

European standard

French standard

NF EN 13445-5 V1
October 2009

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ICS: 23.020.30

Unfired pressure vessels

Part 5: Inspection and testing

F : Récipients sous pression non soumis à la flamme — Partie 5 : Inspection et contrôle
D : Unbefeuerte Druckbehälter — Teil 5: Inspektion und Prüfung

French standard approved

by decision of the Director General of AFNOR on September 2, 2009 taking effect on October 2, 2009.

Replaces the approved standard NF EN 13445-5, dated September 2002 and its amendments A1 dated September 2007, A2 dated November 2005, A3 dated August 2006, A4 dated March 2007, A5 dated December 2006 and A10 dated November 2008.

Correspondence

The European standard EN 13445-5 V1:2009 (issue 1: 2009-07) has the status of French standard.

Analysis

This document defines the requirements for inspection and control of pressure vessels not subjected to flame. The six other parts of this document set the scope, terms, definitions, symbols and units, the requirements for the materials, design and manufacturing, as well as additional requirements for spheroidal graphite cast iron vessels and aluminum vessels.

All parts NF EN 13445-1 to NF EN 13445-6 and NF EN 13445-8 are intended to support the essential requirements of European Directive 97/23/EC "Pressure Equipment".

Descriptors

Technical International Thesaurus: pressure vessels, verification, inspection, design, manufacturing, sub contracting, calibration, marking, conformity tests, nondestructive tests, pressure tests, dimensions, openings, leak detection, acoustic emission, certification.

Modifications

With respect to the replaced documents, revision into a new edition (see Annex Y).

Corrections



National foreword

Version 1 of the new 2009 edition of standard NF EN 13445 replaces the 2002 edition by incorporating amendments and corrected pages having been subject to versions 2 to 36, without any further technical modification.

Amendments to this new edition will be adopted in the future. They will be published in a separate form before being incorporated into the next version that is expected to be published annually.

At the French level, AFNOR will provide these various documents in the form of versions, amendments and corrections identified as follows:

Document type	Identification
Version : Full text of the standard, freestanding	NF EN 13445-5 V1 NF EN 13445-5 V2 ...
Amendment : identification of modifications and/or technical additions to the text of the current version	NF EN 13445-5/A1 ...
Correction : corrected pages to replace the corresponding pages of version N to produce version N+1 For example, NF EN 13445-5/AC1 gives pages that have been corrected in Version 1 to produce Version 2	NF EN 13445-5/AC1 ...

The current version, the pages corrected with respect to the previous version, the amendments adopted at a date later than the current version will be available simultaneously at the AFNOR sites. Any previous document will be obtained from AFNOR at the address: norminfo@afnor.org.

EXAMPLE Given the adoption of EN 13445-5/A1 in January 2010 and EN 13445-5/A2 in November 2010, the following documents will be available from AFNOR:

	2009				2010												2011	
	09	10	11	12	01	02	03	04	05	06	07	08	09	10	11	12	01	..
NF EN 13445-5 V1	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	x	x	x	x	x	x
NF EN 13445-5/A1	—	—	—	—	—	xx	xx	xx	xx	xx	xx	xx	x	x	x	x	x	x
NF EN 13445-5 V2	—	—	—	—	—	—	—	—	—	—	—	—	xx	xx	xx	xx	xx	xx
NF EN 13445-5/AC1	—	—	—	—	—	—	—	—	—	—	—	—	xx	xx	xx	xx	xx	xx
NF EN 13445-5/A2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	xx	xx	xx
xx: document available x: document upon request —: document not available																		



EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 13445-5

July 2009

ICS 23.020.30

Supersedes EN 13445-5:2002

English Version

Unfired pressure vessels - Part 5: Inspection and testing

Réceptacles sous pression non soumis à la flamme - Partie 5
: inspection et contrôles

Unbefeuerte Druckbehälter - Teil 5: Inspektion und Prüfung

This European Standard was approved by CEN on 30 June 2009.

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 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 Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.



EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
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EN 13445-5:2009 (E)
Issue 1 (2009-07)

Contents

Page

Foreword.....	5
1 Scope	6
2 Normative references	6
3 Terms and definitions	7
4 Performance of inspection and testing	9
4.1 General.....	9
4.2 Inspection	9
4.3 Non-destructive testing (NDT).....	9
5 Technical documentation	9
5.1 General.....	9
5.2 Information to be contained in the technical documentation	9
5.2.1 General description of the pressure vessel	9
5.2.2 Conceptual design and construction drawings	10
5.2.3 Descriptions and explanations necessary for an understanding of the drawings and diagrams and the operation of the pressure vessel	10
5.2.4 Results of design calculations and examinations carried out.....	10
5.2.5 Test reports	12
5.2.6 Technical/manufacturing schedule.....	12
5.3 Design review.....	13
5.3.1 General.....	13
5.3.2 Design review.....	13
6 Inspection and testing during fabrication	13
6.1 General.....	13
6.2 Manufacturing procedures and construction drawings	14
6.3 Material traceability	14
6.3.1 General.....	14
6.3.2 Special Conditions - Material marking	14
6.4 Preparation for manufacturing processes	14
6.4.1 General.....	14
6.4.2 Joint preparation testing.....	14
6.4.3 Inspection of vessel supports	14
6.4.4 Inspection associated with forming.....	15
6.4.5 Testing of areas subject to significant through thickness tensile stress.....	15
6.5 Welding	15
6.5.1 General.....	15
6.5.2 Verification of welder and welding operator approval and procedures approval	15
6.5.3 Inspection of repairs	16
6.6 Non-destructive testing of welded joints	16
6.6.1 Extent of non-destructive testing.....	16
6.6.2 Determination of extent of non-destructive testing	19
6.6.3 Performing non-destructive testing.....	27
6.6.4 Description and acceptance level assessment of imperfections	29
6.6.5 Stage of performance.....	29
6.6.6 Procedure for non-destructive retesting	29
6.6.7 Non-destructive testing documentation.....	31
6.7 Destructive testing.....	31
6.7.1 Extent of destructive testing	31
6.7.2 Schedule for destructive testing	31
6.7.3 Verification of destructive tests	31
6.7.4 Records.....	31
6.8 Heat-treatment.....	31

7	Subcontracted elements	32
7.1	General.....	32
7.2	Subcontracted welding related activities.....	32
7.3	Subcontracted non-destructive testing activities	32
7.3.1	Use of contract NDT personnel at the premises of the vessel manufacturer	32
7.3.2	Subcontracting of NDT at a subcontractors premises	32
8	Miscellaneous tests	33
9	Calibration	33
9.1	General.....	33
9.2	Calibration procedure	33
9.2.1	General.....	33
9.2.2	Calibration	34
9.2.3	Frequency.....	34
9.3	Identification	34
9.4	Registration	34
10	Final assessment.....	35
10.1	General.....	35
10.2	Extent of final assessment	35
10.2.1	Visual and dimensional inspection.....	35
10.2.2	Review of documentation	36
10.2.3	Proof test	36
10.2.4	Post pressure test inspection	46
10.2.5	Inspection of safety accessories.	46
11	Marking and declaration of compliance with the standard.	46
11.1	General.....	46
11.2	Marking method	46
11.2.1	Direct stamping.....	47
11.2.2	Nameplate.....	47
11.3	Marking units	47
11.4	Marking contents	47
11.5	Declaration of compliance with the standard	48
12	Records.....	48
12.1	Type of records.....	48
12.2	Control and access of records.....	49
12.3	Retention of records.....	50
13	Shipping.....	50
Annex A (normative) Inspection and testing of serially produced pressure vessels Model acceptance		51
Annex B (normative) Detailed dimensional requirements for pressure vessels.....		57
Annex C (normative) Access and inspection openings, closing mechanisms and special locking elements		59
Annex D (informative) Leak Testing		71
Annex E (informative) Acoustic emission		72
Annex F (normative) Inspection and testing of pressure vessels or parts subject to creep.....		74
Annex G (normative) Inspection and testing of pressure vessels subject to cyclic loads.....		77
Annex H (informative) Declaration of compliance with this standard		79



EN 13445-5:2009 (E)
Issue 1 (2009-07)

Annex I (informative) Specific tests during construction to assist in-service inspection..... 81

Annex Y (informative) Differences between EN 13445-5:2002 and EN 13445-5:2009..... 83

**Annex ZA (informative) Relationship between this European Standard and the Essential Requirements
of the EU Pressure Equipment Directive 97/23/EC..... 84**

Bibliography..... 85



Foreword

This document (EN 13445-5:2009) 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 2009*, and conflicting national standards shall be withdrawn at the latest by *December 2009*.

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*

This document supersedes EN 13445-5:2009. This new edition incorporates the Amendments which have been approved previously by CEN members, and the corrected pages up to Issue 36 without any further technical change. Annex Y to EN 13445-1:2009 and Annex Y to this Part 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 13445:2009 each year, 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, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.



EN 13445-5:2009 (E)
Issue 1 (2009-07)

1 Scope

This Part of this European Standard specifies the inspection and testing of individual and serially produced pressure vessels made of steels in accordance with EN 13445-2:2009 subject to predominantly non_cyclic operation (i.e. vessels operating below 500 full equivalent pressure cycles).

Special provisions for cyclic operation are given in EN 13445-3:2009 and in Annex G of this Part.

Special provisions for vessels or vessel parts working in the creep range are given in Clause 5, Clause 6, Clause 10, Annex H and Annex I of this Part.

NOTE The responsibilities of parties involved in the conformity assessment procedures are given in Directive 97/23/EC. Guidance on this can be found in CR 13445-7.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 287-1:2004, EN 287-1:2004/A2:2005, *Qualification test of welders — Fusion welding — Part 1: Steels.*

EN 473:2008, *Non-destructive testing — Qualification and certification of NDT personnel — General principles.*

EN 571-1:1997, *Non-destructive testing — Penetrant testing — Part 1: General principles.*

CEN/TS 764-6:2004, *Pressure equipment — Part 6: Structure and content of operating instructions.*

EN 583-4:2002, EN 583-4:2002/A1:2003, *Non-destructive testing — Ultrasonic examination — Part 4: Examination for discontinuities perpendicular to the surface.*

EN 895:1995, *Destructive tests on welds in metallic materials — Transverse tensile test.*

EN 970:1997, *Non-destructive examination of fusion welds — Visual examination.*

EN 1289:1998, EN 1289:1998/A1:2002, EN 1289:1998/A2:2003, *Non-destructive testing of welds — Penetrant testing of welds — Acceptance levels.*

EN 1290:1998, EN 1290:1998/A1:2002, EN 1290:1998/A2:2003, *Non-destructive testing of welds — Magnetic particle testing of welds.*

EN 1291:1998, EN 1291:1998/A1:2002, EN 1291:1998/A2:2003, *Non-destructive testing of welds — Magnetic particle testing of welds — Acceptance levels.*

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

EN 1435:1997, EN 1435:1997/A1:2002, EN 1435:1997/A2:2003, *Non-destructive testing of welds — Radiographic testing of welded joints.*

EN 1712:1997, EN 1712:1997/A1:2002, EN 1712:1997/A2:2003, *Non-destructive testing of welds — Ultrasonic testing of welded joints — Acceptance levels.*

EN 1713:1998, EN 1713:1998/A1:2002, EN 1713:1998/A2:2003, *Non-destructive testing of welds — Ultrasonic testing — Characterization of indications in welds.*

EN 1714:1997, EN 1714:1997/A1:2002, EN 1714:1997/A2:2003, *Non-destructive examination of welds — Ultrasonic examination of welded joints.*

EN 1779:1999, EN 1779:1999/A1:2003, *Non-destructive testing — Leak testing — Criteria for method and technique selection.*

EN 12062:1997, EN 12062:1997/A1:2002, EN 12062:1997/A2:2003, *Non-destructive testing of welds — General rules for metallic materials.*

EN 12517-1:2006, *Non-destructive testing of welds — Radiographic testing of welded joints — Acceptance levels.*

EN 13445-1:2009, *Unfired pressure vessels — Part 2: 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 ISO 4063:2000, *Welding and allied processes – Nomenclature of processes and reference numbers (ISO 4063:1998).*

EN ISO 5817:2007, *Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) – Quality levels for imperfections (ISO 5817:2003).*

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

3 Terms and definitions

For the purposes of this European Standard the following terms and definitions apply.

3.1

design review

procedure by which a manufacturer ascertains and attests that the design meets the requirements of this standard

3.2

design approval

procedure by which a responsible authority ascertains and attests that the design meets the requirements of this standard

3.3

testing group

grouping which determines the appropriate level of non-destructive testing (NDT) on a welded joint

NOTE There are four testing groups.

3.4

inspection

survey activity which assesses the compliance of the pressure vessel to the technical specification



EN 13445-5:2009 (E)
Issue 1 (2009-07)

NOTE It is a major activity, undertaken mainly by the manufacturer during design, manufacture and testing of equipment. It can be complemented by inspection by other parties. Inspection includes the assessment of testing activities.

3.5
testing

procedure used to attest vessel compliance with the technical requirements of this standard by one or more tests

3.6
technical specification

technical data included in the order or mandatory for pressure vessels and covering such things as regulations and user's specific requirements

3.7
repair

process of rectifying a condition in either base material or weld to ensure compliance with this standard

NOTE The following definitions all relate to serially produced pressure vessels as described in Annex A.

3.8
serial production

manufacture of identical vessels or parts which subsequently are joined to form a complete vessel and which are manufactured to a single model approval, using the same manufacturing procedure involving a continuous fabrication process

3.9
continuous fabrication process

process where the welding of the main seams and branch welds is essentially continuous

NOTE Stoppages or break-downs requiring resetting of the welding machine and/or NDT equipment constitute a break in continuity. Adjustments to the welding machine within the welding procedure limitations do not qualify as resetting the welding machine.

3.10
model acceptance

procedure which ascertains and attests that a representative sample of the production (a prototype vessel/part) meets the requirements of this standard in respect of design, manufacturing and testing

NOTE Model acceptance is conducted by the manufacturer or the responsible authority depending on the conformity assessment module chosen.

3.11
prototype vessel/part

first or representative example of a series of pressure vessels/parts covered by a single model acceptance

3.12
batch of vessels

part of a series where the welding of the main weld joints and branch welds has been essentially continuous

NOTE A stoppage in vessel production greater than three consecutive days requires the designation of a new batch.

3.13
shift

period of time per day during which the welding operator or operators remain the same



4 Performance of inspection and testing

4.1 General

Each individual vessel shall be inspected during construction and upon completion. Inspections shall be made to ensure that in all respects the design, materials, manufacturing, and testing comply with the requirements of this standard. Documented evidence shall be prepared to verify implementation of this requirement.

4.2 Inspection

Inspection shall be carried out by the manufacturer to verify that all requirements of this standard have been met. The level of non-destructive testing (NDT) shall be dependent on the testing group as described in 4.3.

4.3 Non-destructive testing (NDT)

The type and amount of non-destructive testing of a pressure vessel shall be based upon the testing group or combination of testing groups when permitted in 6.6.1.1.2 (see Table 6.6.1-1: testing groups for steel pressure vessels and Table 6.6.2-1: extent of non-destructive testing).

5 Technical documentation

5.1 General

The vessel manufacturer shall document those items listed in 5.2, which shall be reviewed in accordance with 5.3, prior to manufacture commencing.

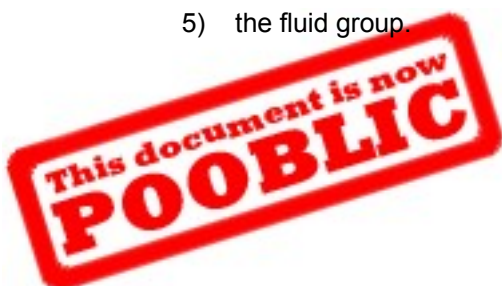
The manufacturer shall state which vessels are covered by the same design documentation.

5.2 Information to be contained in the technical documentation

For the purposes of this standard the following types of documents shall be considered necessary as technical documentation.

5.2.1 General description of the pressure vessel

- a) Name of vessel manufacturer and subcontractors, if applicable;
- b) Location/s of vessel manufacturers and sub-contractors, if applicable;
- c) Document describing design data and special consideration which covers:
 - 1) maximum and minimum allowable pressures, design pressures and test pressures in bar for each compartment (vacuum with minus sign);
 - 2) capacity in litres for each compartment;
 - 3) maximum and minimum design temperatures;
 - 4) nature and location of marking of the pressure vessel, nameplate or stamp;
 - 5) the fluid group.



EN 13445-5:2009 (E)
Issue 1 (2009-07)

- 6) if the vessel is designed for fatigue according to Clause 17 or Clause 18 of EN 13445-3:2009:
 - the cyclic loads considered;
 - the allowed numbers of cycles;
 - the relevant fatigue locations;
- 7) the design method used e.g. if the vessel is totally or in part designed by Design by Analysis – Direct Route of Annex B of EN 13445-3:2009 or designed according to 6.3 of EN 13445-3:2009.
- 8) If the vessel is working in the creep range, the following additional information:
 - the design life (e.g. 100000 h) and expected life for each load case
 - the parts of the vessel which are subjected to creep
 - the value of the weld creep strength reduction factor which has been used for each weld joint subjected to creep
 - whether lifetime monitoring, as defined in Clause 19 of EN 13445-3:2009, is or not being applied.

5.2.2 Conceptual design and construction drawings

The manufacturer analysis of hazards identifying those which apply to the pressure vessel on account of pressure shall be documented and be of sufficient detail.

Details of the conceptual design including the design methods adopted, performance criteria and construction drawings shall be provided. Guidance about the detailed dimensional information that shall be provided is given in Annex B. Process diagrams, sub-assemblies or other data relevant to conceptual design shall also be maintained.

5.2.3 Descriptions and explanations necessary for an understanding of the drawings and diagrams and the operation of the pressure vessel

- a) operating instructions;
- b) special checks to be carried out e.g. tests envisaged on closures, bellows, clamping bolts, etc.
- c) operational position if this is significant with regard to the safety evaluation.

5.2.4 Results of design calculations and examinations carried out

5.2.4.1 Design calculations shall be provided by the vessel manufacturer to the extent necessary to demonstrate compliance with this standard.

Supporting detailed drawings shall be prepared with all dimension notations marked. The drawings shall clearly identify in the case of cyclic loaded vessels, the critical areas. The maximum permissible peaking for cyclically loaded vessels shall also be given in the drawing. At least on the pressure vessel general arrangement drawing, the testing group for each welded joint shall be clearly identified.



5.2.4.2 If calculations are made with the aid of a computer in order to comply with this standard, then at least the following data shall be presented:

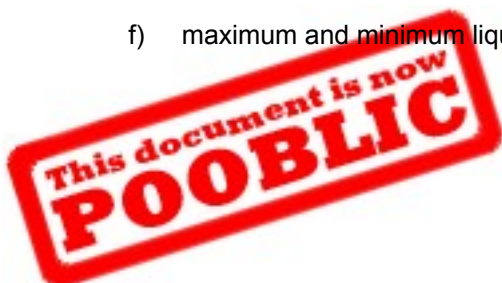
- a) explanation of notations;
- b) input values;
- c) reference number of the standard including edition and reference number of the equation;
- d) results of intermediate equations;
- e) calculated minimum thickness without additions or the calculated stress and its comparison to the allowable stress;
- f) wastage (corrosion) allowance;
- g) thickness tolerance (negative thickness tolerance);
- h) the chosen thickness.

5.2.4.3 In the event that stress analysis is carried out with the finite element method or other design methods they shall be documented as follows:

- a) input data;
- b) plotter graphs (original and copy) form;
 - 1) the element subdivision;
 - 2) the stresses, e.g. as line or arrow figures or equal stress curves; stress curves of surfaces;
 - 3) the displacements;
- c) boundary conditions;
- d) the stresses in the most critical areas;
- e) the dividing and classifying of the stresses into different stress categories;
- f) the comparison of stress intensities and the allowable stress values.

