparation.....	21
7.7 Execution of welded joints	22
7.8 Attachments, supports and stiffeners.....	22
7.9 Preheat.....	23
7.10 Permanent joints other than welding.....	23
7.10.1 General.....	23
7.10.2 Mechanical roller expansion.....	23
7.10.3 Brazing.....	23
8 Manufacture and testing of welds — Production test.....	23
8.1 General.....	23
8.2 Reference criteria.....	24

8.3	Extent of testing.....	27
8.4	Performance of tests and acceptance criteria.....	29
8.4.1	General.....	29
8.4.2	Transverse tensile test.....	29
8.4.3	Longitudinal weld tensile test	29
8.4.4	Impact test.....	29
8.4.5	Bend test.....	29
8.4.6	Macro examination	30
8.4.7	Micro examination	30
8.4.8	Hardness test	30
8.4.9	Retests	30
8.4.10	Test report	31
9	Forming of pressure parts	31
9.1	General.....	31
9.2	Ratio of deformation.....	31
9.2.1	Dished circular products	31
9.2.2	Cylinders and cones made by rolling.....	32
9.2.3	Other product types	33
9.2.4	Tube bends.....	34
9.2.5	Forming of Segments.....	34
9.3	Forming procedures.....	35
9.3.1	Cold forming	35
9.3.2	Hot forming	35
9.4	Heat treatment after forming	38
9.4.1	General.....	38
9.4.2	Heat treatment of flat products after cold forming	38
9.4.3	Heat treatment of tubular products after cold forming.....	40
9.4.4	Heat treatment of clad steels after cold forming.....	40
9.4.5	Heat treatment after hot forming.....	40
9.4.6	Heat treatment of clad steels after hot forming.....	41
9.5	Sampling of formed test coupons.....	41
9.5.1	Cold formed products without heat treatment	41
9.5.2	Hot formed or cold formed products with heat treatment.....	41
9.6	Tests.....	42
9.6.1	Base material	42
9.6.2	Butt welds.....	42
9.6.3	Acceptance criteria for formed test coupons.....	43
9.6.4	Retests of formed coupons	43
9.7	Visual inspection and control of dimension.....	43
9.8	Marking	44
9.9	Documentation.....	44
10	Post weld heat treatment (PWHT).....	44
10.1	General.....	44
10.2	Heat treatment conditions	45
10.3	Method of PWHT	49
10.4	PWHT procedure.....	50
10.5	Mechanical properties after heat treatment	50
10.6	Dissimilar ferritic joints.....	51
10.7	Special materials	52
10.8	Heat Treatment for reasons other than welding.....	52
11	Repairs.....	53
11.1	Repairs of surface defects in the parent metal	53
11.2	Repair of weld defects.....	53
12	Finishing operations	53
Annex A	(informative) Structural tolerances	55
Annex B	(informative) Example of a sub-contractors form	59

EN 13445-4:2014 (E)
Issue 1 (2014-09)

Annex C (normative) Specification and approval of expansion procedures and operators	60
C.1 General	60
C.1.1 Introduction	60
C.1.2 Responsibility	60
C.1.3 Specification of expansion procedures	60
C.1.4 Technical content of expansion procedure specification (EPS)	61
C.1.5 Expansion procedure qualification test (EPQT)	62
C.2 Examination and testing	62
C.2.1 General	62
C.2.2 Visual examination	62
C.2.3 Dimensional verification	62
C.2.4 Testing	63
C.3 Range of approval	63
C.3.1 General	63
C.3.2 Manufacturer	63
C.3.3 Material	63
C.3.4 Tube dimensions	63
C.3.5 Expansion factor	63
C.3.6 Joint design	64
C.3.7 Tool	64
C.3.8 PWHT	64
C.4 Expansion Procedure Approval Record (EPAR)	64
C.5 Expansion operator approval	64
C.5.1 General	64
C.5.2 Validity range of expansion operator qualification	65
C.5.3 Qualification tests	65
C.5.4 Examination and testing	65
C.5.5 Period of validity	65
C.5.6 Certification	66
Annex Y (informative) History of EN 13445-4	67
Y.1 Differences between EN 13445-4:2009 and EN 13445-4:2014	67
Annex ZA (informative) Relationship between this European Standard and the Essential Requirements of the EU Pressure Equipment Directive 97/23/EC	68
Bibliography	69

Foreword

This document (EN 13445-4:2014) 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 13445-4:2009. 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.