5.2.4.4 In specific cases the following information shall be necessary:

- a) type of post weld heat treatment and, where necessary, type and extent of associated material tests;
- b) construction sequence schedule if the structural testing is to be carried out in several partial steps;
- c) fluid(s) being contained and its (their) specific gravity, if this is required for the design of the vessel;
- d) pressure testing medium, if the initial or the periodic pressure tests are to be carried out with a medium other than water, the test minimum metal temperature for proof tests (both hydrostatic and pneumatic);
- e) position of the vessel in the pressure tests (e.g. horizontal or vertical), if this is significant with regard to the safety evaluation;
- f) maximum and minimum liquid levels, if these are required with regard to the safety evaluation;



EN 13445-5:2009 (E)
Issue 1 (2009-07)

- g) static supplementary forces, e.g. bearing forces, wind and snow loads. An extra calculation shall be presented if the supplementary forces essentially affect the design of the pressure vessel;
- h) cyclic and dynamic loading, including seismic loading, where applicable;
- i) additional requirements based on other regulations;
- j) purchaser's requirements based on the vessel operating conditions in addition to the requirements of this standard;
- k) possible corrosion attack, especially in crevices, which shall be taken into account;
- l) joint coefficient.

5.2.5 Test reports

These shall consist, as a minimum, of the following:

- a) welding procedure qualification records, certificate of qualification of welding personnel;
- b) material certificates;
- c) an example of the proposed list of the manufacturing records;
- d) values of measured peaking for vessels subject to cyclic loads.

5.2.6 Technical/manufacturing schedule

This shall consist of the following information:

- a) the welding processes to be used for the pressure containing parts and welding of any temporary or other attachments to pressure containing parts. The following data are required for the structural testing:
 - 1) weld location, shape and preparation and where necessary build up of the layers and treatment of welds;
 - 2) welding process (in the case of multiple processes, identification of the process against the weld joint);
 - 3) welding consumables (classification according to the relevant European Standards or trade names);
 - 4) type and extent of production test, number of test plates, non-destructive tests;

If some of the data listed before are not available for the design review, then these shall be completed before finishing the manufacture.

- b) special checks to be carried out e.g. the tests envisaged on closures, bellows, clamping, bolts;
- c) any pertinent details relative to vessel design and data required in specific cases:
 - 1) additional wall thickness if this is required by the purchaser;
 - 2) operational position if this is significant with regard to the safety evaluation;



- 3) location and size of inspection and access openings and also closing mechanisms and special locking elements in accordance with Annex C;
- 4) special equipment to enter the pressure vessel (e.g. spiral stairs, climbing irons);
- 5) linings, e.g. of masonry and inserts, if significant with regard to the safety evaluation;
- 6) marking of the welds that will be made on the construction site;
- 7) proposals on safety;
- 8) proposals on process requirements such as drainage etc.

5.3 Design review

5.3.1 General

A design review and documented acceptance shall be conducted in all cases.

In particular the review shall include design calculations in accordance with the requirements of this standard, taking into consideration the supporting information of the manufacturer analysis of hazards, and the technical/manufacturing schedule in respect of its intended services. Following the design the pressure vessel shall be manufactured in accordance with the approved manufacturing drawings.

5.3.2 Design review

The design review shall consist of, but not be limited to, the following areas:

- a) the suitability of material for intended use;
- b) welding processes and consumables;
- c) the access to perform the required levels of inspections and tests based on proposed vessel construction geometry;
- d) the suitability of openings and closures in meeting the requirements of this standard;
- e) the provision and adequacy of safety accessories against the requirements of this standard for individual pressure vessels or devices which are contained within the pressure system or assembly. Alternatively the parties responsible for satisfying the provision of safety accessories shall be identified;
- f) the adequacy of proposed pressure retaining boundary (thickness, vessel geometry, weld joint geometry etc.) for design conditions against those required by the design requirements of this standard;
- g) the adequacy of the stress analysis method in accordance with 5.2.4.3;
- h) manufacturing and test procedures.

6 Inspection and testing during fabrication

6.1 General

The inspection and testing activities during fabrication, described in this clause, shall be the responsibility of the manufacturer and shall be fully implemented for all pressure vessels.



EN 13445-5:2009 (E)
Issue 1 (2009-07)

6.2 Manufacturing procedures and construction drawings

The manufacturer shall ensure that all construction drawings and manufacturing procedures reviewed and approved at the design stage in clause 5, shall be available at the appropriate work area and shall be fully implemented in manufacturing. Inspection records shall document the use of the correct and appropriate procedures, and/or drawings including revision status at the time the inspection is performed.

6.3 Material traceability

6.3.1 General

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 vessel can be traced to its origin. This includes the use of welding consumable. The identification system used shall satisfy the requirements of EN 13445-4:2009.

Testing of material traceability, including transfer of markings, shall be performed throughout fabrication and records maintained to document the method used from those permitted in EN 13445-4:2009 (i.e. direct markings visible on the completed vessel, a direct coded marking on the vessel or tabulation/as built sketches). Final records shall include all material certification required by this standard.

6.3.2 Special Conditions - Material marking

Where service conditions prohibit die-stamping for material identification (see EN 13445-4:2009) and when so specified by the purchase order, the manufacturer of the base materials shall mark the required data on the materials in a manner which will allow positive identification during inspection upon delivery. The markings shall be recorded so that each item of material will be positively identified in its position in the completed vessel (e.g. material/position list) and shall form part of the final records.

6.4 Preparation for manufacturing processes

6.4.1 General

Preparation for manufacturing processes such as edge preparation, vessel supports for formed parts prior to welding and forming shall be controlled and inspected to ensure that such activities are not detrimental to the completed vessel.

6.4.2 Joint preparation testing

The extent to which edges are dressed prior to testing shall be in accordance with EN 13445-4:2009. All joint preparations shall be subject to visual inspection prior to any welding. Defects such as laminations, cracks and slag inclusion shall be removed prior to welding. In case of an increased probability of occurrence of imperfections or when imperfections have been detected, a visual inspection shall be supplemented by additional non-destructive testing.

All inspections shall be carried out by qualified personnel. The result of joint preparation testing shall be recorded in the NDT inspection schedule.

6.4.3 Inspection of vessel supports

All tack welds associated with bars, jacks, clamps, or other appropriate means used to hold the edges of vessel parts and/or provide support in welding shall be inspected.



- Welds of permanent attachments to pressure parts shall be examined to the extent described in Table 6.6.2-1 (line 21).
- Welds of temporary attachments shall be examined after removal for surface cracks to the extent described in Table 6.6.2-1 (line 22).
- Any repairs necessary following removal of temporary attachments shall be tested as described in 6.5.3.

6.4.4 Inspection associated with forming

Prior to any forming the material to be formed shall be subject to visual inspection and thickness measurement in accordance with the requirements of EN 13445-4:2009. The result of the inspection shall be recorded in the NDT inspection schedule.

6.4.5 Testing of areas subject to significant through thickness tensile stress

In case of an increased probability of internal damage in areas subject to significant through thickness tensile stress caused by welding, these areas shall be examined for internal imperfections prior to welding. The result of the inspection shall be recorded in the NDT inspection schedule

6.5 Welding

6.5.1 General

When permitted by EN 13445-3:2009, permanent backing strip and joggle joint shall be fitted and adjusted such that the quality of the weld achieved is the same as a conventional single-sided butt weld. The weld shall be subject to the same type of non-destructive testing and acceptance criteria as a single-sided butt weld.

Welds in all testing groups shall be subject to in-process inspections, especially welds of testing groups 3 or 4 not required to be subject to NDT under Table 6.6.1.2-1 shall be specifically subject to visual inspection at the "fit-up" and "chip back of second side of sound metal" stages.

All finished welding shall be subject to visual inspection. In addition, depending on the testing group, the finished welds shall be subject to NDT in accordance with Tables 6.6.1-1 and 6.6.2-1 for that type of weld.

6.5.2 Verification of welder and welding operator approval and procedures approval

The vessel manufacturer shall verify that welding has been done only by welders and operators who have been approved under the requirements of EN 287-1:2004 and EN 1418:1997. Procedures shall be qualified in accordance with EN 13445-4:2009.

Welder and welding operators identification shall be controlled in accordance with EN 13445-4:2009.

Traceability of the welder and welding operator shall be monitored by inspection throughout construction of the pressure vessel and shall be verified at the final assessment, see 10.2.2.



EN 13445-5:2009 (E)
Issue 1 (2009-07)

6.5.3 Inspection of repairs

All welded repairs shall be subject to the same non-destructive testing requirements as those which detected the imperfection. This includes the same acceptance criteria. Such repairs shall be carried out using approved weld procedures and approved welders and welding operators. The extent of testing of repairs shall comply with Table 6.6.2-1 and cover 100 % of the area repaired.

Non welded repairs by surface dressing are permissible providing that the area of repair is subject to NDT according to Table 6.6.2-1 and free from unacceptable imperfections, see 6.6.5 for retesting requirements.

Weld metal deposited to restore base material shall be subject to non-destructive testing for the full surface area involved, using Magnetic Particle Testing (MT) or Penetrant Testing (PT).

6.6 Non-destructive testing of welded joints

6.6.1 Extent of non-destructive testing

The required extent of non-destructive testing depends both on the testing group and the type of the welded joints. Guidance to determine the required extent of testing is given in the following clauses.

For serially produced pressure vessels an alternative route is given in Annex A. This annex is not applicable to vessels or vessel parts designed according to Design by Analysis – Direct Route of Annex B of EN 13445-3:2009 or designed according to 6.3 of EN 13445-3:2009. This annex is not applicable for vessels or vessel parts working in the creep range.

6.6.1.1 Use of testing groups

6.6.1.1.1 General

The non-destructive testing of welded joints for final acceptance purposes shall depend upon the testing group or subgroup of the welded joint under consideration.

In Table 6.6.1-1, testing groups 1, 2, 3 and 4 apply below the creep range. Testing groups 1, 2 and 3 are subdivided into sub-groups 1a, 1b, 2a, 2b, 3a, 3b, in order to reflect crack sensitivity of the material. In Table F.2-1 of Annex F, testing sub-groups 1c and 3c apply to creep.

NOTE 1 The testing groups or sub-groups take into consideration the manufacturing difficulties associated with different groups of steel, maximum thickness, welding process, service temperature range and joint coefficient. It is intended that any of the testing groups will provide adequate integrity for typical applications within the limitations contained within Tables 6.6.1-1 and F.2-1.

For vessels (or vessel parts) designed according to Design by Analysis – Direct Route of Annex B of EN 13445-3:2009 or designed according to 6.3 of EN 13445-3:2009, only testing group 1 is permissible.

NOTE 2 Further restrictions are given in Annex A of EN 13445-3:2009.

For vessels designed by experimental methods, the testing group to be considered for the vessel or vessel part shall be determined according to the rules given in Table 6.6.1-1 and the possible limitations stated in T.5 of EN 13445-3:2009.

NOTE 3 The joint coefficient is not used in design by the experimental method without calculation.



For vessels (or vessel parts) working in the creep range only testing groups 1c and 3c are permissible. The extent of NDT is given in Table F.2-1 of Annex F. Testing groups 1, 2 and 3 are permissible for any welded joint not subjected to creep.

6.6.1.1.2 Testing groups 1, 2 and 3

It is intended that a single testing group is applied to the entire vessel.

When the vessel is made of several sections (courses), a combination of testing groups 1, 2, and 3 is permissible providing that the requirements of Table 6.6.1-1 are met.

If a combination of testing groups is necessary, for example as the result the use of DBA Direct Route, of the Alternative Route, of design in the creep range or for fatigue in a section (course), the following shall apply:

- a) in each section (course) of the vessel, the testing group of the shell governing welded joints, where present, shall determine the minimum testing group for all the welds, including the nozzle welds, in that section;
- b) the testing group of the weld between two welded sections of different testing groups shall be the higher of the two testing groups;
- c) the minimum testing group (i.e. the one with the lower level of NDT) of the welds between a welded component and a seamless one (not welded), or between two seamless components, shall be determined by the available thickness (i.e. actual thickness less tolerances less corrosion allowance) at the weld. Where the available thickness is greater than 1,17 (this is equivalent to $1/0,85$) times the minimum thickness, the testing group of the weld shall be 3 as a minimum requirement. Otherwise it shall be testing group 1 or 2 according to Table 6.6.1-1.

6.6.1.1.3 Testing group 4

Testing group 4 shall be used as a single group for the entire vessel and shall not be used with any other testing group.

6.6.1.1.4 Demonstration of satisfactory experience for testing group 2

Satisfactory experience shall be a minimum amount of welds or vessels of successfully produced and tested within the scope/parameters of the welding procedure approval test, as given below:

- in case of groups 1.1, 1.2 and 8.1 materials, the successful production is 25 consecutive pressure vessels or 50 consecutive metres of governing welded joints;
- in case of materials of other groups, it is 50 consecutive pressure vessels or consecutive 100 m of governing welded joints;
- experience in material group 3.1 covers experience in material groups 1.1, 1.2 and 1.3;
- experience in material group 1.3 covers experience in material groups 1.1, 1.2;
- experience is accepted as long as there is a valid welding procedure approval test for a more critical or at least a comparable material.

Any imperfection requiring repair during the process of demonstrating experience shall require that the manufacturer start again the complete demonstration process.

Subsequently, (after demonstration of experience) isolated imperfections shall be handled in accordance with 6.5.3. and shall not affect the demonstration of experience.



EN 13445-5:2009 (E)
Issue 1 (2009-07)

However, multiple, systematic or process imperfections shall be investigated, corrected and the full demonstration of experience repeated. Such imperfections tend to be repetitive and similar in nature. They can be the result of inadequate welding parameters (e.g. resulting from equipment malfunction, a too large range of parameters, incorrect use of parameters within the range of approval) or operator error. In the case of inadequate parameters, consideration of requalification of the Welding Procedure Specification (WPS) should be performed.

Documentary evidence of the process of demonstration of experience shall be maintained by the manufacturer.



Table 6.6.1-1 — Testing groups for steel pressure vessels

Requirements	Testing group ^a						
	1a	1b	2a	2b	3a	3b	4 ^{b,j}
Permitted materials ^g	1 to 10	1.1, 1.2, 8.1	8.2, 9.1, 9.2, 9.3, 10	1.1, 1.2, 8.1	8.2, 9.1, 9.2, 10	1.1, 1.2, 8.1	1.1, 8.1
Extent of NDT for governing welded joints ^{e,h}	100 %	100 %	100 % - 10% ^d	100 % - 10 % ^d	25 %	10 %	0 %
NDT of other welds	Defined for each type of weld in Table 6.6.2-1						
Joint coefficient	1	1	1	1	0,85	0,85	0,7
Maximum thickness for which specific materials are permitted	Unlimited ^f	Unlimited ^f	30 mm for groups 9.1, 9.2 16 mm for groups 9.3, 8.2 ⁱ , 10	50 mm for groups 1.1, 8.1 30 mm for group 1.2	30 mm for groups 9.2, 9.1 16 mm for groups 8.2, 10	50 mm for groups 1.1, 8.1 30 mm for group 1.2	12 mm for groups 1.1, 8.1
Welding process	Unlimited ^f	Unlimited ^f	Fully mechanical welding only ^c		Unlimited ^f	Unlimited ^f	Unlimited ^f
Service temperature range	Unlimited ^f	Unlimited ^f	Unlimited ^f	Unlimited ^f	Unlimited ^f		Limited to (-10 to +200) °C for group 1.1 (-50 to +300) °C for group 8.1

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

^b Testing group 4 shall be applicable only for:

- Group 2 fluids; and
- $P_S \leq 20$ bar; and
- $P_S V \leq 20\,000$ bar·L above 100 °C; or
- $P_S V \leq 50\,000$ bar·L if temperature is equal or less than 100 °C;

- higher pressure test (See clause 10);
- maximum number of full pressure cycle less than 500;
- lower level of nominal design stress (See EN 13445-3:2009).

^c Fully mechanised and/or automatic welding process (See EN 1418:1997).

^d First figure: initially, second figure: after satisfactory experience. For definition of "satisfactory experience", see 6.6.1.1.4

^e Testing details are given in Table 6.6.2-1

^f Unlimited means no additional restriction due to testing. The limitations mentioned in the table are limitations imposed by testing. Other limitations given in the various clauses of the standard (such as design, or material limitations, etc.) shall also be taken into account.

^g See EN 13445-2:2009 for permitted materials.

^h The percentage relates to the percentage of welds of each individual vessel

ⁱ 30 mm for group 8.2 material is allowed if delta ferrite containing welding consumables are used for depositing filling passes up to but not including the capping run.

^j Limited to single compartment vessels and single material group.

6.6.2 Determination of extent of non-destructive testing

6.6.2.1 General

As a general rule, the extent of non-destructive testing, given as a percentage value, shall be in accordance with Table 6.6.2-1 which only covers the processes listed in EN 13445-4:2009. This percentage value reflects the extent of non-destructive testing of the total length of the welded joint and takes into consideration the testing group and type of weld.



EN 13445-5:2009 (E)
Issue 1 (2009-07)

For vessels designed by experimental methods, the required extent of non-destructive testing of welded joints shall be determined according to the rules given in Table 6.6.2-1.

In case where it is not obvious whether the welded joint is a governing one or not, due to the complex shape of the vessel and/or the particular location of that joint, a conservative assumption shall be made, i.e. the welded joint shall be considered as a governing welded joint and tested accordingly.

NOTE For definition of governing welded joint, see EN 13445-3:2009, definition 3.13. For examples of governing welded joints, see EN 13445-3:2009, subclause 5.6.

If no weld is present in the vessel or vessel part, testing group 1 shall be assumed.

6.6.2.2 Welded joints covered by Table 6.6.2-1

Table 6.6.2-1 is designed for steel for:

- multilayer welds welded as single or double side welds;
- single run one side circumferential welds;
- performed with consumables;
- produced by the following typical processes: Manual Metal Arc (MMA) 111, Submerged Arc (SAW) 121, Metal Active Gas (MAG) 135, Metal Inert Gas (MIG) 131, Tungsten Inert Gas (TIG) 141, Plasma MIG welding 151.

6.6.2.3 Other welded joints

6.6.2.3.1 General

Special problems arising from elements such as those described below are not covered in Table 6.6.2-1 and shall be considered for all butt-welded joints especially for longitudinal/governing joints:

- single run one side governing welds;
- joints between dissimilar materials or dissimilar consumables.

6.6.2.3.2 Single run one side governing welds

For single run governing welds made from one side, the thickness shall be limited to 10 mm. It is also noted that these vessels are limited to non cyclic duty i.e. 500 full pressure cycles. For volumetric NDT of single runs, one of the two options below shall be used:

- a) NDT extent shall be as prescribed in Table 6.6.2-1 conditional upon a hydrotest at a higher test pressure performed as specified in paragraph 10.2.3.3.1, Table 10.2.3.3-1 with control of peaking and excess weld.
- b) NDT extent prescribed in Table 6.6.2-1 shall be multiplied by 2 without exceeding 100 % but not less than 25 % for longitudinal and 10 % for circumferential. When there is a change which could influence the performance of the welding process (e.g. before changing the copper bar or the gas, after changing the wire or the powder and production test specimens, before changing the copper bar or gas and after changing wire) additional NDT shall be performed at the start of those seams.

For both a) and b), welding shall require qualification with welding procedure test, as requested in EN 13445-4:2009, on the actual nominal thickness of the weld joint that is welded by the single run from one side. The range of qualification shall be restricted to $0,8 \cdot t$ to t , where t is the actual nominal thickness of the test coupon.

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For all thicknesses, X-Ray in the direction of the weld preparation shall be used.

6.6.2.3.3 Non destructive testing of joints between dissimilar materials or dissimilar consumables

NDT on these joints must be performed to a specific written procedure with additional attention to interpretation of the results.

6.6.2.4 Testing group 2

For testing group 2, the reduction in percentage of NDT given in Table 6.6.2-1 is given by the two figures (e.g. 100 % - 10 %). The first value refers to the initial extent of NDT required until sufficient satisfactory experience (See 6.6.1.1.4) is established when the second lower value applies.

6.6.2.5 When less than 100 % NDT is required by the selected testing group in Table 6.6.1-1

In case of less than 100 % required testing, the extent and location of non-destructive testing shall be determined by the following criteria. The joints selected shall be representative of all welding on the pressure vessel.

- a) For shells, formed heads, communicating chambers and jackets
 - 1) non-destructive testing shall be performed at all intersections of longitudinal and circumferential butt joints. The minimum tested length shall be 200 mm. Where the inclusion of all intersections exceeds the percentage in Table 6.6.2-1 then this higher value will apply;
 - 2) if necessary to attain the percentage required in Table 6.6.2-1, additional randomly selected locations on the butt welded joint shall be subject to non-destructive testing;
 - 3) openings within main welds (longitudinal or circumferential) or within a distance of 12 mm from the main welds shall be examined for a length of not less than the diameter of the opening on each side of the opening. These shall be included as an addition to the percentage in Table 6.6.2-1, if applicable.
- b) Nozzles and branches attached to the vessel (butt welds).

To determine the extent of non-destructive testing, the total number of nozzles and branches which have full penetration butt welds shall be grouped as follows:

- 1) for 100 % non-destructive testing: the size of the group is 1 (i.e. every individual nozzle and branch) ;
- 2) for 25 % non-destructive testing: the size group size is 4 (i.e. at least one complete nozzle or branch for each group of 4) ;
- 3) for 10 % non-destructive testing: the size of the group is 10 (i.e. at least one complete nozzle or branch for each group of 10).

Thereafter, the complete circumferential and longitudinal butt joints of at least one nozzle or branch in each group or partial group shall be tested. When the inclusion of the number of complete circumferential and longitudinal butt welds or nozzles exceeds the percentage in Table 6.6.2-1, then the higher value will apply.



Table 6.6.2-1 — Extent of non-destructive testing

TYPE OF WELD a, p			TESTING ^b	EXTENT FOR TESTING GROUP ^o						
				1a	1b	2a ⁱ	2b ⁱ	3a	3b	4
				EXTENT FOR PARENT MATERIALS l,m,n						
				1 to 10	1.1, 1.2, 8.1	8.2, 9.1, 9.2, 9.3, 10	1.1, 1.2 8.1	8.2, 9.1, 9.2, 10	1.1, 1.2, 8.1	1.1, 8.1
Full penetration butt weld	1	Longitudinal joints	RT or UT MT or PT	100 % 10 %	100 % 10 % d	(100-10) % 10 %	(100-10) % 10 % d	25 % 10 %	10 % 10 % d	0 0
	2a	Circumferential joints on a shell	RT or UT MT or PT	100 % 10 %	25 % 10 % d	(100-10) % 10 %	(25-10) % 10 % d	10 % 10 %	10 % ^c 10 % d	0 0
	2b	Circumferential joints on a shell with backing strip ^k	RT or UT MT or PT	NA NA	100 % 10 %	NA NA	25 % 10 %	NA NA	25 % 10 %	0 0
	2c	Circumferential joggle joint ^k	RT or UT MT or PT	NA NA	100 % 10 %	NA NA	25 % 10 %	NA NA	25 % 10 %	0 0
	3a	Circumferential joints on a nozzle $d_i > 150$ mm or $e > 16$ mm	RT or UT MT or PT	100 % 10 %	25 % 10 % d	(100-10) % 10 %	(25-10) % 10 % d	10 % 10 %	10 % ^c 10 % d	0 0
	3b	Circumferential joints on a nozzle $d_i > 150$ mm or $e > 16$ mm with backing strip ^k	RT or UT MT or PT	NA NA	100 % 10 %	NA NA	25 % 10 %	NA NA	25 % 10 %	0 0
	4	Circumferential joints on a nozzle $d_i \leq 150$ mm and $e \leq 16$ mm	RT or UT MT or PT	0 100 %	0 10 %	0 (100-10) %	0 10 %	0 10 %	0 10 %	0 0
	5	All welds in spheres, heads and hemispherical heads to shells	RT or UT MT or PT	100 % 10 %	100 % 10 % d	(100-10) % 10 %	(100-10) % 10 % d	25 % 10 %	10 % 10 % d	0 0
	6	Assembly of a conical shell with a cylindrical shell without a knuckle (large end of the cone) q, r	RT or UT MT or PT	100 % 100 %	25 % 100 %	(100-10) % 100 %	(25-10) % 100 %	10 % 100 %	10 % 100 %	0 100 %
	7	Assembly of a conical shell with a cylindrical shell without a knuckle (small end of the cone)	RT or UT MT or PT	100 % 10 %	25 % 10 % d	(100-10) % 10 %	(25-10) % 10 % d	10 % 10 %	10 % 10 % d	0 0
Circumferential lapped joints ^k	8a	General application shell to head	RT or UT MT or PT	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	0 0
	8b	Bellows to shell $e \leq 8$ mm	MT or PT RT or UT	100 % 0 %	100 % 0 %	100 % 0 %	25 % 0 %	25 % 0 %	10 % 0 %	0 0



Table 6.6.2-1 (continued)

TYPE OF WELD a, p			TESTING ^b	EXTENT FOR TESTING GROUP ^o						
				1a	1b	2a ⁱ	2b ⁱ	3a	3b	4
				EXTENT FOR PARENT MATERIALS ^{l,m,n}						
				1 to 10	1.1, 1.2, 8.1	8.2, 9.1, 9.2, 9.3, 10	1.1, 1.2 8.1	8.2, 9.1, 9.2, 10	1.1, 1.2, 8.1	1.1, 8.1
Assembly of a flat head or a tubesheet, with a cylindrical shell Assembly of a flange or a collar with a shell	9	With full penetration	RT or UT MT or PT	100 % 10 %	100 % 10 % d	(100-10) % 10 %	(100-10) % 10 % d	25 % 10 %	10 % 10 % d	0 0
	10	With partial penetration if $a > 16$ mm (a as defined in figure 6.6.2-1) ^j	RT or UT MT or PT	NA NA	NA NA	NA NA	NA NA	25 % 10 %	10 % 10 %	0 0
	11	With partial penetration if $a \leq 16$ mm (a as defined in figure 6.6.2-1) ^j	RT or UT MT or PT	NA NA	NA NA	NA NA	NA NA	0 10 %	0 10 %	0 0
Assembly of a flange or a collar with a nozzle	12	With full penetration	RT or UT MT or PT	100 % 10 %	100 % 10 % d	(100-10) % 10 %	(100-10) % 10 % d	25 % 10 %	10 % 10 % d	0 0
	13	With partial penetration ^j	RT or UT MT or PT	NA NA	NA NA	NA NA	NA NA	0 10 %	0 10 %	0 0
	14	With full or partial penetration $di \leq 150$ mm and $e \leq 16$ mm ^j	RT or UT MT or PT	0 10 %	0 10 % d	0 10 %	0 10 % d	0 10 %	0 10 %	0 0
Nozzle or branch ^e	15	With full penetration $di > 150$ mm or $e > 16$ mm	RT or UT MT or PT	100 % 10 %	25 % 10 % d	(100-25) % 10 %	(25-10) % 10 % d	25 % 10 %	10 % 10 % d	0 0
	16	With full penetration $di \leq 150$ mm and $e \leq 16$ mm.	RT or UT MT or PT	0 100 %	0 10 %	0 (100-10) %	0 10 %	0 10 %	0 10 %	0 0
	17	with partial penetration for any di $a > 16$ mm (see figure 6.6.2-2)	RT or UT MT or PT ^j	100 % 10 %	25 % 10 % d	(100-25) % 10 %	(25-10) % 10 % d	25 % 10 %	10 % 10 % d	0 0
	18	with partial penetration $di > 150$ mm. $a \leq 16$ mm.(see figure 6.6.2-2)	RT or UT MT or PT ^j	NA NA	NA NA	NA NA	NA NA	0 10 %	0 10 %	0 0
	19	With partial penetration $di \leq 150$ mm. $a \leq 16$ mm.(see figure 6.6.2-2)	RT or UT MT or PT ^j	0 100 %	0 10 %	0 (100-10) %	0 10 %	0 10 %	0 10 %	0 0
Tube ends into tubesheet	20		MT or PT	100 %	100 %	100 %	100 %	25 %	10 %	0
Permanent attachments ^f	21	With full penetration or partial penetration	RT or UT MT or PT	25 % ^g 100 %	10 % d 10 %	10 % 100 %	10 % d 10 %	10 % 100 %	10 % d 10 % d	0 0



Table 6.6.2-1 (continued)

TYPE OF WELD a, p			TESTING ^b	EXTENT FOR TESTING GROUP ^o						
				1a	1b	2a ⁱ	2b ⁱ	3a	3b	4
				EXTENT FOR PARENT MATERIALS ^{l,m,n}						
				1 to 10	1.1, 1.2, 8.1	8.2, 9.1, 9.2, 9.3, 10	1.1, 1.2 8.1	8.2, 9.1, 9.2, 10	1.1, 1.2, 8.1	1.1, 8.1
Pressure retaining areas after removal of temporary attachments	22		MT or PT	100 %	100 %	100 %	100 %	100 %	100 %	0
Cladding by welding ^h	23		MT or PT	100 %	100 %	100 %	100 %	100 %	100 %	0
Repairs	24		RT or UT MT or PT	100 % 100 %	100 % 100 %	100 % 100 %	100 % 100 %	100 % 100 %	100 % 100 %	0 0

^a See figure 6.6.2-3

^b RT = Radiographic testing, UT = Ultrasonic testing, MT = Magnetic particle testing, PT = Penetrant testing

^c 2 % if $e \leq 30$ mm and same WPS as longitudinal, for steel groups 1.1 and 8.1

^d 10 % if $e > 30$ mm, 0 % if $e \leq 30$ mm

^e Percentage in the table refers to the aggregate weld length of all the nozzles see 6.6.1.2 b).

^f No RT or UT for weld throat thickness ≤ 16 mm

^g 10 % for steel groups 8.2, 9.1, 9.2, 9.3 and 10

^h Volumetric testing if risks of cracks due to parent material or heat treatment

ⁱ For explanation of the reduction in NDT in testing group 2, see 6.6.1.2

^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. RT & UT, MT & PT). See table 6.6.3-1 for other circumstances for use of both techniques

^k For limitations of application see EN 13445-3:2009, 5.7.3.2.

^l The percentage of surface examination refers to the percentage of length of the welds both on the inside and the outside

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

ⁿ NA means "type of joint not allowed" (see EN 13445-3:2009, Annex A).

^o In case of cyclic loading refer to Annex G.2.

^p Annex A of EN 13445-3:2009 gives design limitations on welds.

^q Unless the design is such that the thickness at the weld exceeds $1,4 e_j$ (See clause 7.6.6 of EN 13445-3:2009). In which case, use NDT of line 2a.

^r For connections with a knuckle, case 2a applies.



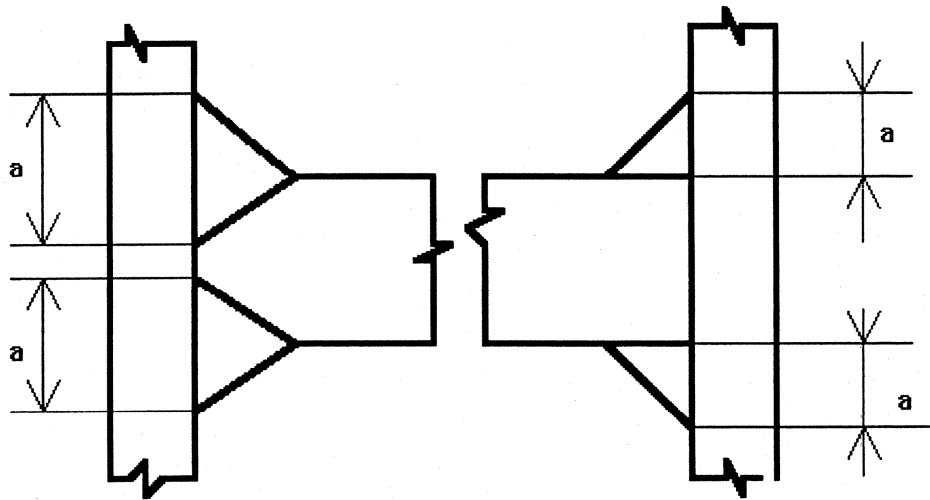


Figure 6.6.2-1 — Definition of “a” for types of weld 10 and 11

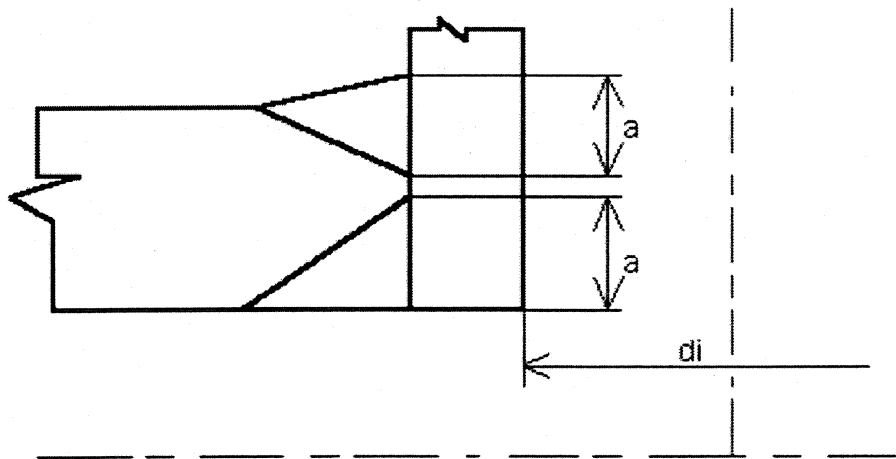
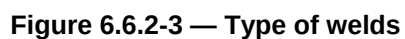


Figure 6.6.2-2 — Definition of “a” for types of weld 17, 18 and 19





6.6.3 Performing non-destructive testing

6.6.3.1 General

Visual inspection shall be carried out on all welds.

Non-destructive testing of welded joints for final acceptance purposes shall depend upon testing group of the joint.

6.6.3.2 Applicable non-destructive testing techniques

Table 6.6.3-1 shows the method, characterisation and acceptance criteria. This table is based on EN 12062:1997 and also on Quality level C of EN ISO 5817:2007.

Table 6.6.3-1 — NDT methods, techniques, characterisation, acceptance criteria

NDT Methods (abbreviations)	Techniques	Characterisation	Acceptance Criteria
Visual inspection (VT)	EN 970:1997	EN ISO 5817:2007 (surface imperfections)	EN ISO 5817:2007 (surface imperfections Acceptance level C) ^c
Radiography (RT)	EN 1435:1997 class B	EN 12517-1:2006 and additional Table 6.6.4-1	EN 12517-1:2006, Acceptance level 2, and Table 6.6.4-1
Ultrasonic Testing(UT)	EN 1714:1997 at least Class B ^a	EN 1713:1998 ^b	EN 1712:1997 Acceptance level 2 + no planar imperfections accepted
Penetrant Testing (PT)	EN 571-1:1997 + testing parameters of EN 1289:1998, Table A.1	EN 1289:1998	EN 1289:1998, Acceptance level 2X
Magnetic Particle Testing (MT)	EN 1290:1998 + testing parameters of EN 1291:1998, Table A.1	EN 1291:1998	EN 1291:1998, Acceptance level 2X
^a For thickness > 100 mm, Class C or Class D is required. ^b EN 1713:1998 is a recommendation only. ^c Additional requirements for the following imperfections: - stray arc (601) – removal plus 100 % MT or 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 on components made of group 1 materials; - torn surface (603), grinding mark (604), 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 (calculated thickness + corrosion allowance).			

6.6.3.3 Selection of non-destructive testing methods for internal imperfections (full and partial penetration)

The choice as to whether radiographic or ultrasonic examination, or combinations, is used shall be as specified in Table 6.6.3-2.

Where two techniques are shown, the least preferred technique is shown between brackets.



EN 13445-5:2009 (E)
Issue 1 (2009-07)

Table 6.6.3-2 — Selection of non-destructive testing method ^a for detection of internal flaws in full penetration joints, in accordance with EN 12062:1997, Table 3

Material and type of joint	Parent material nominal thickness (e in millimetres)			
	$e \leq 8$	$8 < e \leq 40$	$40 < e \leq 100$	$e > 100$
Ferritic butt joints	RT	RT or UT or UT _D	UT ^{b)} or UT _D or (RT)	UT _D ^{b)}
Ferritic T-joints	UT _D or RT	UT or (RT) or UT _D	UT or (UT _D) or (RT)	UT _D
Austenitic stainless and austenitic ferritic (duplex) butt joints	RT	RT or (UT _D)	RT or UT _D ^{b)}	UT _D ^{b)}
Austenitic stainless and austenitic ferritic (duplex) T-joints	UT _D or RT	UT _D or RT	UT _D or RT	UT _D
^a - RT and UT mean radiographic and ultrasonic testing in accordance with the standards mentioned in Table 6.6.2-1 - UT _D refers to Class D of EN 1714:1997 and may apply to all kinds of ultrasonic testing, like mechanised testing or use of twin crystal probes. It requires specific written procedures for testing parameters and acceptance criteria and shall meet quality level C of EN ISO 5817:2007. ^b For $e \geq 60$ mm UT shall include examination for imperfections perpendicular to the surface in accordance with EN 583-4:2002.				

The choice in Table 6.6.3-2 is based on the most suitable method to the relevant application in relation to the material type and thickness. It is possible that other important consideration such as joint geometry, sensitivity of the material to cracking in welding process, may have an overriding influence of method different from that in Table 6.6.3-2. The manufacturer shall record the basis for such a choice.

NOTE In exceptional cases or where the design or load bearing on the joint is critical, particularly for partial penetration joints, it can be necessary to employ both methods on the same joint or weld.

6.6.3.4 Selection of non-destructive testing methods for surface imperfections

For ferritic steels magnetic particle methods (MT) shall be used. For austenitic steels, liquid penetrant (PT) method shall be employed.

6.6.3.5 Surface condition and preparation for non-destructive testing

The surface condition necessary for performing all NDT shall be in accordance with the standard given in Table 6.6.3-1. Welded surfaces need not to be dressed unless the irregularities will interfere with application and/or interpretation. Special attention is necessary for vessels subject to cyclic loading, criteria are given in Annex G.

6.6.3.6 Schedule for non-destructive testing

A comprehensive schedule shall be prepared covering the non-destructive testing requirements for each vessel, identifying the stages of manufacture at which non-destructive testing is performed, the choice of method, the procedure to be used, acceptance criteria, and records to be made.



6.6.3.7 Qualification of non-destructive testing personnel

Non-destructive testing personnel shall be qualified and certified in accordance with EN 473:2008 except for visual inspection for which personnel shall be qualified but need not be certified. Non-destructive testing personnel shall hold an appropriate certificate of competence (e.g. personnel certification on non-destructive testing level 1, 2 or 3 as appropriate).

6.6.4 Description and acceptance level assessment of imperfections

6.6.4.1 Description

The terminology used to describe the imperfection shall be in accordance with EN ISO 6520-1:2007.

6.6.4.2 Acceptability criteria

The criteria used to assess the acceptability of imperfections shall be as presented in Tables 6.6.3-1 and 6.6.4-1.

6.6.5 Stage of performance

The non-destructive testing shall be carried out after completion of post-weld heat treatment (PWHT) but before the proof test in all testing groups.

Where a material is not sensitive to PWHT cracking e.g. material groups 1.1 and 8.1, NDT may be performed before PWHT.

All vessels shall be inspected during and after the manufacturing process to assure the quality of the finished welds. Such inspections include joint geometry, dimensional checking, alignment, etc.

In particular, testing group 4 vessels shall be inspected during fabrication both in the initial assembly and after preparation of the joint from the second side in double welded seams.

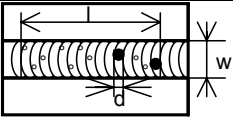
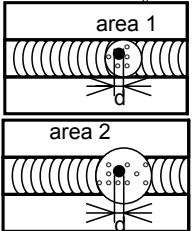
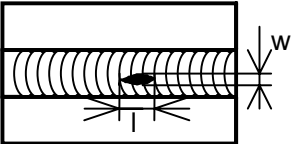
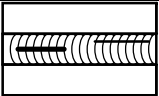
6.6.6 Procedure for non-destructive retesting

The locations selected under a) and b) of 6.6.2 shall be deemed to be representative of the welds inspected. An imperfection detected on the circumferential seam shall be considered as representing the condition of the whole circumferential seam. A defect detected on the longitudinal seam shall be considered as representing the condition of the whole longitudinal seam. An imperfection detected on a nozzle or branch shall be considered as representing the condition of the group of nozzles or branches. According to the defect type, retesting shall be as follows:

- a) planar imperfections: if one or more planar imperfections are present in the samples examined, the total length of butt weld represented by the sample shall be tested by the same non-destructive testing method and assessed according to the appropriate acceptance criteria;
- b) non planar imperfections: if the sample is free of planar defects but contains other non planar defects in excess of that permitted in the acceptance criteria, then two further random samples shall be non-destructively tested and the results assessed against the original criteria. Each of the further samples shall be at least the same length as the original. If these two further samples are acceptable, the original sample shall be repaired and reassessed using the same non-destructive testing technique. If one or both of further samples fail, then 100 % of the weld joint shall be tested.