EN 13445-4:2014 (E)
Issue 1 (2014-09)

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.

iTeh STANDARD PREVIEW

(standards.iteh.ai)

[SIST EN 13445-4:2014](https://standards.iteh.ai/catalog/standards/sist/287304e9-cfb6-46ad-a7e7-dd0305aed9fb/sist-en-13445-4-2014)

<https://standards.iteh.ai/catalog/standards/sist/287304e9-cfb6-46ad-a7e7-dd0305aed9fb/sist-en-13445-4-2014>

1 Scope

This document specifies requirements for the manufacture of unfired pressure vessels and their parts, made of steels, including their connections to non-pressure parts. It specifies requirements for material traceability, manufacturing tolerances, welding requirements, requirements for permanent joints other than welding, production tests, forming requirements, heat treatment, repairs and finishing operations.

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 287-1:2011¹⁾, *Qualification test of welders — Fusion welding — Part 1: Steels*

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 10216-1:2013, *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 1: Non-alloy steel tubes with specified room temperature properties*

EN 10216-2:2013, *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 2: Non-alloy and alloy steel tubes with specified elevated temperature properties*

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 10217-1:2002, EN 10217-1:2002/A1:2005, *Welded steel tubes for pressure purposes — Technical delivery conditions — Part 1: Non-alloy steel tubes with specified room temperature properties*

EN 10217-2:2002, EN 10217-2:2002/A1:2005, *Welded steel tubes for pressure purposes — Technical delivery conditions — Part 2: Electric welded non-alloy and alloy steel tubes with specified elevated temperature properties*

EN 10217-3:2002, EN 10217-3:2002/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 and alloy steel tubes with specified low temperature properties*

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.

EN 13445-4:2014 (E)
Issue 1 (2014-09)

EN 10217-5:2002, EN 10217-5:2002/A1:2005, *Welded steel tubes for pressure purposes — Technical delivery conditions — Part 5: Submerged arc welded non-alloy and alloy steel tubes with specified elevated 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 10222-2:1999, *Steel forgings for pressure purposes — Part 2: Ferritic and martensitic steels with specified elevated temperature properties*

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

EN 10222-4:1998+A1:2002, *Steel forgings for pressure purposes — Part 4: Weldable fine grain steels with high proof strength*

EN 13134:2000, *Brazing — Procedure approval*

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

EN 13445-2:2014, *Unfired pressure vessels — Part 2: Materials*

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

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

EN 14276-1:2006+A1:2011, *Pressure equipment for refrigerating systems and heat pumps — Part 1: Vessels — General requirements*

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 4136:2012, *Destructive tests on welds in metallic materials — Transverse tensile test (ISO 4136:2012)*

EN ISO 5173:2010, *Destructive tests on welds in metallic materials — Bend tests (ISO 5173:2009)*

EN ISO 5178:2011, *Destructive tests on welds in metallic materials — Longitudinal tensile test on weld metal in fusion welded joints (ISO 5178:2001)*

EN ISO 9015-1:2011, *Destructive tests on welds in metallic materials — Hardness testing — Part 1: Hardness test on arc welded joints (ISO 9015-1:2001)*

EN ISO 9016:2012, *Destructive tests on welds in metallic materials — Impact tests — Test specimen location, notch orientation and examination (ISO 9016:2012)*

EN ISO 13585:2012, *Brazing — Qualification test of brazers and brazing operators (ISO 13585:2012)*

EN ISO 14732:2013, *Welding personnel — Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials (ISO 14732:2013)*

EN ISO 15609-1:2004, *Specification and qualification of welding procedures for metallic materials — Welding procedure specification — Part 1: Arc welding (ISO 15609-1:2004)*

EN ISO 15611:2003, *Specification and qualification of welding procedures for metallic materials — Qualification based on previous welding experience* (ISO 15611:2003)

EN ISO 15612:2004, *Specification and qualification of welding procedures for metallic materials — Qualification by adoption of a standard welding procedure* (ISO 15612:2004)

EN ISO 15613:2004, *Specification and qualification of welding procedures for metallic materials — Qualification based on pre-production welding test* (ISO 15613:2004)

EN ISO 15614-1:2004, EN ISO 15614-1:2004/A1:2008, *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, ISO 15614-1:2004/A1:2008)

EN ISO 17639:2013, *Destructive tests on welds in metallic materials — Macroscopic and microscopic examination of welds* (ISO 17639:2013)

3 Requirements for manufacturing and subcontracting

3.1 Manufacturing

The general responsibilities of the pressure vessel manufacturer are stated in EN 13445-1:2014. Additionally to those requirements, the manufacturer shall ensure that:

- a) the organisation for the control of manufacturing operations which includes special processes such as welding, forming and heat treatment shall be clearly defined by the manufacturer;
- b) the manufacturing procedures such as welding, forming and heat treatment are adequate for the purpose and the pressure vessel meets the requirements of this standard. Where specific requirements are associated with materials these shall be taken into account, e.g. EAMs;
- c) the manufacturing equipment is adequate for fabrication;
- d) the staff is adequate for the assigned tasks;

NOTE As far as welding co-ordination is concerned, the qualifications, tasks and responsibilities can be defined by the manufacturer in accordance with EN ISO 14731:2007 [1] in the job assignment.

- e) the quality requirements for welding defined in EN ISO 3834-3:2005 are met as a minimum.

3.2 Subcontracting

The manufacturer may subcontract work, but shall ensure that the subcontractor carries out the work in accordance with the requirements of this European Standard. The manufacturer is responsible for the adequate definition of the subcontracted task and the need for any associated records.

On all occasions that the subcontractor work includes

- a) welding;
- b) forming including associated heat treatment;
- c) post weld heat treatment;
- d) non-destructive testing of welds (see EN 13445-5:2014),

the manufacturer shall obtain a subcontractor form (see Annex B).

EN 13445-4:2014 (E) Issue 1 (2014-09)

Where welding operations are subcontracted, the manufacturer shall also either obtain copies of the welding procedure and welding operator qualification records or take other action to ensure that they comply with this standard.

In discharging his responsibility to ensure that the subcontractor carries out the work in accordance with this standard the manufacturer shall ensure that surveillance of the subcontracted work is performed.

Where a manufacturer is producing equipment that requires the intervention of a responsible authority, the manufacturer should inform the responsible authority of his intention to subcontract so that the responsible authority has the opportunity to take part in the subcontractor surveillance.

NOTE 1 See also EN 764-3:2002, 2.11 [2] and CR 13445-7.

NOTE 2 When the manufacturer is producing equipment based on quality assurance, the controls a manufacturer applies over subcontractors should be described in his approved quality system.

4 Materials

4.1 General

Materials for pressure vessels and the grouping of materials for pressure vessels shall be in accordance with EN 13445-2:2014.

The grouping applies regardless of product form, i.e. plate, forging, piping.

4.2 Material traceability

4.2.1 General

SIST EN 13445-4:2014
<https://standards.iteh.ai/catalog/standards/sist/287304e9-cfb6-46ad-a7e7-dd0305aed9fb/sist-en-13445-4-2014>

The vessel manufacturer shall have and maintain an identification system for materials used in fabrication, so that all material subject to stress due to pressure and those welded thereto in the completed work can be traced to its origin. This includes the use of welding consumables.

4.2.2 Identification system

4.2.2.1 The vessel manufacturer's identification system shall assure that all materials to be used in the vessel have been subjected to and satisfactorily passed the following:

- a) examination of material before fabrication for the purpose of detecting, as far as possible, imperfections which would affect the safety of the work;
- b) check of material to determine that it has the required thickness;
- c) check of the material to assure that the materials are permitted by this European Standard, fully traceable to the correct material certification and as specified in the design documentation;
- d) check of the welding consumables to assure the correct markings and that correct conditions are maintained to prevent deterioration.

4.2.2.2 Material traceability to the original identification markings shall be by one or more of the following methods:

- a) accurate transfer of the original identification markings to a location where the markings will be visible on the completed vessel;
- b) identification by a coded marking traceable to the original required marking;
- c) recording the identification markings using material lists or as built sketches which assure identification of each piece of material during fabrication and subsequent identification in the completed vessel;
- d) the batch numbers of welding consumables shall be recorded.

4.2.3 Visibility

Materials which cannot be stamped or which will not be visible after the vessel is completed or for small multiple parts or non pressure parts the manufacturer may operate a documented system which ensures material traceability for all materials in the completed vessel.

4.2.4 Review of material certification and material identification

All material certification shall be reviewed upon receipt. The review shall cover the completeness and adequacy of the reports against the following:

- a) mechanical and chemical properties required to be reported by the material specification;
- b) assuring that the reported results meet the requirements of the specification;
- c) all markings required by the material specification are satisfied and that there is traceability between the actual markings and those recorded on the material certification.

All materials certification shall be made readily available throughout manufacture.

<https://standards.iteh.ai/catalog/standards/sist/287304e9-cfb6-46ad-a7e7-dd0305aed9fb/sist-en-13445-4-2014>

4.2.5 Transfer of markings

In case the original identification markings are unavoidably cut out or the material is divided into two or more pieces the markings shall be accurately transferred by the manufacturer's nominated personnel prior to cutting.

The actual material marking shall be by methods which are not harmful to the material in subsequent use/operation.

The transfer of markings shall take place before partitioning of the product and after verification of the marks present with the corresponding certification.