Table 6.6.4-1 — Radiographic testing acceptance criteria

IDENTIFICATION OF IMPERFECTIONS				MAXIMUM PERMITTED
EN ISO 6520-1:2007 Group n°	imperfection reference n°	Type of imperfection ^a		Definition of maximum permitted
2	2012	Uniformly distributed porosity		Not permitted if the total projected surface of porosity exceeds 2% of the considered projected surface of weld ($l \cdot w$). (1% for critical areas of cyclic loaded vessels according to Annex G). Max. single porosity 0,4. e but not greater than 4 mm
	2013	Clustered (localized) porosity		Not permitted if the total projected surface of porosity exceeds 4% of the considered projected surface of weld, which is the greatest of the two following areas: - area 1: a circle with a diameter corresponding to the weld width; - area 2: an envelope surrounding all the pores
	202	Shrinkage cavity	see 2015	Not permitted
3	301	Slag inclusion		$w = 0,3e$ maximum 3 mm $l = e$ with a maximum of 50 mm ($w = 0,2e$ maximum 2 mm and $l = e$ with a maximum of 25 mm for critical areas of cyclic loaded vessels according to Annex G)
4	400	Lack of fusion and penetration		Not permitted if a full penetrated weld is required
^a The followings symbols are used: d is the diameter of pore; e is the thickness of parent material; w is the width of the projected indication in millimetres; l is the length of the projected indication in millimetres.				

6.6.7 Non-destructive testing documentation

All NDT shall be performed in accordance with written procedures and by qualified personnel, as specified in 6.6.3.7. In support of NDT activities written test reports shall be prepared in accordance with the standards referred to in Table 6.6.3-1.

The documentation described above should be sufficient to verify the scope of NDT performed and shall form part of the records described in clause 12.

6.7 Destructive testing

6.7.1 Extent of destructive testing

The level of destructive tests shall be in accordance with EN 13445-2:2009 and EN 13445-4:2009.

6.7.2 Schedule for destructive testing

The vessel manufacturer shall be responsible for preparing a comprehensive schedule covering the destructive testing requirements for each vessel or series of vessels, identifying the stages of manufacture at which the destructive testing is performed, the choice of tests, the testing procedure to be used, acceptance criteria and records required to be made.

6.7.3 Verification of destructive tests

The following activities shall be witnessed:

- identification/validation of test coupons;
- mechanical testing;
- preparation or certification of test reports.

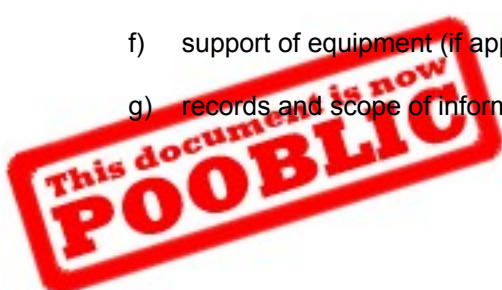
6.7.4 Records

All documentation associated with destructive testing in accordance with this standard shall form part of the final documentation in accordance with clause 12 and shall be readily available.

6.8 Heat-treatment

Heat-treatments shall be performed in accordance with written procedures and verified by inspection. Such procedures shall describe the parameters critical to the heat-treatment process. The procedures shall cover the appropriate criteria depending on the heat treatment process. As a minimum this shall include where appropriate:

- a) rate of heating;
- b) hold or soak time and temperature;
- c) rate of cooling;
- d) heating medium and furnace type;
- e) type and number of temperature measuring devices;
- f) support of equipment (if applicable);
- g) records and scope of information to be contained.



EN 13445-5:2009 (E)
Issue 1 (2009-07)

7 Subcontracted elements

7.1 General

The vessel manufacturer completing any work on a complete vessel or part of a vessel shall certify that any work done by others also complies with the requirements of this standard.

NOTE Some types of work which may be subcontracted by the vessel manufacturer and performed by other organizations would include:

- a) design
- b) cutting
- c) forming
- d) welding area activities,
- e) heat treatment.
- f) non-destructive testing.

For example of subcontractor's form, see EN 13445-4:2009, Annex B.

7.2 Subcontracted welding related activities

Subcontracted welding related activities shall be in accordance with EN 13445-4:2009.

7.3 Subcontracted non-destructive testing activities

7.3.1 Use of contract NDT personnel at the premises of the vessel manufacturer

The vessel manufacturer shall be responsible for assuring that NDT personnel, not in the full-time employ of the manufacturer, are trained, qualified and certified in accordance with EN 473:2008. Adequately documented records shall be provided so that the vessel manufacturer can verify the qualifications of personnel and such records shall be retained and made readily available.

All NDT shall be conducted against written procedures and the results documented and retained in accordance with the vessels manufacturers NDT requirements. The vessel manufacturer shall be responsible for assuring that all such procedures are fully implemented. The vessel manufacturer shall ensure that records are maintained which address the use of subcontracted personnel to the activities they undertake and shall have the authority to assign and remove NDT personnel at his discretion. The vessel manufacturer shall be responsible for retaining all records of work undertaken by subcontracted personnel in accordance with clause 12.

7.3.2 Subcontracting of NDT at a subcontractors premises

Any NDT which is performed at a subcontractors location shall be undertaken under the responsibility of the vessel manufacturer. All personnel used shall be trained, qualified and certified in accordance with EN 473:2008 and adequate records supporting their qualification shall be maintained by the vessel manufacturer. All procedures shall be documented and all test results shall be made available and all copies retained by the vessel manufacturer.



NOTE The vessel manufacturer shall ensure that those parties with responsibilities under the Conformity Assessment Procedures shall be given free access to the extent they consider necessary to fulfil their duties and obligations.

8 Miscellaneous tests

For guidelines on leak testing, see Annex D.

9 Calibration

9.1 General

All measurement and test equipment used for final acceptance of vessels shall be calibrated in accordance 9.2 to 9.4 and written procedures.

When used in this clause, calibration is an all encompassing term involving the use of procedures and testing equipment to determine the accuracy of equipment.

Certain types of equipment once initially calibrated may thereafter be validated. Examples of validated equipment are densitometers and welding equipment.

NOTE The equipment to be calibrated includes but is not limited to:

- a) Tensile testing machines;
- b) impact test machines;
- c) hardness tester;
- d) non-destructive testing equipment including densitometer and step wedge comparison films;
- e) pressure gauges;
- f) furnace and contact thermocouples;
- g) time/temperature recorders;
- h) dimensional measuring equipment;
- i) welding equipment (see EN ISO 17662).

9.2 Calibration procedure

9.2.1 General

Procedures shall be prepared for each type of equipment showing:

- a) the scope of activities and those responsible for conducting the calibration;
- b) reference to the European Standards or National Standards, where not available secondary standards/gauges, if used;
- c) calibration frequency;
- d) acceptance criteria.

Wherever possible European or National Standards shall be used. When such standards do not exist the calibration method shall be approved as specified in the procedures.

EN 13445-5:2009 (E)
Issue 1 (2009-07)

9.2.2 Calibration

Calibration of measurement, testing and test equipment used on pressure vessels for final acceptance shall always be the responsibility of the vessel manufacturer.

With the exception of the special equipment specified in Table 9.2.2-1, the vessel manufacturer shall either perform the calibration itself or shall subcontract to a nationally accredited testing laboratory (NATL). The NATL shall provide certified records of calibration and has suitable reference standards whose accuracy is traceable to European/National Standards.

Table 9.2.2-1 — Calibration frequency and performance

Equipment	Frequency	Performance
Tensile Testing Machines and associated equipment	1 year	National accredited testing laboratory (NATL)
Charpy Impact Machine and associated measurement apparatus	1 year	NATL
Hardness Tester	1 year	NATL
Master pressure gauges	1 year	NATL

9.2.3 Frequency

The frequency of calibration of an equipment shall either be in accordance with Table 9.2.2-1 or in an applicable European/National standard or, if such does not exist and is not covered in Table 9.2.2-1, to the recommendations by the measuring equipment manufacturer.

9.3 Identification

All measuring, testing and test equipment shall be identified by marking the item or its container/box with a unique identification serial number.

In addition to its identification number the equipment should have a calibration sticker giving a visual identification as to its status.

9.4 Registration

9.4.1 All equipment within the calibration system shall be documented on a list which as a minimum shall show:

- a) who is responsible for calibration, department, individual, subcontractor;
- b) items identification serial number;
- c) item location;
- d) calibration procedure number.

9.4.2 Record shall be kept for individual items indicating:

- a) calibration date;
- b) its "as-found" condition or the "actual measured" condition;



- c) identification of standard or master gauge used.

All records relating to calibration shall be available to the authorized inspection body.

10 Final assessment

10.1 General

Each completed pressure vessel designed and constructed to this standard shall be subject to a final assessment for compliance with the requirements of the approved construction drawings and this standard.

If due to internal elements (i.e. tube bundles, trays etc.) internal examination is not possible upon completion of the pressure vessel, then the vessel manufacturer shall have assured that those elements were subject to final examination prior to their assembly.

The final assessment consists of:

- a visual and dimensional inspection of the vessel;
- an examination of the documentation;
- a proof test;
- a post proof test examination;
- inspection of safety accessories.

Those performing the final assessment shall have access to all of the files/records as per clause 12 relevant to the pressure vessel under examination.

10.2 Extent of final assessment

10.2.1 Visual and dimensional inspection

The visual and dimensional inspection shall be performed following completion of all welding activities and post-weld heat treatments but before application of any coating, irrespective of type, and before the proof test. If the pressure vessel is to be partially or totally assembled on site, the vessel manufacturer shall determine elements which can receive protective coatings prior to dispatch to site.

Provisions shall be made to allow safe access to all areas of the pressure vessel in order to conduct this examination. Also provision of adequate lighting, calibrated measurement equipment and dimensional aids shall be assured to those performing the examination.

The scope of the visual and dimensional inspection shall include, but not be limited to, the following:

- check of compliance of construction with the approved vessel manufacturing drawings including dimensional requirements to the tolerances specified on the drawings and in this standard. Annex B provides a list of items that shall be given attention. The results of the dimensional examination ("as built condition") shall be documented on the certificate of dimensional report;
- check of the condition of a completed pressure vessel with particular attention to finished weld joints, nozzle connections and attachments in respect of weld profile, peaking measurement and general weld geometry in compliance with the approved manufacturing drawings and this standard;
- check of material markings for traceability of material against documented records;



EN 13445-5:2009 (E)
Issue 1 (2009-07)

— check of welders and NDT identification on the vessel against documentation, if applicable.

Any remedial actions resulting from this inspection shall be accomplished, re-examined and cleared prior to the proof test.

10.2.2 Review of documentation

The scope of the examination of documentation shall include, but not be limited to, the check of documents (e.g. tests certificates of the welding procedures approval, certificates of the welders approval, certificates for NDT personnel certification, production tests reports, NDT reports, postweld heat-treatments records, dimensional checking records, etc.).

The extent of the review and all deviations shall be reported. Any remedial actions resulting from this inspection shall be accomplished, re-inspected and cleared prior to the proof test.

10.2.3 Proof test

10.2.3.1 General

All vessels shall be subjected to a proof test to demonstrate the integrity of the finished product.

NOTE For category 1 (see the definition in the PED 97/23/EC and CR 13445-7) series-produced pressure equipment for which CE marking is sought, this test may be performed on a statistical basis, according to Annex A.

The proof test is part of the final assessment.

The hydrostatic pressure test shall be the standard proof test.

If this is not practical then it may be substituted by:

- a) pneumatic test. Pneumatic testing is potentially a much more dangerous operation than hydrostatic testing. Therefore it is permitted to be carried out but only subject to the following conditions:
 - for vessels having such a design and construction that it is not practicable for them to be filled with liquid;
 - for vessels that are to be used in processes where even small traces of liquid cannot be tolerated;
 - following early consultation at the design stage.
- b) combined hydrostatic/pneumatic test. In some cases it may be desirable to test a vessel when it is partly filled with liquid. This is as dangerous as the pneumatic test.

10.2.3.2 Basic requirements

10.2.3.2.1 The proof test shall be carried out under controlled conditions, with appropriate safety precautions and equipment, and in such a way that the persons responsible for the test are able to make inspections of all pressurized parts.

10.2.3.2.2 Where practicable the finished vessel shall be proof tested after all fabrication has been completed and all inspections have been performed. However, operations that influence the inspectability of the pressurized vessel, such as: painting, insulation, brickwork, rubber lining, leadlining, galvanizing, enamelling etc., shall be carried out following satisfactory completion of the proof test.



NOTE Alternatively, when a vessel is lined or coated by a process which could impair the integrity of the structure e.g. glass lining, it is permissible to reduce the proof test pressure after completion of lining to not less than 1,1 times the maximum allowable pressure P_S provided that the standard proof test has been applied before lining.

For coated or lined vessels which have jackets attached after the lining process (but not welded directly to the lined vessel) the jacket shall be subject to a proof test of $1,25 \cdot P_S$.

10.2.3.2.3 The pressure equipment shall be provided with the prescribed marking (e.g. nameplate) at the time when the proof test is performed at the latest, and when there are a number of pressurized compartments at the time when the final proof test is performed.

10.2.3.2.4 If it is not practicable, due to size or mode of manufacture, to proof test a complete vessel the test procedure to be followed shall be approved at the design stage.

10.2.3.2.5 If water is used as the test fluid, the quality of the water used shall be such as to prevent both corrosion and any residual impervious solids.

For stainless steel vessels in group 8 the following requirements apply:

- For vessels without access for cleaning or containing construction elements/joints which permit an ingress of water - water analysis shall be limited to maximum 1×10^{-6} chloride content;
- For vessels with access and which shall be cleaned immediately after the proof test - water analysis shall be limited to maximum 20×10^{-6} chloride content;
- For all vessels, a greater chloride content than in 1) or 2) is permissible, subject to documented technical justification in the hazard analysis.

NOTE Where other liquids are used additional precautions may be necessary depending on the nature of the liquid.

10.2.3.2.6 All temporary pipes and connections and blanking devices shall be designed to withstand the test pressure and shall not form a part of what is to be supplied with the vessel. Following the performance of the proof test, all pipes and connections and blanking devices shall be either removed at once or positively marked in order to prevent incorrect use. In case of bolted connections the bolts supplied shall be used and the tightening shall be uniform and to a degree no greater than necessary for sealing purposes.

10.2.3.2.7 Vessels which have been repaired during or following the pressure test shall again be subjected to the specified proof test after completion of the repair and any required post weld heat treatment (PWHT).

10.2.3.2.8 No vessel shall be subject to any form of shock loading such as hammer testing when undergoing proof testing.

10.2.3.2.9 All deviations from these basic requirements shall be approved at the design stage.

10.2.3.3 Standard hydrostatic test

10.2.3.3.1 For a single-compartment vessel¹⁾ subjected to internal pressure, working below the creep range, and designed according to testing group 1, 2 or 3, the test pressure, applied as internal pressure at the highest point of the chamber of the vessel for either horizontal or vertical test positions, shall be as specified in a). The modifications of the test pressure due to the hydrostatic pressure are specified in b).

¹⁾ The case of multi-compartment vessels is covered in 10.2.3.3.3



EN 13445-5:2009 (E)
Issue 1 (2009-07)

Special provisions are given in c) for single-run governing welds and in d) for complete vessels or parts of vessels working in the creep range.

a) The test pressure shall be determined by the greater of:

$$P_t = 1,25 \cdot P_d \frac{f_a}{f_{T_d}} \quad (10.2.3.3.1-1)$$

or

$$P_t = 1,43 \cdot P_s \quad (10.2.3.3.1-2)$$

where:

P_t is the test pressure measured at the highest point of the chamber of the vessel in the test position;

P_d and T_d are the coincident design pressure and design temperature values for the maximum pressure load case;

P_s is the maximum allowable pressure of the vessel;

f_a is the nominal design stress for normal operating load cases of the material of the part under consideration at the test temperature;

f_{T_d} is the nominal design stress for normal operating load cases of the material of the part under consideration at temperature T_d ;

Since the ratio $\frac{f_a}{f_{T_d}}$ depends on the material of the part under consideration, the value $\frac{f_a}{f_{T_d}}$ to be used for calculation of P_t shall not be less than the smallest ratio obtained considering the different materials of the main pressure bearing parts (e.g. shells, ends, tubesheets of heat exchangers, tube bundles, main flanges but ignoring bolting associated to main flanges). Main pressure bearing parts do not include pressure rated standard flanges and bolting designed without calculation according to the rules of 11.4.2 of EN 13445-3:2009.

NOTE 1 The rules of 11.4.2 of EN 13445-3:2009 deal with the use of standard flanges without calculation.

P_t , P_s , f_a and f_{T_d} shall have consistent units.

The maximum pressure load case is that set of coincident design pressure and design temperature which gives the highest test pressure.

If the bolting associated with the main flanges is overstressed due to the test pressure, the test pressure may be reduced until the bolt stresses are acceptable.

The design of the vessel shall be such that in no part the test pressure exceeds the maximum permissible pressure for testing load cases defined in 5.3.2.3 of EN 13445-3:2009 according to the relevant design rules of EN 13445-3:2009. For Design By Formulae (DBF) and Design By Analysis (DBA) according to Annex C, the maximum permissible pressure is determined using the nominal design stress given in Table 6-1 for testing load cases. For DBA – Direct Route according to Annex B, the maximum permissible pressure is determined using the safety coefficients for testing load cases given in Tables B.8-3 and B.8-4.

NOTE 2 For testing load cases during final assessment the corrosion allowance may be ignored (but not for any in service test).

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NOTE 3 The pressure test is not aimed to dimension the pressure vessel. However, possible increase of the thickness of tall vessels tested in the vertical position may be necessary to meet the criteria of EN 13445-3:2009.

- b) For vessels with hydrostatic pressure during operation which exceeds 3% of the design pressure the test pressure shall be modified according to equation 10.2.3.3.1-3:

$$P_{t,mod} = P_t + (P_{hyd,ope} - P_{hyd,test}) \text{ but always: } P_{t,mod} \geq P_t \quad (10.2.3.3.1-3)$$

where:

$P_{t,mod}$ is the modified test pressure

P_t is as determined in a)

$P_{hyd,ope}$ is the maximum hydrostatic pressure during operation

$P_{hyd,test}$ is the maximum hydrostatic pressure during hydrostatic test

NOTE This modified test pressure is decisive only when the hydrostatic pressure during operation is higher than the hydrostatic pressure during test. This is possible if the vessel in operation contains liquid with specific gravity higher than the specific gravity of the test medium or if a vertical vessel is tested in the horizontal position.

- c) For vessels with single-run governing welds not made by fully mechanical welding (see Table 6.6.1-1) and inspected according to 6.6.2.3.2 a), the proof test pressure shall be as given in a) but replacing 1,25 by F_k in formula 10.2.3.3.1-1.

$$P_t = F_k \cdot P_d \cdot \frac{f_a}{f_{T_d}} \quad (10.2.3.3.1-4)$$

The values of F_k are given by Table 10.2.3.3.1-1.



EN 13445-5:2009 (E)
Issue 1 (2009-07)

Table 10.2.3.3.1-1 — Value of F_k

Actual thickness of the shell e	F_k	Corrosion allowance c	maximum shape deviations h : peaking (measured after test) e_w : excess weld
$e \leq 4 \text{ mm}$	2,1	$c \geq 1 \text{ mm}$	$h + 0,5 \cdot e_w \leq 0,75 \cdot e_{\min}$
		$c < 1 \text{ mm}$	$h \leq 0,5 \cdot e_{\min}$ $e_w \leq 0,75 \cdot e_{\min}$
$e \leq 4 \text{ mm}$	2,0	$c \geq 1 \text{ mm}$	$h + 0,5 \cdot e_w \leq 0,5 \cdot e_{\min}$
	2,1	$c < 1 \text{ mm}$	$h \leq 0,5 \cdot e_{\min}$ $e_w \leq 0,5 \cdot e_{\min}$
$4 < e \leq 5 \text{ mm}$	1,9	$c \geq 1 \text{ mm}$	$h + 0,5 \cdot e_w \leq 0,5 \cdot e_{\min}$
	2,1	$c < 1 \text{ mm}$	$h \leq \frac{1}{3} \cdot e_{\min}$ $e_w \leq 0,25 \cdot e_{\min}$
$5 < e \leq 7 \text{ mm}$	1,8	$c \geq 1 \text{ mm}$	$h < \frac{1}{4} \cdot e_{\min}$
	2,0	$c < 1 \text{ mm}$	$e_w < 50\%$ of allowed value given in Table 6.6.3-1
$7 < e \leq 10 \text{ mm}$	1,7	$c \geq 1 \text{ mm}$	$h < \frac{1}{6} \cdot e_{\min}$
	1,9	$c < 1 \text{ mm}$	$e_w < 50\%$ of allowed value given in Table 6.6.3-1

In Table 10.2.3.3.1-1:

$e_{\min}$ is the minimum possible fabrication thickness, as defined in EN 13445-3:2009

h is the peaking after test, measured as defined in EN 13445-4:2009

e_w is the excess weld, as illustrated by h in number 1.9 of EN ISO 5817:2007

The circumferential membrane stress σ_c in the main seams with the actual or nominal thickness shall not exceed the nominal design stress f_{test} given in Table 6-1 of EN 13445-3:2009 for testing and exceptional load cases but shall be greater or equal to $0,85 \cdot f_{\text{test}}$.