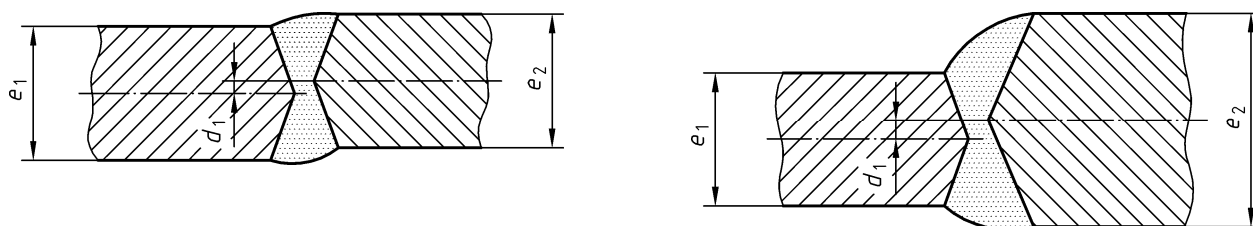
5 Manufacturing tolerances

5.1 Surface geometry of welds

The surface geometry of welded butt and fillet joints shall meet the requirements of EN 13445-5:2014 unless the drawing specifies more stringent requirements.

5.2 Middle line alignment

The misalignment tolerances of middle lines shall be as specified in Tables 5.2-1, 5.2-2, 5.2-3 and Figure 5.2-1.



a) Middle line alignment d_1 at equal thickness $e_1 = e_2$ b) Middle line alignment d_1 at different thickness $e_1 \leq e_2$

Figure 5.2-1 — Middle line alignment d_1

For longitudinal welds in cylinders, cones and rectangular/prismatic structures the middle lines of adjacent components (whether of equal or different thickness) shall be aligned within the tolerances specified in Table 5.2-1.

Table 5.2-1 — Offset of middle lines for longitudinal welds in cylinders, cones and rectangular/prismatic structures

Dimensions in millimetres

Thinner part thickness e_1	Maximum misalignment d_1
$e_1 \leq 2$	0,5
$2 < e_1 \leq 4$	$e_1/4$
$4 < e_1 \leq 10$	1
$10 < e_1 \leq 30$	$e_1/10$
$30 < e_1 \leq 60$	$e_1/30 + 2$
$60 < e_1$	4

For longitudinal welds in dished ends and welds in spherical components the middle lines of adjacent parts (whether of equal or different thickness) shall be aligned within the tolerances specified in Table 5.2-2.

Table 5.2-2 — Offset of middle lines for longitudinal welds in dished ends and in spherical components of adjacent parts

Dimensions in millimetres

Thinner part thickness e_1	Maximum misalignment d_1
$e_1 \leq 2$	0,5
$2 < e_1 \leq 4$	$e_1/4$
$4 < e_1 \leq 10$	1
$10 < e_1 \leq 30$	$e_1/10$
$30 < e_1 \leq 120$	$e_1/30 + 2$
$120 < e_1$	6

For circumferential welds the middle lines of adjacent parts (whether of equal or different thickness) shall be aligned within the tolerances specified in Table 5.2-3.

Table 5.2-3 — Offset of middle lines of circumferential welds of adjacent parts

Dimensions in millimetres

Thinner part thickness e_1	Maximum misalignment d_1
$e_1 \leq 30$	$e_1/10 + 1$
$30 < e_1 \leq 150$	$e_1/30 + 3$
$150 < e_1$	8

5.3 Surface alignment

5.3.1 Surface misalignment between parts

Where there is misalignment at the surface between parts of the same nominal thickness the transition across the weld shall be smooth and gradual with a slope of 1 in 4 over the width of the weld. If this taper cannot be accommodated within the weld width it is permissible to either:

- grind the higher plate surface, where this will not reduce the joint thickness at any point below the nominal specified plate thickness minus the plate thickness tolerance;
- build up the lower plate surface with added weld metal

5.3.2 Joining of parts of different thickness

Where different thickness are being joined a taper shall be produced in accordance with EN 13445-3:2014 by either:

- taper the thicker plate in accordance with the design drawing and then applying the requirements above for the same nominal thickness parts; or
- obtain the required slope across the width of the welds, or by a combination of weld build up on the lower surface with added weld metal and thereafter obtain the required slope across the weld width.

5.4 Tolerances for vessels subjected to internal pressure

5.4.1 External diameter

For cylindrical and spherical pressure vessels the mean external diameter derived from the circumference shall not deviate by more than 1,5 % from the specified external diameter.

For rectangular vessels and/or prismatic structures each external dimension shall not deviate by more than 1,5 % from the specified external dimension.

5.4.2 Out of roundness

Out of roundness (O) shall be calculated in accordance with the following Equation (5.4-1):

$$O [\%] = \frac{2 \cdot (D_{\max} - D_{\min})}{D_{\max} + D_{\min}} \cdot 100 \quad (5.4-1)$$

It shall not exceed the following values:

- 1,5 % for the ratio of $e/D < 0,01$;