During the hydrotest a value of 1 for the joint coefficient z defined in EN 13445-1:2009 shall be used.

It is acceptable to replace the actual or nominal thickness by $e_{\min}$.



- d) For complete vessels or parts of vessels working in the creep range, the test pressure shall be calculated as in a) above but with f_{T_d} replaced by f_{nc,T_d} the nominal design stress for normal operating load cases of the material of the part under consideration at design temperature T_d of the maximum pressure load case, using time-independent material characteristics.

If the required time-independent characteristics are not available in the materials standard at that temperature they may be determined as follows:

- For vessels designed to testing group 1c (see Table F.2-1): at the highest temperature for which time-independent characteristics are available in the materials standard;
- For vessels designed to testing group 3c (see Table F.2-1): using Annex S of EN 13445-3:2009;
- Alternatively time-dependent material characteristics can be taken.

From the three methods described above for determining the nominal design stresses for normal operating load cases, a consistent method shall be used for all parts.

NOTE 1 The level of the test pressure has no relevance to the safety of the vessel with respect to creep behaviour. It has been established to assure consistency with operation below the creep range.

NOTE 2 Use of the time-independent characteristics at the highest temperature for which they are available in the materials standard (when no such characteristics are available at T_d), gives a lower test pressure, but nevertheless provides adequate demonstration of strength in the context of testing group 1c.

NOTE 3 The nominal design stress values given in Annex S of EN 13445-3:2009 are based on a logical extrapolation into the creep range of the time-independent characteristics given in the materials standard below the creep range.

NOTE 4 Use of the time-dependent material characteristics gives a higher test pressure and therefore assures a conservative demonstration of strength.

10.2.3.3.2 For testing group 4 vessels the test pressure shall not be less than that determined by the following equations:

- For materials of the Group 1.1:

if $c < 1 \text{ mm}$

and (measured peaking + $0,5 \cdot \text{excess weld}$) $\leq 0,5 \cdot e_{\min}$

$$P_t = 2,2 \cdot P_d \cdot \frac{f_a}{f_{T_d}} \cdot \frac{e_{\min}}{e_{\min} - c} \quad (10.2.3.3.2-1)$$

or

if $c \geq 1 \text{ mm}$

and (measured peaking + $0,5 \cdot \text{excess weld}$) $\leq 0,75 \cdot e_{\min}$

and measured peaking $\leq 0,5 \cdot e_{\min}$

and measured excess weld $\leq 0,75 \cdot e_{\min}$



EN 13445-5:2009 (E)
Issue 1 (2009-07)

$$P_t = 2,0 \cdot P_d \cdot \frac{f_a}{f_{T_d}} \cdot \frac{e_{\min}}{e_{\min} - c} \quad (10.2.3.3.2-2)$$

where

$e_{\min}$ is the minimum possible fabrication thickness of the section under consideration, as indicated on the drawings, see 5.2.3 of EN 13445-3:2009.

c is the corrosion allowance, as indicated on the drawings

For other symbols see 10.2.3.3.1.

The peaking may be measured after the hydrostatic test and the excessive weld may be measured after grinding if applied before the hydrostatic test.

— For materials of the Group 8.1:

$$P_t = 1,85 \cdot P_d \cdot \frac{f_a}{f_{T_d}} \quad (10.2.3.3.2-3)$$

$$\text{if (measured peaking + 0,5 excess weld)} \leq 0,5 \cdot e_{\min} \quad (10.2.3.3.2-4)$$

The applied test pressure shall include the amount of any static head acting in service and in testing at the point under consideration. However, the static pressure caused by the content of the vessel during service and/or testing does not need to be taken into account if it does not increase the stress in the wall by more than 5 %.

For vessels constructed using testing group 4, the maximum allowable stress in the test conditions (see EN 13445-3:2009, clause 6) shall not be exceeded. This may require an increase in the relevant thicknesses or dimensions (e.g. vessel wall thickness, flange, bolt diameter, etc.). In no circumstances, shall the hydrostatic test pressure be reduced from that specified above.

10.2.3.3.3 In the case of multi-compartment vessels each chamber, when designed as separate vessels, shall be tested independently with the appropriate standard test pressure without support from pressure in any adjoining chamber.

If the common elements are designed for a larger differential pressure than the design pressure of the adjacent chambers, the test pressure shall subject the common elements to at least their design differential pressure as well as meeting the requirements for each independent chamber.

For vessels with common dividing walls designed for the maximum differential pressure that can possibly occur during start up, operation and shutdown, and where the differential pressure is less than the higher pressure in the adjacent chambers, then the common elements shall be subjected to a test pressure calculated in accordance with 10.2.3.3.1 where P_d and T_d are the coincident design differential pressure and design temperature values for the maximum differential pressure load case. The test pressure of pressure equipment made of several communicating compartments shall be the lower bound of the test pressures of the various compartments.

10.2.3.3.4 For full or partial jacketed vessels, the inner vessel shall be subject to the maximum differential pressure caused by the vacuum in the adjacent chamber. An identical approach shall apply in determining the test pressure for the jacket.

Therefore the determination of the test pressure given by formulae (10.2.3.3.1-1) and (10.2.3.3.1-2) for full or partial vacuum is modified by replacing P_d by $(P_d + v)$ in formula (10.2.3.3.1-1) and P_s by $(P_s + v)$ in formula (10.2.3.3.1-2)

where

$v = 0,1$ (full vacuum);

$v \leq 0,1$ (partial vacuum);

$v = 0$ (no vacuum).

In the above formulae, the pressures are expressed in MPa.

For vessels of full or partial vacuum in $\frac{1}{2}$ coil or $\frac{1}{2}$ pipe or box channels designed to EN 13445-3:2009, as illustrated in figure 8.5-11 or 8.5-12, the external pressure caused by vacuum can be ignored when determining the test pressure.

Where it is reasonably practicable, single wall vessels subject to operation under vacuum conditions should be tested under vacuum or applied external pressure to simulate vacuum conditions.

The pressure whether resulting from external pressure or from vacuum should be 1,25 times the external design pressure, if possible, but in no case less than the external design pressure.

10.2.3.3.5 The temperature of the pressurization liquid shall satisfy all of the following requirements:

- a) 5 K above solidification point;
- b) 10 K below atmospheric boiling point;
- c) and shall be of sufficient temperature that the risk of brittle fracture is avoided (See EN 13445-2:2009, Annex B).

Thick wall vessels shall not be pressurized until the metal temperature is approximately equal with the pressurisation medium. During the hydrostatic test the vessel external shall remain dry. If the toughness of the material or of the component imposes a limit on the test temperature according to annex B of EN 13445-2:2009 or on the rate at which the pressure is increased, account shall be taken of this and documented in the test data certificate.

10.2.3.3.6 Vents shall be provided at all high points of the vessel to purge possible air pockets while filling the vessel. There shall also be adequate venting before drainage to prevent collapse particularly in the case of large thin wall vessels. Attention shall be given to the support of the vessel during test to protect individuals from additional risk and the vessel from damage.

10.2.3.3.7 Glasses of sight glasses shall be submitted to an individual proof test at 2 times the design pressure prior to fitting them on to the vessel. During the proof test of the vessel, measures shall be taken to protect the personnel from bursting of the glasses e.g. protection covers.

10.2.3.3.8 Pressure of vessels under test shall be gradually increased to a value of approximately 50 % of the specified test pressure, thereafter the pressure shall be increased in stages of approximately 10 % of the specified test pressure until this is reached. The required test pressure shall be maintained for not less than 30 min. At no stage shall the vessel be approached for close examination until the pressure has been positively reduced by at least 10 % to a level lower than that previously attained. The pressure shall be maintained at the specified close examination level for a sufficient length of time to permit a visual inspection to be made of all surfaces and joints.



EN 13445-5:2009 (E)
Issue 1 (2009-07)

10.2.3.4 Pneumatic test

10.2.3.4.1

NOTE 1 Attention is drawn to national regulations, with respect to the hazard involved in proof testing using a compressible medium.

NOTE 2 Consideration may be given to the use of acoustic emission during the test, see Annex E.

Due to the hazard involved in proof testing using a compressible medium, special consideration shall be given to such factors as:

- a) location of the vessel and its position relative to factors such as other buildings, plants, public roads, and areas open to public and all other equipment and structures in the vicinity of the vessel to be tested;
- b) maintaining during the test the highest practicable standards of safety and ensuring that only personnel involved in the testing have access to the testing area, that if the testing is not performed in a special room the region in the immediate vicinity of the testing area is sealed off and warning signs used highlighting the danger zone and prohibited area;
- c) resistance of the vessel materials to fast fracture and the absolute necessity of avoiding brittle fracture;
- d) metal temperature at test shall be at least 25 °C above the impact temperature required in this standard for vessels which have not been previously subjected to a hydrostatic test at a pressure exceeding pneumatic test pressure. Attention is drawn to the fact that if the gas pressure is let down to the vessel under test from high pressure storage, its temperature will fall. Therefore the pressurising equipment shall be such that the temperature of the gas entering the vessel exceeds the minimum temperature indicated;
- e) the extent of remote monitoring provided during the test.

10.2.3.4.2 The pneumatic test pressure shall be in accordance with 10.2.3.3.1. Vessels subjected to this pressure shall be located in an enclosed and restricted area, e.g. a special chamber (bunker) capable of withstanding the explosion or being properly anchored in a water basin and adequate measures taken to prevent parts from shooting away in case of explosion. Alternatively, when it is not practicable to test vessels as described above such vessels shall be proof tested after the following NDT. All governing welded joints are required to be 100 % RT or equivalent volumetric tested. All other welded joints shall be subjected to MT or PT, if they are not subjected to volumetric testing.

10.2.3.4.3 The pressure shall be gradually increased to a value of 50 % of the required test pressure. Thereafter the pressure shall be increased in steps of approximately 10 % of the required test pressure until this is reached. The pressure shall then be reduced to the inspection pressure P_i :

$$P_i = P_s \frac{f_a}{f_T} \quad (10.2.3.4.3-1)$$

and held during the inspection of the vessel.

10.2.3.5 Combined hydrostatic/pneumatic test

10.2.3.5.1 The pneumatic pressure is applied above the liquid and at no point in the vessel shall the total pressure applied during test cause the general membrane stress to exceed value specified in EN 13445-3:2009. All requirements as detailed in 10.2.3.4 shall apply.

10.2.3.5.2 If during filling, pre-pressurizing, etc., strain measurements are to be performed values given in EN 13445-3:2009 shall not be exceeded.

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10.2.3.6 Jacketed vessels

Where the inner vessel of a jacketed vessel is designed to operate at atmospheric pressure or under vacuum conditions, the test pressure need only apply to the jacket space. In such cases P_s shall be taken as the differential design pressure between the jacket and the inner vessel for the purpose of calculating test pressure in accordance with 10.2.3. 3 or 10.2.3.4.

10.2.3.7 Low pressure leak test

If a gas leak test is carried out before the hydrostatic or pneumatic acceptance test, the test pressure shall not exceed 10 % of the design pressure or 0,5 bar whichever is less. See also Annex D.

10.2.3.8 Test pressure in excess of 100 bar or metal/medium temperatures greater than 50 °C

In the case of proof tests using water with test pressures in excess of 100 bar, or in the case of hydrostatic pressure tests with the medium employed for the tests at temperatures greater than 50 °C, one of the following shall be observed:

- a) the proof tests shall be performed in a room or in a section of a shop to which, during the course of the test, only the personnel involved in the testing have access; or
- b) if a special room is not available, suitable safeguards shall be adopted e.g. the setting up of protective walls. The region in the immediate vicinity of the pressure vessel that is to be tested shall be sealed off, and warning signs shall be utilized to designate this region as a danger zone and prohibited area.

It shall be possible to determine the pressure that is indicated from a safe distance or from a safeguarded point.

Direct examination is permitted to be carried out only when the pressure vessel has been subjected to the test pressure for a period of 30 min and when, subsequently, in the case of hydrostatic pressure tests the pressure has been reduced to around the permissible service pressure.

10.2.3.9 Acceptance criteria

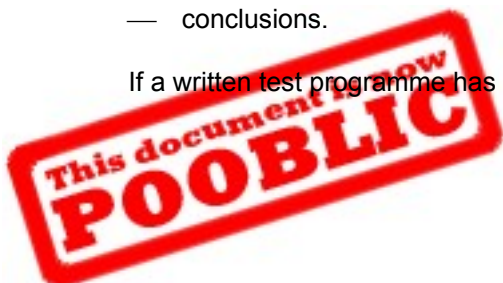
During the proof test the vessel shall show no signs of general plastic yielding. Local deformation which is identified by visual inspection and which is cause for concern shall be referred to the designer for reconciliation against the design specification. During the proof test no leaks are permitted from the pressure envelope.

10.2.3.10 Records

For each proof test a report shall be issued, and the following data shall be recorded:

- vessel manufacturer and identification of the pressure vessel;
- name of inspector and the responsible authority if applicable;
- test pressure;
- pressurization medium, if water is not used, and medium temperature;
- holding time of the test pressure;
- identification of test gauges;
- conclusions.

If a written test programme has been followed, reference shall be made to this programme.



EN 13445-5:2009 (E)
Issue 1 (2009-07)

10.2.3.11 Pressure gauges

When dial indicating and recording pressure gauge(s) are used, they shall have the dial graduated over a range of about double the intended maximum pressure, but in no case shall the range be less than 1,5 nor more than 4 times that pressure.

When components are to be proof tested, the indicating gauge(s) shall be connected to the component, or to the component from a remote location, with the gauge(s) readily visible to the operator controlling the pressure throughout the duration of pressurising, testing and de pressurising or venting of the component. For large vessels and systems when more than one gauge is specified, or required, a recording type gauge is recommended, and it is substituted for one of the indicating type gauges.

All indicating and recording type gauges used shall be calibrated against a standard dead weight tester, a calibrated master gauge or a mercury column, and re-calibrated at least once a year, unless specified differently by this standard. All gauges used shall provide results accurate to within the listed accuracy of the standard and shall be re-calibrated at any time that there is reason to believe they are in error.

For the possible case of a wrong indicating manometer the test pressure shall not be exceeded, e.g. monitored with a second calibrated manometer.

10.2.4 Post pressure test inspection

This is a visual inspection which shall be carried out after the pressure test and after the vessel has been drained and cleaned.

The inspection shall determine if there has been any deterioration resulting from the pressure test. The scope shall also cover the fitting, if applicable, of safety accessories, operation of quick release doors or similar devices and the application and accuracy of markings as required by clause 11 and the approved manufacturing drawings.

The application of surface coatings shall also be included in this inspection.

The extent of the inspections and all deviations shall be reported.

10.2.5 Inspection of safety accessories.

For assemblies the safety accessories shall be checked for full compliance with this standard.

11 Marking and declaration of compliance with the standard.

11.1 General

Equipment and accessories manufactured in accordance with all the requirements of this standard shall be marked with the number of this standard and year.

The required marking shall be located in a conspicuous place so that it will be accessible after installation.

11.2 Marking method

The marking shall be done:

- by direct stamping on the equipment;
- on a separate nameplate which shall be permanently attached to the equipment or accessory;



- on a pad, bracket or structure which is directly and permanently attached to the equipment or accessory.

11.2.1 Direct stamping

When the required marking is applied directly to the equipment or accessory, "low stress" stamps shall be used. The height of the characters shall not be less than 5 mm.

Direct stamping shall not be used on equipment manufactured of:

- steel plates less than 6 mm thick;
- quenched and tempered materials less than 12 mm thick;
- or as otherwise prohibited by this standard.

11.2.2 Nameplate

Nameplates shall be made of material suitable for the intended service and with a thickness sufficient to withstand distortion due to the application of the marking and be compatible with the method of attachment. The minimum thickness shall be not less than 1 mm.

Marking shall be done in characters not less than 5 mm high and shall be produced by casting, etching, embossing, debossing, stamping or engraving, including the identification of EN 13445.

The marking may be applied before the nameplate is affixed to the equipment providing the vessel manufacturer ensures that the nameplate is applied to the correct equipment.

The nameplate shall be attached in such a way that removal would require the wilful destruction of the nameplate or its attachment system.

The nameplate shall remain visible and legible for the lifetime of the vessel.

11.3 Marking units

The units of measurement used in marking or stamping the equipment and accessories shall follow the SI units. The unit "bar" for pressure shall be used.

11.4 Marking contents

The nameplate shall contain the following information. As a minimum the requirements of a) and b) below shall be fully marked. Depending on the type of equipment the requirements of c) shall be marked.

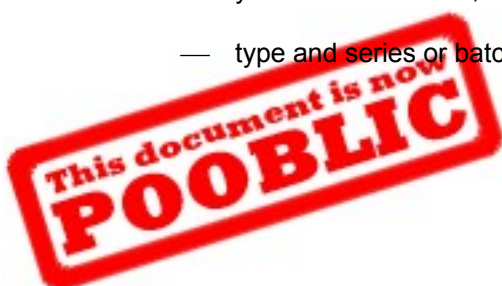
a) All equipment

1) Administrative information

- vessel manufacturer's name or symbol and address;
- reference to this standard, i.e. EN 13445, and applicable edition;

NOTE Marking of EN 13445 means that all applicable Parts have been applied.

- year of manufacture;
- type and series or batch identification and serial number identifying the equipment;



EN 13445-5:2009 (E)
Issue 1 (2009-07)

- 2) Technical data
 - maximum allowable pressure PS in bar;
 - maximum allowable temperature TS_{max} in °C
 - minimum allowable temperature TS_{min} in °C;
- b) Depending on type of equipment, supplementary information
 - identification of fluids, including warning symbols if applicable;
 - design pressure P_d in bar;
 - design temperature T_d in °C;
 - test pressure P_t in bar and date
 - internal volume in L;
 - safety accessories set pressure in bar;
 - equipment output in kW;
 - voltage supply in V;
 - intended use;
 - filling ratio in kg/L;
 - maximum filling mass in kg;
 - tare mass in kg;
 - fluid group;
 - removable parts made traceable to equipment of which they form a part.
- c) where necessary, warnings fixed to the pressure equipment drawing attention to foreseeable misuse which experience has shown may occur.

11.5 Declaration of compliance with the standard

The written declaration of compliance with the standard shall be based upon the appropriate form in accordance with Annex H.

12 Records

12.1 Type of records

The records will vary depending on the type and complexity of the pressure vessel, however, to the extent applicable the following elements shall be covered:

- an index of the records for each pressure vessel against its serial identification number;
- technical specification of equipment;

- manufacturers analysis of hazard;
- the design and manufacturing schedule;
- design calculations and drawings (including a list of all drawings with revision status);
- design review, design approval (if applicable);
- model acceptance, type approval (if applicable);
- tabulated list of materials used in the pressure vessel;
- material certification including welding consumables;
- procedures for assuring material traceability;
- quality plans (if applicable) or testing schedule;
- forming procedures;
- data related to the preparation of component parts (e.g. forming, chamfering);
- lists of approved welding procedure specifications used and approved welders and/or welding operators;
- list of any subcontracted services or parts;
- results of production test coupons (if applicable);
- list of NDT procedures and qualified personnel used;
- NDT test reports (including radiographs);
- PWHT procedures and results (time/temperature charts);
- copies of non conformity reports, repair procedures;
- report of final examination and post pressure test examination;
- report of proof test;
- dimensional report (as built condition);
- record of marking and nameplate details (rubbing, photography or other);
- copy of written declaration of compliance with this standard;
- operating instructions in accordance with CEN/TS 764-6:2004.

12.2 Control and access of records

The above records shall be readily available to the relevant bodies, see CR 13445-7:2002, Annex C.

All documents shall be legible and fully identifiable with the pressure vessel concerned. The records shall be protected against deterioration and damage.



EN 13445-5:2009 (E)
Issue 1 (2009-07)

12.3 Retention of records

After completion of the pressure vessel, stamping and certification, the vessel manufacturer or his agent shall be responsible for the safe-keeping of all records for a minimum period of 10 years. During this period such records shall be readily available to the relevant National Authorities responsible for inspection during the lifetime of the equipment in service.

Prior to destroying the records, the vessel manufacturer shall offer the records to the user of the pressure vessel when such records are deemed essential by National Authorities performing in-service inspection or when required to be retained for the life of the pressure vessel. Alternatively, the vessel manufacturer and purchaser shall agree on the retention of records at order stage in which case no further contact after the 10 years is necessary.

13 Shipping

The vessel manufacturer shall be responsible for assuring that all necessary protections against damage or deterioration in transportation and/or storage are taken including provision of blanks, protective coatings, adequate supports, nitrogen purge etc.



Annex A **(normative)**

Inspection and testing of serially produced pressure vessels **Model acceptance**

A.1 Introduction

Where the design, production, inspection and testing of a pressure vessel comply with this standard, the same procedure may be used to produce other items of the same model without repeated review of the design and manufacturing documentation. A written model acceptance, based on inspection and test results of the prototype, shall be available.

This annex describes the level of inspection and testing of serially produced pressure vessels in accordance with this standard to permit the reduced levels of NDT during serial production.

Users of this annex are cautioned that they shall satisfy all requirements of EN 13445-5:2009 unless specifically modified by this annex. This annex has specific requirements which includes the model limitation (A.3) and the availability of a model acceptance (A.5) which shall be met if they wish to implement the inspection and testing requirements (A.7 through A.8).

See 6.6.1 in case of Design by Analysis.

NOTE See clause 3 of this part for terms and definitions which are specifically relevant to serially produced pressure vessels of this annex.

A.2 Limitations for vessels permitted to be classified as serially produced

Pressure vessels serially produced under a model acceptance may be inspected and tested as described in A.7 providing the following limitations can be satisfied.

- a) The design and construction of the vessels, except where otherwise specified in this annex, is limited to testing group 2b or 3b (Table 6.6.1-1) and material groups 1.1, 1.2 and 8.1 only.
- b) The design pressure of the vessel does not exceed 30 bar and, the product of that pressure and the capacity of the vessel ($P_s V$) does not exceed 10 000 bar·L. The vessel diameter does not exceed 1,5 m, the nominal length (between tangents) does not exceed 3,5 m and the shell thickness does not exceed 16 mm.
- c) All governing welded joints are welded by a fully mechanised or an automatic welding process.
- d) Vessels identification numbers contain the suffix 'A' to denote that they have been manufactured in accordance with this annex and the standard.
- e) The number of vessels shall be 10 or more.
- f) A quality or manufacturing plan (A.6) shall be available.



EN 13445-5:2009 (E)
Issue 1 (2009-07)

A.3 Limitations for model

Vessels are considered of the same model if they comply with all the following:

- a) in accordance with the same technical specification, with same working conditions and same method of support;
- b) manufactured by same manufacturer using the same processes;
- c) same geometrical form except for variations in nozzle position which do not affect the vessel design;
- d) same material specification as indicated in the technical documents or the choice of material specification as limited by the technical documents and the relevant welding procedure qualification;
- e) same weld materials/weld consumables as allowed by the welding procedure qualification;
- f) variations in diameter and/or wall thickness to ± 10 % limited by the general membrane stress and by the range of the welding procedure qualification;
- g) same length, diameter and wall thickness in the case of external pressure;
- h) variation in the length, except those affecting the size of inspection openings or other design consideration, are permitted up to + 150 %;
- i) nozzle apertures of the same type (i.e. nozzle orientation variations acceptable subject to these not affecting the design parameter);
- j) same arrangement of tubeplate layout for boilers and heat exchangers;
- k) same classification group of fluids.

A.4 Prototype test

The inspection and tests shall be conducted on each prototype vessel representing a single model acceptance.

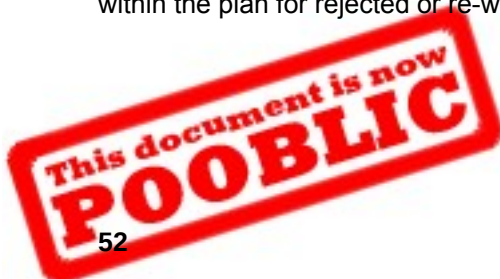
A.5 Model acceptance

Where the prototype vessel satisfies the requirements of this standard, a model acceptance shall be issued. The model acceptance shall contain all necessary data for identification of the approved model, conclusions of the examination and a list of the relevant parts of the technical documentation.

All modification to the model acceptance shall be assessed to ensure that they do not affect compliance with this standard or prescribed conditions for use. The assessment shall be documented on an additional certificate traceable to the original model acceptance.

A.6 Quality or manufacturing plan

Before production commences, a detailed manufacturing or quality plan shall be prepared by the manufacturer. This plan shall indicate the inspection or sampling points and the frequency of testing. Provision shall be made within the plan for rejected or re-worked components to be re-inspected. The plan shall ensure the following:



- a) The materials used in the manufacture of the vessels comply with the materials standards as specified;
- b) All variables in the manufacturing procedures that affect the integrity of the vessel are specified, monitored and controlled;
- c) The testing and inspection of the vessel is done at least at the frequency given in this standard, using appropriate test methods;
- d) The inspection functions within the manufacturer's organisation are clearly prescribed.

A.7 Inspection, non-destructive testing and pressure testing

A.7.1 Introduction

Inspection of manufacturing activities shall generally be in accordance with 6.1 with the following additional requirements to reflect aspects which are geared to address pressure vessels produced serially.

The following paragraphs describe the requirements and alternative procedures permissible for determination of the levels of NDT in serial produced vessels.

The approach described in A.7.2 is a general procedure permissible for vessels to testing groups 2b and 3b.

The procedure described in A.7.3 is an alternative approach which is permissible only for series produced pressure vessels to testing group 3b.

A.7.2 General procedure for serial produced pressure vessels

A.7.2.1 First vessels in each series

The inspection and non-destructive testing of the first vessel in a series shall be as follows:

- a) The whole length of all welds shall be 100 % tested by the methods specified in Table 6.6.3-2 and the acceptance criteria given in Table 6.6.3-1;
- b) Final assessment including proof test in accordance with 10.2.

A.7.2.2 First vessels in each batch

- a) At least 50 % of all welds shall be tested by the methods specified in table 6.6.3-2 and the acceptance criteria given in table 6.6.3-1;
- b) Subsequent vessels in each batch. For all subsequent vessels in that batch, except as permitted in A.7.2.3, at least 20 % of all welds shall be assessed.

A.7.2.3 Reduced NDT on vessels in each batch based on satisfactory NDT results

Except as prohibited in A.7.2.4, and based on satisfactory NDT results of at least 10 vessels in a batch the requirements of A.7.2.2.b may be further reduced to:

- a) Each longitudinal and circumferential weld joint shall be radiographed or ultrasonically tested once per vessel with a minimum length of 150 mm and with a minimum of 10 % of the finished welds per shift. This percentage shall include intersections of longitudinal and circumferential weld joints such that 10 % of the intersections per shift are examined;



EN 13445-5:2009 (E)
Issue 1 (2009-07)

- b) At least 10 % of the length of attachment welds shall be tested using either magnetic particle or dye penetrant methods.

A.7.2.4 Provisions for further adjustments to the extent of NDT

A.7.2.4.1 Reduced NDT

When production is considered consistently satisfactory, reduction in the extent of NDT from 10 % to 5 % is permissible.

Production is considered consistently satisfactory when no more than 3 unacceptable imperfections were found in the immediate 25 vessels non-destructively tested from that same batch. Any unacceptable imperfections shall be repaired and re-examined in accordance with 6.6.6.

A.7.2.4.2 Increased NDT

- a) The provisions of A.7.2.3 and A.7.2.4.1 shall be increased when more than 3 unacceptable imperfections are found in the previous 100 non-destructively tested vessels of the same batch.

The extent of NDT shall be increased as follows:

- 1) to 15 % if the inspection frequency was 10 %;
- 2) to 10 % if the inspection frequency was 5 %.

The level in A.7.2.4.2 shall be maintained until the number of unacceptable imperfections in an immediate batch of 25 vessels is less than 4.

- b) If the number of unacceptable imperfections exceeds 10 in an immediate batch of 25 vessels, then following investigation and correction of the cause, production shall commence as a new batch as per A.7.2.2.

A.7.3 Alternative procedure for determining the level of NDT for serially produced pressure vessels, testing group 3b only

For serially produced vessels made from materials 1.1, 1.2 and 8.1, testing group 3b, with a weld efficiency of 0,85 the following alternative route may be used in lieu of A.7.2:

A.7.3.1 General level of NDT

Volumetric testing 100 % of the longitudinal welds from

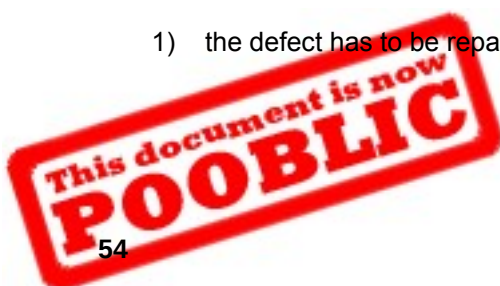
- the first vessel at the beginning of each shift and the last vessel of each shift;
- in addition 100 % of the longitudinal welds of each 25th vessel.

Those vessels subject to volumetric testing of the longitudinal weld joint shall also be subject to 10 % volumetric examination of the circumferential welds and all T-joints. Where the circumferential weld joints are not made in the same numerical sequence as the longitudinal weld joints, then the circumferential volumetric testing shall be made of the first and the last circumferential weld joints of the shift and T-joints on the same vessels.

A.7.3.2 Provisions for further adjustments to levels of NDT

- a) In the case of an unacceptable isolated imperfection the following shall apply:

- 1) the defect has to be repaired and the weld seam re-tested 100 %;



- 2) welds of the same type in two additional vessels, one before and one after, shall be tested at 100 %;
- 3) In case of further unacceptable isolated imperfections, the amount of welds to be tested has to be doubled;
- b) In the case of multiple defects the welds of this type of that shift shall be 100 % tested until the defects no longer occur. In addition the next vessel shall be tested for confirmation.

A.7.4 Pressure test for serially produced pressure vessels

Every vessel shall be pressure tested in accordance with 10.2.3 except for serially produced vessels of hazard category I which may be tested using a statistical basis in accordance with A.11:

A.8 Acceptance criteria

A.8.1 Isolated imperfections

If a defect is found during the partial non-destructive testing of a vessel, re-examination and repair shall be in accordance with 6.6.6. However, imperfections found in intersection regions of the vessel examined shall be regarded as representing the seam in which they are located.

A.8.2 Multiple imperfections

A.8.2.1 If a recurrence of unacceptable imperfections is found in that vessel seam when the whole of the seam is inspected, then the vessels produced immediately before and after it in the batch shall also have the same weld seams examined in accordance with 6.6.6 procedure for non-destructive testing.

A.8.2.2 If no unacceptable imperfections are found in the appropriate seams of those two vessels, no further special examinations shall be carried out.

A.8.2.3 If unacceptable imperfections are found in either of the preceding or following vessels, then further vessels in sequence shall be assessed in accordance with A.7.2 until a vessel with no unacceptable imperfections is found.

A.9 Marking

All vessels shall be inspected before dispatch to ensure that the marking conforms to clause 11. The vessels shall be marked "A" to denote that they have been manufactured in accordance with this annex.

Where some time elapses between pressure test and dispatch, e.g. stock vessels, assurance shall be made that no deterioration or damage has occurred in the interim period. Where a temporary nameplate has been attached it shall be assured that the permanent plate conforms in all respects to clause 11.

A.10 Documentation/Certification

A declaration of compliance with this standard shall be issued for each vessel. The declaration shall state clearly the serial number of the vessel covered. The reasons for any missing numbers in the series shall be clearly stated.

Records of manufacture described in clause 12 shall be retained.



EN 13445-5:2009 (E)
Issue 1 (2009-07)

A.11 Pressure testing using a statistical basis for serially produced vessels

Pressure testing on a statistical basis may only be carried out when all the following conditions are satisfied:

- a) materials are limited to material groups 1.1, 1.2 and 8.1;
- b) the main seam weld joints shall permit meaningful volumetric examination.

A.11.1 General level of NDT

All vessels shall be visually, magnetic particle and volumetrically tested for 100 % of all welds. The testing shall be carried out to the requirements of 6.6.3.

A.11.2 Fatigue

The vessel fatigue life shall not exceed 500 cycles.

A.11.3 Acceptance criteria

If unacceptable imperfections are found during the NDT, the vessel shall be removed from the series produced classification, and be repaired and inspected as an individual vessel, according to 6.6.6.

A.11.4 Statistical basis pressure testing

All pressure testing shall be carried out on the following basis:

- the first vessel at the beginning of each shift and the last vessel of each shift.
- each 5th vessel, or a statistical selection plan which will give a 95 % confidence limit.

If one vessel fails the pressure test, all vessels in that batch will be pressure tested. If other vessels in this batch fail the pressure test, the whole of the immediately preceding and subsequent batches shall be pressure tested.

A.11.5 Marking

All vessels shall be inspected before dispatch to ensure that the marking conforms to clause 11. The vessels shall be marked TC 54 "A-S" to denote that they have been manufactured in accordance with this annex, but tested in accordance with the provisions of a statistical basis. The nameplate shall clearly state that a pressure test has not been carried out. It should also state the test pressure to be used for in service inspection.



Annex B (normative)

Detailed dimensional requirements for pressure vessels

Particular attention shall be given to ensure that the following information is included for the various items to facilitate calculation and constructional assessment:

- dished ends: crown radius, inside corner radius, or ellipsoidal shape plus minimum thickness after forming and inside/outside diameter; forming method and heat treatment;
- shell barrel: thickness, diameter, linear alignment tolerance if applicable;
- flanges (including blind flanges): type, standard and rating or, if special: minimum thickness, drilling, inside and outside diameters, hub dimensions and facing details and weld details; additional NDT where cut from plate material;
- bolting: diameter, type of thread, length of bolt, number of bolts, tapping depth for studs and thickness of metal between bottom of stud holes and pressure retaining surface;
- gaskets: type, rating, material, thickness, inside and outside diameters and gasket seating data;
- nozzles: wall thickness (minimum), outside diameter, method of attachment to vessel, dimensions and projection into vessel; loads to be specified if applicable; location of openings to each other and main welded joints;
- welds: weld profiles and sizes plus dimensional details of the weld preparation e.g. gap, nose thickness, preparation angle;
- reinforcing plates for nozzles, supports, lifting lugs etc.: plate dimensions required including width x length x thickness and radius of corners including angle of support reinforcing plates, plus bleed hole details;
- tubeplates (heat exchangers): drilling arrangements of tubeholes, i.e. pattern, number of holes, dimensions of tubes (e.g. outside diameter and wall thickness), minimum thickness of plate, weld details;
- covers: dimensions including minimum thickness, drilling size of bolt holes and pitch circle diameter;
- conical sections: included angle of cone, radius of knuckle to shell (if applicable) ; diameter at large and small ends of cone, minimum thickness and straight length of cone;
- supports (horizontal vessel): number off, dimensions including number and thickness of webs and flanges, baseplate, foundation bolt, hole pitch and diameters ; distance from tangent line of dished ends to centre of supports, distance between supports and height of vessel centre line to support foot baseplate;
- supports (vertical vessel): skirt dimensions including diameter, height, thickness, method of attachment to shell, dished end ; if supports are used, number off thickness of webs, height, etc., base ring diameters, inside and outside, thickness, number and pitch of foundation bolt holes and diameter;



EN 13445-5:2009 (E)
Issue 1 (2009-07)

- lifting lugs: number off, thickness, hole size lifting angle, lug dimensions, location or lugs;
- flat plates: length, width and thickness including stiffener characteristics (cross section, number of, pitch, weld details), if fitted;
- bellows: spring rate, pressure, diameter, allowable axial, lateral and angular movements, allowable number of cycles;
- safety valves: number, size and set pressure and capacity ; specifications/code and approval; minimum flow area;
- internals: weld details (welds to vessel wall);
- tolerances: including special tolerances, if applicable;
- bursting disc: type including housing, rating.



Annex C **(normative)**

Access and inspection openings, closing mechanisms and special locking elements

C.1 General

All vessels shall be provided with openings adequate in size and number to allow access for internal inspection and cleaning.

The number, size and location of inspection openings shall be in accordance with the requirements given in clauses 2 and 3.

If due to design considerations the dimensions of the heights of the openings are to be exceeded, the diameter of the openings is to be enlarged in order to hold the visible area the same.

The limits for the height of necks or rings given in subclause 2 may be exceeded if the internal dimensions are increased accordingly. Rings and necks of conical shape shall have an inclination of at least 15°; for inclinations less than 15° the limits for cylindrical shapes apply. Access and inspection openings of the type in which the internal pressure forces the cover plate against a flat gasket shall have a total clearance between the neck or ring and the spigot or recess of such covers not exceeding 3 mm, i.e. 1,5 mm all round, and the spigot depth shall be sufficient to trap the gasket.

C.2 Types and dimensions of access and inspection openings

C.2.1 Sightholes

Sightholes are openings with an inside diameter of at least 50 mm (large sightholes); sightholes with an inside diameter of 30 mm (small sightholes) can be accepted for small vessels. The flange height shall not exceed the diameter of the opening.

C.2.2 Handholes

A handhole for cleaning shall be not less than 80 mm x 100 mm or shall have an inside diameter of 100 mm.

A handhole for inspection shall be not less than 100 mm x 150 mm or shall have an inside diameter of 120 mm. The height of the neck or ring shall not exceed 65 mm, or 100 mm if the neck or ring is conical.

C.2.3 Headholes

Headholes are openings through which the head, an arm and a lamp can be introduced simultaneously. Headhole dimensions shall be not less than 220 mm x 320 mm or 320 mm inside diameter. The height of the neck or ring shall not exceed 100 mm or 120 mm in the case of a conical shape.



EN 13445-5:2009 (E)
Issue 1 (2009-07)

C.2.4 Manholes

Manholes are opening through which a person not carrying any auxiliary equipment can enter and leave the vessel. Manhole dimensions shall not be less than 320 mm x 420 mm or 420 mm inside diameter. The height of the neck or ring shall not exceed 150 mm, unless the minimum diameter is greater than 460 mm diameter or at least 460x410 mm oval.

C.2.5 Rescue holes

Rescue holes are holes permitting entry and exit of a person equipped with rescue and protective equipment. They shall be 600 mm in diameter. If it is not possible, due to design considerations, to achieve an opening of 600 mm, the size of a rescue hole can be reduced to not less than 500 mm provided the height of the neck does not exceed 250 mm. In this case, special equipment shall allow safe access inside the vessel.

C.3 Types, location and minimum number of access and inspection openings.

Inspection openings shall preferably allow an inspection of the longitudinal and circumferential seams from the inside of the vessel and especially high stressed and high risk areas.

High stressed areas are e.g. corner joints, knuckles and areas around larger openings.

Areas of high risk are e.g. the fluid sump or the bottom of the vessel, the area of the fluid level and areas at which corrosion or erosion might occur due to the experience.

The types, location and minimum number of inspection openings required for all vessels other than spherical vessels shall be in accordance with Table C.3-1, for spherical vessels in Table C.3-2. Additional inspection openings may be required if, due to the design, the access is not possible.

Detachable ends or covers, flanged connections from which piping, instruments, or similar attachments can be removed may replace all the other examination holes if, by their dimensions and position, a general view of the interior is provided which is at least equivalent to that obtained by the examination holes which otherwise would be required.



Table C.3-1 — Types and minimum number of access and inspection openings in vessels other than spherical vessels

Internal diameter D_i mm	Length of cylindrical section, L mm	Minimum number and type of openings
$D_i \leq 300$	$L \leq 1000$	1 small sighthole in each end.
	$L > 1000$	1 small sighthole in each end. The distance between the axis of sightholes and any part of seam to examine does not exceed 500 mm. If not, an additional large sighthole ^a shall be provided
$300 < D_i \leq 450$	$L \leq 1500$	2 large sightholes, one near or in each end, or 1 handhole ^a in the central third of the cylindrical section.
	$L > 1500$	1 handhole near each end of the cylindrical section ^a or in the ends. The distance between the axis of handholes and any part of seam to examine does not exceed 750 mm. If not, an additional handhole ^a shall be provided
$450 < D_i \leq 840$	$L \leq 1500$	1 large sighthole and 1 handhole, one near or in each end.
	$1500 < L \leq 3000$	1 headhole in the central third of the cylindrical section, or handholes as in the case $300 < D_i \leq 450$, $L > 1500$
	$L > 3000$	The number of inspection openings shall be increased such that the maximum distance between the axis of headhole and any part of weld to examine does not exceed 1500 mm (1000 mm for handholes). Handholes shall at least be located near each end of the cylindrical section or in each end.
$840 < D_i \leq 1200$	$L \leq 2000$	1 headhole in the central third of the cylindrical section, or 2 handholes, one near each end of the cylindrical section or in the ends, or 1 manhole.
	$L > 2000$	1 manhole, or headholes as in the case $D_i \leq 840$, $L > 3000$
$D_i > 1200$		1 manhole or 1 rescue hole if required
NOTE Requirements for rescue holes or manholes of different dimensions for special cases should come from the purchaser. Where other alternatives are provided for, the choice is at discretion of the manufacturer.		
^a Sightholes and handholes have to be located such as to provide a view of the longitudinal seam		

Table C.3-2 — Types and minimum number of access and inspection openings in spherical vessels

Internal diameter D_i mm	Minimum number and type of openings
$D_i \leq 450$	2 large sightholes, or 1 handhole
$450 < D_i \leq 840$	1 handhole, or 1 headhole
$840 < D_i \leq 1200$	1 headhole, or 1 manhole
$D_i > 1200$	1 manhole or 1 rescue hole if required
NOTE Requirements for rescue holes or manholes of different dimensions for special cases should come from the purchaser. Where other alternatives are provided for, the choice is at discretion of the manufacturer	

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EN 13445-5:2009 (E)
Issue 1 (2009-07)

C.4 Alternative requirements for sightholes openings on small vessels

For vessels with internal diameter lower than or equal to 300 mm the requirements of C.2 and C.3 and Table C.3-1 may be modified as follows:

- a) The inside diameter of the sightholes shall be large enough to permit proper internal cleaning and shall not be less than: 19 mm for vessels with an internal diameter up to and including 300 mm;
- b) If through these smaller sightholes the internal surface is not completely visible, then the visual inspection shall be supplemented by an additional inspection method which shall be detailed by the manufacturer in his instructions.

C.5 Closing mechanisms and special locking elements

C.5.1 Purpose

This clause deals with the requirements for all types of closures.

C.5.2 Definitions

C.5.2.1

opening and closing devices

parts of a vessel which can be removed for operation activities, for example: examination, draining or venting, filling or discharge

C.5.2.2

quick opening and closing devices

all types of opening and closing devices with a single control which can be opened and closed faster than those with several locking elements, each of which requires to be operated individually

C.5.3 Materials of construction, design

Opening and closing devices shall be designed and manufactured so that their tightness is ensured even under test pressure and that they cannot be opened inadvertently while under pressure.

Suitable materials shall be used from those permitted in EN 13445-2:2009 for all elements of opening and closing devices. Design requirements of EN 13445-3:2009 and manufacturing requirements of EN 13445-4:2009 shall apply.

In opening and closing devices with several locking elements, these parts shall be designed and machined so that under operating conditions the load is distributed evenly among them.

In determining the permissible pressure per unit area of opening and closing devices (e.g. cams on bayonet-type opening and closing devices), both the quality of the surface (i.e. machined) and the alignment of the bayonets (i.e. machined alignment) need to be taken into consideration.

For fully machined and aligned elements giving uniformity of load distribution 100 % of allowable permissible unit area may be used.

For those not fully machined the allowable permissible unit area shall not exceed 75 %.

For a possible weakening of the closing elements by wear or corrosion, calculated dimensions shall be increased by adequate allowances.

For opening and closing devices with more than 3 locking elements, the theoretical, i.e. calculated stress load acting on each locking element, shall be increased by at least 20 %.

If the contents of the vessel are explosive, flammable, toxic, oxidizing or corrosive, special measures of design shall be taken to ensure tightness of the opening and closing device. The cover shall be designed so that the gaskets cannot be pressed out. In the event of a leakage of a seal, provisions shall be made in design for safe venting or evacuation of the contents in order to minimise the consequences of the leakage.

Gaskets shall be closed rings, or packings with several hoops of material.

For internal covers to be fastened by means of a yoke and central bolting, the clearance relative to the edge of the hole shall not exceed the following values:

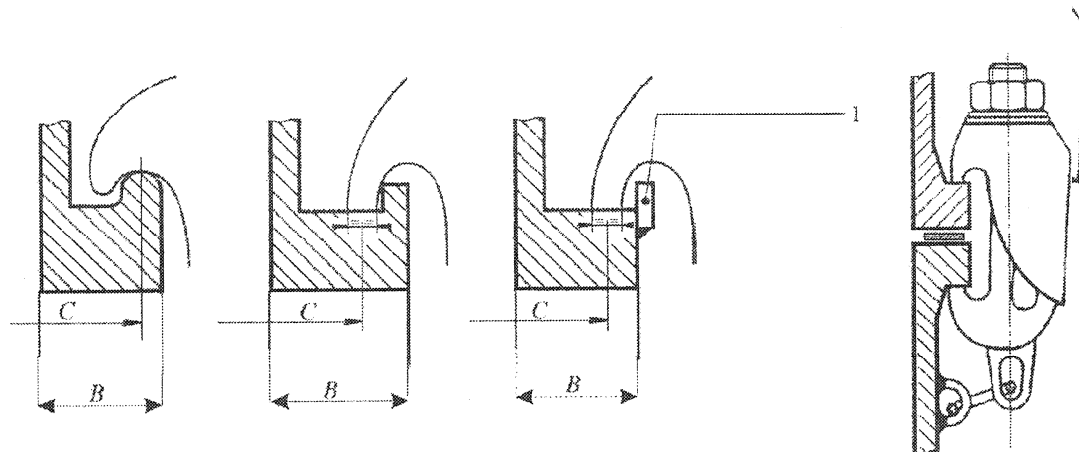
- a) 3 mm for pressures ≤ 32 bar;
- b) 2 mm for pressures > 32 bar.

C.5.4 Screw clamps

Screw clamps, see Figure C.5.4-1, shall be verified as suitable.

They shall be secured against slipping off, and they shall be attached to the vessel so that they cannot fall off when hinged down.

The number, size and quality of the screw clamps of each closure shall be indicated on the manufacturer name plate on the vessel.



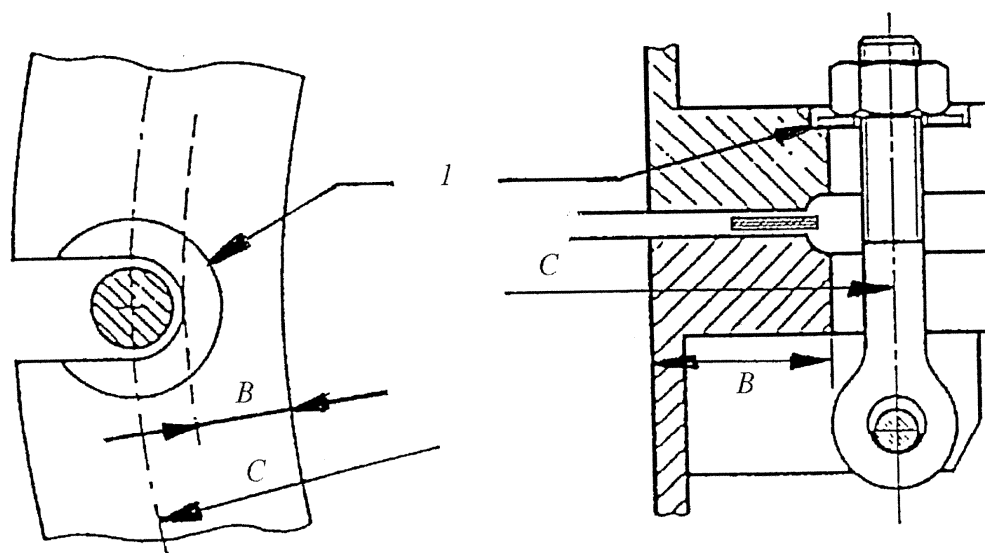
Key

- 1: Hold ring
- B: Flange width (mm)
- C: Bolt circle diameter (mm)

Figure C.5.4-1 — Flanges assembled by screw clamps with typical examples of security against slipping off

C.5.5 Hinged bolts

Hinged bolts to be swung into slots (e.g. eyebolts) shall be secured against slipping off, see Figure C.5.5-1. Nuts and washers shall bear on the entire surface outside the slot.



Key

- 1: Security against sliding
- B: Flange width (mm)
- C: Bolt circle diameter (mm)

Figure C.5.5-1 — Flanges assembled by hinged bolts

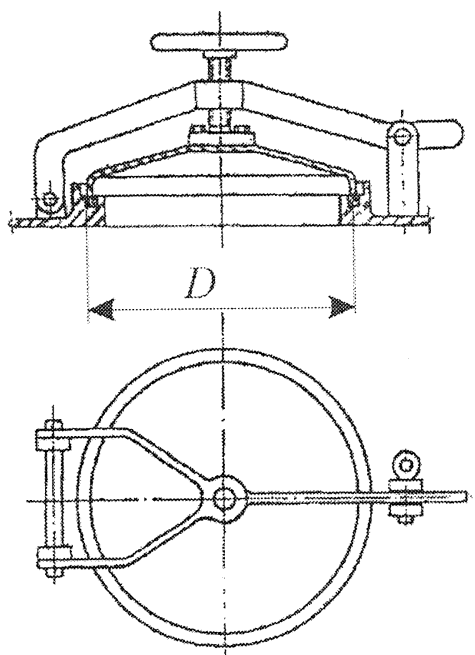
C.5.6 Yoke-type closures

This type of closure, see Figure C.5.6-1, consists of an external cover which is hinged on one side and closed on the opposite side with one or several closing elements (e.g. tightening screws).

Yoke-type closures for external covers shall be designed so that when the tightening device is opened the cover is lifted off before the yoke can be removed.

The mean diameter of the gasket of a yoke-type closure shall not exceed

- a) 500 mm for pressures $\leq 3,0$ bar
- b) 350 mm for pressures $> 3,0$ bar.



Key

D : Mean gasket diameter (mm)

Figure C.5.6-1 — Yoke-type closure

C.5.7 Quick opening and closing devices

C.5.7.1 General

The term "quick opening and closing devices" covers mainly:

- bayonet-type closures;
- central locking devices;
- ring-type closures;
- yoke-type closures for larger gasket diameters than defined in C.5.6;
- sliding door locks and the like.

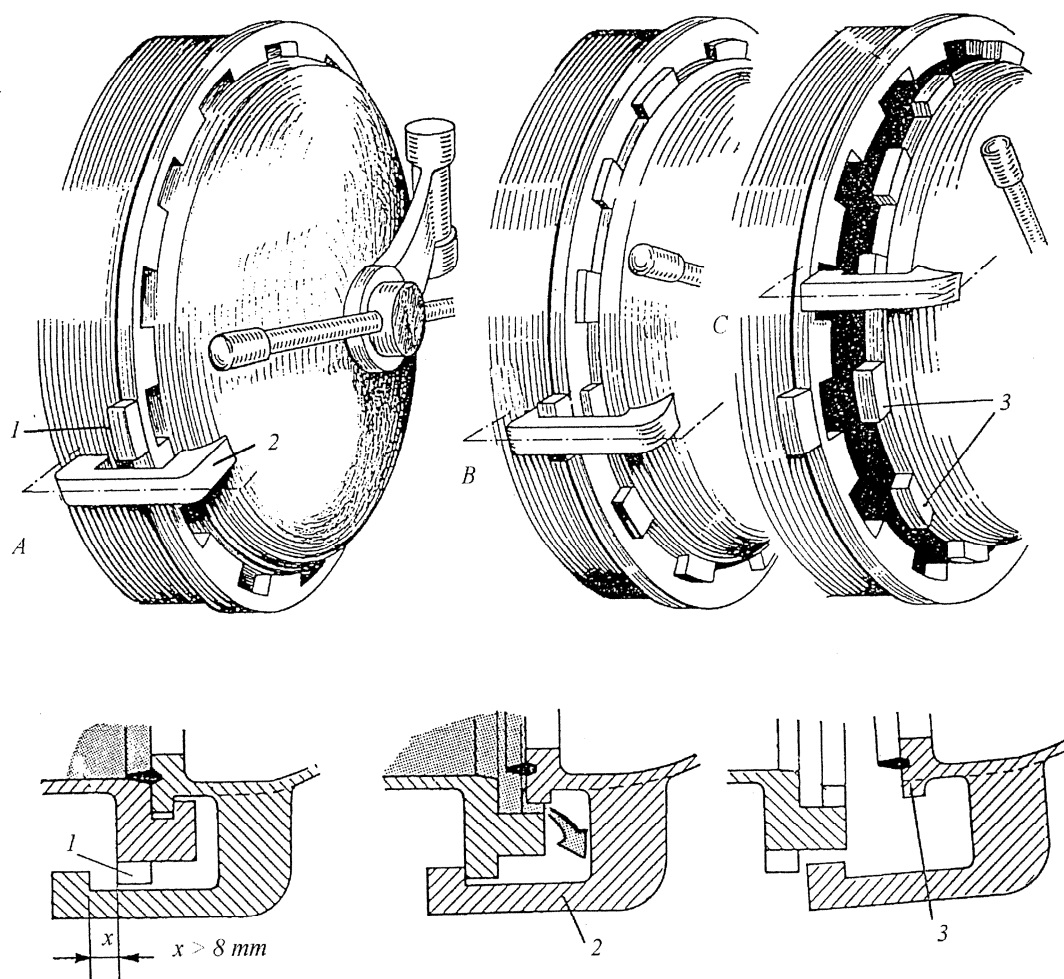
Typical for the devices covered by this paragraph are opening and closing devices with the following features:

- power or manually operated;
- movements initiated by control impulses given manually or automatically,
- function which may be monitored automatically.

Opening and closing devices with more than one screwed connection do not fall within the scope of this paragraph.

An example of quick opening and closing device is shown in Figure C.5.7-1.





Key

- A: Door closed, locking cams at final position.
- B: Door kept closed by safety hook, decrease of residual pressure.
- C: Opening of the door is possible, safety hook and locking cams are clear.
- 1: Safety hook
- 2: Blocking element
- 3: Locking cam

Figure C.5.7-1 — Typical example of quick opening and closing device

C.5.7.2 Design

In *manually operated* opening and closing devices, the cover or the door as well as the locking element are moved manually to the closing or locking position. Locking elements are e.g. bolts, latches, cams, rings and locking disks which, when engaged, will prevent that the door or cover can swing open.

In *power operated* opening and closing devices, the cover or door as well as any locking element are moved to closing or locking position by external energy. Power operated opening and closing devices do not need a special locking element if it is ensured by other means of design and construction - e.g. by suitable guiding devices - that the cover or door cannot swing open.

In opening and closing devices with several locking elements, these elements shall reach their final position positively and simultaneously.

C.5.7.3 Safety devices

C.5.7.3.1 General

Quick opening and closing devices shall be designed and arranged so that:

- their function cannot be impaired or rendered ineffective by the contents of the vessel;
- they are protected against fouling and against tampering by unauthorized persons;
- maintenance and function checks are possible at any time.

All moving parts which could cause an accident shall be so designed and/or safeguarded that persons will not be endangered.

Safety devices shall be provided on moving parts, such as:

- covers or guards on drives;
- contact stops on sliding doors;
- non-contact barriers;
- impulse contact controls on power operated doors and covers.

C.5.7.3.2 Prevention of pressurisation

Vessels fitted with quick opening access covers or doors shall be provided with devices which ensure that the vessel cannot be pressurised unless the access door is completely closed, the securing mechanism fully engaged and the initial load has been supplied to the sealing element.

In mechanisms with several interconnected locking elements, the element shall reach their final position positively and simultaneously.

Manually operated locking mechanisms shall be deemed to comply with this requirement if, after the closing operation, the cover or door is shut, the locking elements are in position and their final position is monitored.

Monitoring of the locking element can be achieved e.g. by:

- a) pressure warning device (e.g. a small opening to the inside of the vessel) which can only be closed when the locking elements are in the locked position, or;
- b) an interlocking device between the door locking mechanism and the pressurising system, or;
- c) a limit switch(s), in the case of remotely controlled pressure inlet to the vessel or pressure venting valves.

Pressure warning devices dependent upon an opening shall have an internal diameter of at least 8 mm. Where there is a risk of blockage, it shall be possible to manually clear the blockage without endangering the operator.

For interlocking devices where pressure is applied from an external source, the interlock shall be situated between the door locking mechanism and the pressurising fluid inlet valve.



EN 13445-5:2009 (E)
Issue 1 (2009-07)

If pressure is raised by energy input into the vessel, the interlocking arrangements shall be between the door locking mechanism and the source of energy. Where pressure is applied by a pump, it shall not be possible for the pump to pressurise the system unless the door securing mechanism is fully engaged.

Power operated mechanisms shall be deemed to comply with this requirement if the closed position of the cover or door is monitored so that the vessel can only be pressurised when the cover or door is completely closed and the locking mechanism is fully engaged as specified by the manufacturer.

C.5.7.3.3 Depressurisation

Vessels fitted with quick opening access doors shall be provided with devices which ensure that the source of pressure is isolated and the vessel vented to reduce the internal pressure to atmospheric conditions before the closure or door securing mechanism can be disengaged.

The hazard analysis shall consider the effects of the vented fluid on the operator.

C.5.7.3.4 Residual pressure and temperature warning

Vessels fitted with quick opening access doors shall be provided with devices which:

- a) warn the operator of any residual pressure, any remaining fluid which can leak out, and any process fluid at an unsafe temperature, and;
- b) ensure that the temperature of the process fluid has been reduced to a safe level, or any toxic fluids that can leak out the vessel have been completely removed before the closure or door securing mechanism can be disengaged.

This may be achieved by providing indicators and warning devices as in which will not put the person carrying the test at risk.

Where the door seal is prone to sticking, devices shall be provided which either:

- 1) break the seal before all the locking elements are disengaged, or;
- 2) restrict the door opening to not more than 8 mm until a harmless residual pressure has been reached.

This requirement may also be achieved by instrument and control measures. In this case, the following requirements also apply:

- I) the reduction of pressure down to a harmless level shall be monitored by at least two independent pressure sensors, and;
- II) the signal to open the door or cover shall become active only when the pressure venting valve has reached its open position and the signal for equilibrium between internal and external pressure has been given.

If one of these signals is not interrupted during the next pressure cycle, the process shall be brought to a safe state, and,

- a) in the case of electrical power failure or failure of a control medium (e.g. instrument air), all processes shall be interrupted or controlled so that persons will not be endangered, and;
- b) if it is possible for the cover or door to swing open, then one of the devices described in C.5.7.3.5 shall be fitted.

NOTE A pressure is considered harmless if the forces generated on the door, by the pressure, are too small to cause injury to persons standing in front of it and if it opens in an uncontrolled manner.

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Similarly, if a vessel contains other material, in containers or otherwise, in addition to the process fluid, the temperature of these too shall be monitored.

This can be achieved by using an interlock arrangement incorporating a temperature sensing device located in that part of the vessel or contents which is/are expected to remain at the highest temperature at the end of the process.

C.5.7.3.5 Door movement restriction

Vessels fitted with quick opening access doors shall be provided with devices which ensure that the closure does not open violently because of any residual pressure remaining in the vessel.

This can be achieved by fitting the cover or door with a safety device which ensures that:

- a) the cover or door cannot swing open, or;
- b) the opening process requires several consecutive manipulations or several manual turns so that the cover or door can only be opened when a harmless residual pressure has been reached.

Each power operated door shall be provided with at least one easily accessible and prominently placed shutdown device. These devices shall not be self-resetting. When any of these devices are operated:

- a) any residual movement of the door shall not create a hazard, and;
- b) all other components related to safety shall return to a safe condition, e.g. valves, seals etc., used to control the flow of fluids, and;
- c) use of a special tool, key or code shall be required to reset the shutdown device, in order to restore the normal control system, and such resetting shall not cause a hazard.

C.5.7.3.6 Inflatable or pressure activated seals

The additional requirements set down below have been established for door closures with inflatable or pressure-activated seals.

- a) gaskets utilising an auxiliary sealing pressure shall not be regarded as being part of the locking elements;
- b) persons shall not be endangered during the build-up, release or unintended loss of the auxiliary sealing pressure;
- c) gaskets shall only be pressurised when the locking element has reached its fully engaged position;
- d) the valve allowing pressurised fluid to enter the vessel shall only be opened after the sealing pressure of the gasket has reached its design value;
- e) during the door opening process, the signal "pressure venting valve open, vessel depressurised" (e.g. from the two pressure sensors) shall initiate the step "release auxiliary sealing pressure" before the cover or door is unlocked;
- f) a device shall be fitted such that if the door seal pressure falls below the minimum pressure specified by the manufacturer, then:
 - entry of fluid into the vessel shall be prevented, and;
 - the operation shall abort and be brought to a safe state, and;



EN 13445-5:2009 (E)
Issue 1 (2009-07)

- a fault condition shall be indicated, and;
- the door shall remain closed, and;
- no hazard shall be caused.

C.5.7.4 Testing

The functions according the requirements of this standard shall be tested within the final test of the pressure vessel at the manufacturers. If it is not possible it shall be tested in the installed conditions of the pressure vessel before being put into service.

All quick opening and closing devices used in series production vessels shall be subject to a model acceptance procedure.

In the case of quick opening and closing devices not using a model acceptance procedure and used in one off vessels, they may be only used subject to a design review and functional test prior to operation.

C.5.7.5 Marking

Each device shall be marked with the following information:

- a) Identification of the manufacturer,
- b) Identification of the device,
- c) Identification of limitation of operating parameters and temperatures.

C.5.7.6 Operating and maintenance instructions

The manufacturer shall compile, and hand over to the purchaser/user, operating and maintenance instructions for operating personnel.

These instructions shall contain at least the following information:

- The service/maintenance-intervals. These shall be specified and observed.
- That the user shall keep maintenance records.
- Checks of the closing mechanism with regard to deformations, wear, damage etc. and indications on the replacement of worn parts that may become necessary.
- That where necessary, the manufacturer shall prescribe measures and, if required, also tolerances. The replaceable parts subject to wear shall be clearly identified in the maintenance manual with their designation and materials specifications, to be in compliance with type examination or approval.
- That other materials may be used only after prior consultation with the manufacturer of the quick opening and closing device and after due consideration of the special operating conditions.
- That operating personnel shall be given adequate instructions and training for safe operations.
- That the operating instructions shall be set out in printed form and shall be available on the site where the vessel is operated.



Annex D (informative)

Leak Testing

D.1 General

Criteria for the selection of a suitable leak testing method are given in EN 1779:1999. Bubble test is specified in EN 1593, helium test in EN 13185, and pressure change test in EN 13184.

Any low pressure leak test should be carried out prior to any hydrostatic pressure test.

D.2 Leak testing personnel

Personnel performing leak testing should be qualified in accordance with EN 473:2008.



Annex E **(informative)**

Acoustic emission

E.1 General

The acoustic emission technology, as described in this annex, is not intended as a replacement of the mandatory testing and examination requirements but as a complementary measure for pneumatic test and combined hydrostatic/pneumatic test.

The method may be applied to pressure vessels of simple geometry, e.g. spheres and cylinders with dished or flat ends and should not be used for pressure vessels with discontinuities and pressure vessels with joggle joints and/or welds on backing strips.

E.2 Useful standards

The following standards apply to acoustic emission:

EN 1330-9 Non-destructive testing — Terminology — Part 9: terms used in Acoustic Emission testing

EN 13554 Non-destructive testing — Acoustic Emission — General principles

EN 13477-1 Non-destructive testing — Acoustic emission — Equipment characterisation — Part 1: equipment description

EN 13477-2 Non-destructive testing — Acoustic emission — Equipment characterisation — Part 2: verification of operating characteristics

EN 14584 Non-destructive testing — Acoustic Emission — Acoustic emission during proof testing

E.3 Acoustic emission personnel

Personnel performing acoustic emission should be qualified to EN 473:2008.

E.4 Additional requirements

The preparation, test performance and reporting should be performed according to EN 14584. The number of the sensors should be sufficient to achieve 100 % volumetric monitoring of the tested pressure equipment.

The pressurisation rate should not exceed 1 % of the maximum test pressure per minute.

The measurement should be continued also during the depressurisation till the pressure P_1 for the visual inspection of the pressure equipment is reached.



Table E.4-E.1 — Values of K (for the determination of the maximum allowed sensor spacing)

	Yield strength (MPa)	
	275 to 355	> 355
K-value	12 dB	6 dB

NOTE 1 For material groups 8, 9, 10 and 11 the K-values have to be specified within a written procedure (based on the data base or laboratory test).

NOTE 2 For repetition tests and the second loading of the pressure vessel the K-value should be increased by 6 dB.



Annex F

(normative)

Inspection and testing of pressure vessels or parts subject to creep

F.1 General

For vessels or vessel parts subject to creep, Quality Level B of EN ISO 5817:2007 is the reference quality level for maximum allowable imperfection in these areas. The absence of surface imperfections (no undercut, no root concavity and no lack of penetration) and the necessity of smooth transitions are essential. Similarly, shape imperfections, such as peaking, may be critical and the manufacturing tolerances specified in EN 13445-4:2009 shall be respected. In particular, the maximum peaking of EN 13445-4:2009 or the value permitted by the design methods of EN 13445-3:2009 shall not be exceeded.

Extent of Non-Destructive Testing (NDT) of this annex is based on the general requirements of testing sub-groups 1c and 3c, as defined in Table F.2-1.

If lifetime monitoring is a design option, any procedure for control and testing shall be part of the Instructions for use prepared by the manufacturer.

NOTE Supplementary tests may also be prescribed by the manufacturer. These tests will be specified in the Instructions for use.

F.2 Extent of inspection and testing

In addition to the requirements of 6.6.2, all areas subject to creep shall be inspected by NDT, according to the following Table F.2-1.



Table F.2-1 — Extent of non-destructive testing

TYPE OF WELD ^a			TESTING ^b	EXTENT FOR TESTING GROUP	
				1c	3c
				EXTENT FOR PARENT MATERIALS	
				1 to 10	1.1, 1.2, 8.1, 8.2, 9.1, 9.2, 10
Full penetration butt weld	1	Longitudinal joints	RT or UT MT or PT	100 % 25 %	25 % 25 %
	2a	Circumferential joints on a shell	RT or UT MT or PT	100 % 25 %	25 % 25 %
	3a	Circumferential joints on a nozzle $d_i > 150$ mm or $e > 16$ mm	RT or UT MT or PT	100 % 25 %	25 % 25 %
	4	Circumferential joints on a nozzle $d_i \leq 150$ mm and $e \leq 16$ mm	RT or UT MT or PT	25 % 100 %	25 % 25 %
	5	All welds in spheres, heads and hemispherical heads to shells	RT or UT MT or PT	100 % 25 %	25 % 25 %
	6	Assembly of a conical shell with a cylindrical shell without a knuckle (large end of the cone) ^{p,q}	RT or UT MT or PT	100 % 100 %	25 % 100 %
	7	Assembly of a conical shell with a cylindrical shell without a knuckle (small end of the cone)	RT or UT MT or PT	100 % 25 %	25 % 25 %
Assembly of a flat head or a tubesheet, with a cylindrical shell Assembly of a flange or a collar with a shell	9	With full penetration	RT or UT MT or PT	100 % 100 %	25 % 25 %
Assembly of a flange or a collar with a nozzle	12	With full penetration	RT or UT MT or PT	100 % 25 %	25 % 25 %
Nozzle or branch ^c	15	With full penetration $d_i > 150$ mm or $e > 16$ mm	RT or UT MT or PT	100 % 100 %	25 % 25 %
	16	With full penetration $d_i \leq 150$ mm and $e \leq 16$ mm.	RT or UT MT or PT	100 % 100 %	25 % 25 %
Tube ends into tubesheet	20		MT or PT	100 %	25 %
Permanent attachments ^d	21	With full penetration	RT or UT MT or PT	25 % 100 %	25 % 100 %
Pressure retaining areas after removal of temporary attachments	22		MT or PT	100 %	100 %
Cladding by welding ^e	23		MT or PT	100 %	100 %
Repairs	24		RT or UT MT or PT	100 % 100 %	100 % 100 %

^a See Figure 6.6.2.3
^b RT= Radiographic testing, UT = Ultrasonic testing, MT = Magnetic Particle testing, PT= Penetrant testing
^c Percentage in the table refers to the aggregate weld length of all the nozzles see 6.6.2 b)
^d No RT or UT for weld throat thickness ≤ 16 mm
^e Volumetric testing if risks of underclad cracking due to parent material or heat treatment



EN 13445-5:2009 (E)
Issue 1 (2009-07)

F.3 Performance of NDT and acceptance criteria

Table F.3-1 shows the method, characterisation and acceptance criteria. This table is based on EN 12062:1997.

Table F.3-1 — NDT methods, techniques, characterisation, acceptance criteria for vessels and parts subject to creep

NDT Methods (abbreviations)	Techniques	Characterisation	Acceptance Criteria
Visual inspection (VT)	EN 970:1997	EN ISO 5817:2007 (surface imperfections)	EN ISO 5817:2007 (surface imperfections Acceptance level B) ^c
Radiography (RT)	EN 1435:1997 class B	EN 12517-1:2006 and additional Table 6.6.4-1	EN 12517-1:2006 Acceptance level 1 + Table 6.6.4-1
Ultrasonic Testing(UT)	EN 1714:1997 at least Class B ^a	EN 1713:1998 ^b	EN 1712:1997 Acceptance level 2 + no planar imperfections accepted
Penetrant Testing (PT)	EN 571-1:1997 + testing parameters of EN 1289:1998, Table A.1 - Acceptance level 1	EN 1289:1998	EN 1289:1998, Acceptance level 1
Magnetic Particle Testing (MT)	EN 1290:1998 + testing parameters of EN 1291:1998, Table A.1 - Acceptance level 1	EN 1291:1998	EN 1291:1998, Acceptance level 1

^a For thickness > 100 mm, Class C or D is required.

^b EN 1713:1998 is a recommendation only.

^c Additional requirements for the following imperfections:

- stray arc (601) – removal plus 100 % MT or 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 on components made of group 1 materials;
- 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 (calculated thickness + corrosion allowance).

F.4 Records

In addition to the requirements of 12.3, for vessels or parts designed for creep, all NDT records shall be retained for the whole design life of the vessel.



Annex G (normative)

Inspection and testing of pressure vessels subject to cyclic loads

G.1 General

To avoid fatigue damage in case of cyclic loading, more severe inspection and testing requirements are needed for critical areas of the pressure vessels, i.e. areas that can limit the lifetime of the vessel for $n_{eq} > 500$ full range or equivalent pressure cycles (See EN 13445-3:2009, Clause 17.2.16 or 18.10.5 for definition of critical areas).

To reflect this, Quality Level B of EN ISO 5817:2007 is the reference quality level for maximum allowable welds imperfections in these critical areas.

For cyclic loaded vessels the absence of surface imperfections (no undercut, no root concavity, no lack of penetration for full penetration welds) and the necessity of smooth transitions are essential. Only smooth transitions are allowed, see EN 13445-3:2009, Figure 18-7.

Similarly, shape imperfections such as peaking are absolutely critical and the maximum permissible peaking of EN 13445-4:2009, Clause 5.4.4 or the value permitted in the fatigue analysis of clauses 17 and 18 of EN 13445-3:2009 and referred to below, shall not be exceeded.

These testing requirements are in addition to the general vessel testing requirements based on the vessel testing groups 1, 2 or 3.

All critical areas shall be clearly designated in the design documentation, see EN 13445-3:2009 and Clause 5 of this Part.

G.2 Extent of inspection and testing

In addition to the requirements of 6.6.2, all critical areas shall be 100% inspected, visually and by NDT, for both surface and volumetric imperfections (6.6.3.3 and 6.6.3.4).

G.3 Performance and acceptance criteria

Table G.3-1 shows the method, characterisation and acceptance criteria. This table is based on EN 12062:1997.



EN 13445-5:2009 (E)
Issue 1 (2009-07)

Table G.3-1 — NDT methods, techniques, characterisation, acceptance criteria for critical areas of cyclic loaded components.

NDT Methods (abbreviations)	Techniques	Characterisation	Acceptance Criteria
Visual inspection (VT)	EN 970:1997	EN ISO 5817:2007 (surface imperfections)	EN ISO 5817:2007 ^c (surface imperfections Acceptance level B)
Radiography (RT)	EN 1435:1997 class B	EN 12517-1:2006 and additional Table 6.6.4-1	EN 12517-1:2006, Acceptance level 1 + Table 6.6.4-1
Ultrasonic Testing(UT)	EN 1714:1997 at least Class B ^a	EN 1713:1998 ^b	EN 1712:1997 Acceptance level 2 + no planar imperfections accepted
Penetrant Testing (PT)	EN 571-1:1997 + testing parameters of EN 1289:1998, Table A.1-Acceptance level 1	EN 1289:1998	EN 1289:1998, Acceptance level 1
Magnetic Particle Testing (MT)	EN 1290:1998 + testing parameters of EN 1291:1998, Table A.1 - Acceptance level 1	EN 1291:1998	EN 1291:1998, Acceptance level 1
^a For thickness > 100 mm, Class C or D is required. ^b EN 1713:1998 is a recommendation only. ^c Additional requirements for the following imperfections: - stray arc (601) – removal plus 100 % MT or 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 on components made of group 1 materials; - torn surface (603), grinding mark (604), 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 (calculated thickness + corrosion allowance).			

G.4 Technical documentation, additional requirements

The supporting detailed construction drawings are required to clearly locate the critical areas identified in the design fatigue analysis. In addition, the maximum permissible peaking and other critical imperfections shall also be given in the drawings.

A test report shall prepared documenting the measured values of peaking and other critical imperfections identified on the drawings.



Annex H (informative)

Declaration of compliance with this standard

MANUFACTURER'S DECLARATION OF COMPLIANCE FOR DESIGN, MANUFACTURE AND INSPECTION OF PRESSURE VESSEL		Document N°
Pressure vessel Description	Category Conformity assessment module used General arrangement drawing N° Year of manufacture	
Volume (L) Maximum allowable pressure (bar) Maximum allowable temperature (°C) Minimum allowable temperature (°C) Contents Corrosion allowance (mm)	Safety valves Capacity Set pressure Date	
DESIGN		
Responsible Authority	Name Address Identification number	
Design approval	Number Date	
Type approval certificate	Number Date	



EN 13445-5:2009 (E)
Issue 1 (2009-07)

MANUFACTURE AND INSPECTION	
Responsible Authority	Name Address Identification number
Certificate	Number Date
QUALITY SYSTEM	
Responsible Authority	Name Address Identification number
System assessment certificate	Number Date
VERSION OF EN 13445 USED	
Year of issue: 2009	Latest amendment/issue included
The undersigned declares that the design, manufacture and inspection of this pressure vessel is in compliance with the requirements of EN 13445 Date : Name : Position : Company stamp: Signature :	

Figure H.1 — Declaration of compliance by the manufacturer



Annex I **(informative)**

Specific tests during construction to assist in-service inspection

I.1 General

This annex provides guidance on tests which may be made during fabrication to provide baseline data for inspection in service. It should be considered in conjunction with Annex M of EN 13445-3:2009.

I.2 Metallographic investigation

Metallographic investigation of welded joints and base material may be used to record the initial material structure and to be able to assess material ageing at future inspections. The following requirements apply:

- Replicas should be performed at the end of the fabrication process (after all heat treatments, welding, etc);
- Number and extent of replicas should be representative of the critical regions for creep damage, e.g. welds operating at high stress and temperature;
- Replica locations should include base material, HAZ and welded material. Areas of larger stress and temperature should be preferred;
- Replicas should be stored in a proper way and kept for the whole life of the vessel.

I.3 Hardness measurements

Hardness measurements of welded joints and base material may be used to record the initial material condition and to be able to assess material ageing at future inspections. The following requirements apply:

- Hardness measurements should be performed at the end of the fabrication process (after all heat treatments, welding, etc);
- Number and extent of hardness measurements should be representative of the size and complexity of the pressure vessel, and the critical zones for creep damage;
- Hardness records should be stored in a proper way and kept for the whole life of the vessel.



EN 13445-5:2009 (E)
Issue 1 (2009-07)

I.4 Dimensional measurements

High precision diameter measurements of creep designed components may be taken during fabrication to assess the evolution of creep deformation.

The precision on the measurement of diameter should be as follows:

— Diameter up to 100 mm	0,01 mm
— $100 < \text{Diameter} \leq 500$ mm	0,02 mm
— $500 < \text{Diameter} \leq 1000$ mm	0,05 mm
— Diameter > 1000 mm	0,1 mm

Measurements of circumference or other key dimensions may also be taken.



Annex Y (informative)

Differences between EN 13445-5:2002 and EN 13445-5:2009

The 2009 edition of EN 13445-5 contains the 2002 edition of the standard and all Amendments and corrections issued in the meantime.

The most important changes include:

- Adaptation of the determination of the test pressure for the standard hydrostatic test:
 - conditions where a direct determination is possible;
 - methodology to determine the test pressure when a direct determination is not possible;
 - situations where the test pressure exceeds the maximum pressure for testing load cases of certain parts of the vessel. In case of reduction of the test pressure, then additional tests may be required.
- Addition of specific requirements for vessels (or vessels parts) subject to creep:
 - information in the Technical Documentation (Clause 5);
 - testing groups 1c and 3c (Clause 6 and Annex H);
 - determination of the test pressure (Clause 10);
 - specific tests during construction to assist in-service inspection (Annex I).
- Clarification of testing conditions of welded joints: normal joints for which current testing requirements of Table 6.6.2-1 apply and other joints such as single run welds from one side. For the latter, additional NDT is necessary. Alternatively this additional NDT may be replaced by a pressure test at higher pressure defined in 10.2.3.3.1.
- Specific provisions for vessels (or vessel parts) designed according to Design by analysis – direct route of Annex B of EN 13445-3:2009 or designed according to the alternative route for steels of Clause 6.3 of EN 13445-3:2009: only testing group 1 is permissible; Annex A (Serially produced pressure vessels) is not applicable.



Annex ZA (informative)

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

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

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

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

Clause(s)/subclause(s) of this EN	Essential Requirements (ERs) of Pressure Equipment Directive 97/23/EC	Qualifying remarks/Notes
4	3.1	Manufacturing procedures
5	3.3 b)	Technical documentation
6.2	3.1	Manufacturing procedures and construction drawings
6.3	3.1.5	Material traceability
6.4	3.1.1	Preparation of the component parts
6.5	3.1.2	Permanent joining
6.6, Annex A, Annex F, Annex G	3.1.3	Internal and surface defect
6.7	3.1	Destructive testing
6.8	3.1.4	Heat treatment
7	3.1	Manufacturing procedures
10	3.2	Final assessment
10.2.1, Annex A, Annex F, Annex G	3.2.1	Final inspection
10.2.2	3.2.1	Review of documentation
10.2.3	3.2.2	Proof test
11	3.3	Marking and labelling
12	3.3 b)	Documentation
Annex C	2.5	Draining and venting
C.2, C.3 and C.4	2.4 and 2.5	Means of examination
C.5	2.3	Provisions to ensure safe handling and operation
C.5	2.9	Provisions for filling and discharge

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

Bibliography

- [1] EN 1593, *Non-destructive testing — Leak testing — Bubble emission techniques*
- [2] EN 13184, *Non-destructive testing — Leak testing — Pressure change method*
- [3] EN 13185, *Non-destructive testing — Leak testing — Tracer gas method*
- [4] EN ISO 17662, *Welding — Calibration, verification and validation of equipment used for welding, including ancillary activities (ISO 17622:2005)*

