



BSI Standards Publication

LPG equipment and accessories — Static welded steel cylindrical pressure vessels, serially produced for the storage of Liquefied Petroleum Gas (LPG) having a volume not greater than 13 m³ — Design and manufacture

National foreword

This British Standard is the UK implementation of EN 12542:2020. It supersedes BS EN 12542:2010, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PVE/19, LPG containers and their associated fittings.

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

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

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English Version

LPG equipment and accessories - Static welded steel
cylindrical pressure vessels, serially produced for the
storage of Liquefied Petroleum Gas (LPG) having a volume
not greater than 13 m³ - Design and manufacture

Équipements pour gaz de pétrole liquéfié et leurs
accessoires - Réservoirs cylindriques fixes, aériens, en
acier soudé, fabriqués en série pour le stockage de gaz
de pétrole liquéfié (GPL) ayant un volume inférieur ou
égal à 13 m³ - Conception et fabrication

Flüssiggas-Geräte und Ausrüstungsteile - Ortsfeste,
geschweißte zylindrische Behälter aus Stahl, die
serienmäßig für die Lagerung von Flüssiggas (LPG)
hergestellt werden, mit einem Fassungsvermögen bis
13 m³ - Gestaltung und Herstellung

This European Standard was approved by CEN on 15 June 2020.

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COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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European foreword

This document (EN 12542:2020) has been prepared by Technical Committee CEN/TC 286 “Liquefied petroleum gas equipment and accessories”, the secretariat of which is held by NSAI.

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of an identical text or by endorsement, at the latest by February 2021, and conflicting national standards shall be withdrawn at the latest by February 2021.

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

This document has been prepared under a standardization request 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 document supersedes EN 12542:2010.

The following main changes have been introduced during the revision of EN 12542:2010:

- a reference to “CEN/TS 16765 LPG equipment and accessories - Environmental considerations for CEN/TC 286 standards” has been added and the existing wording has been amended (including the deletion of environmental references throughout this document);
- Annex J Environmental checklist has been deleted;
- inclusion of the use of compensation calculations from EN 13445-3:2014, in order to reduce the distance between openings or branches;
- a new informative Annex J Exterior corrosion protective coating with special performance against chemical and mechanical attacks has been added.

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

Introduction

This document calls for the use of substances and procedures that may be injurious to health and/or the environment if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations at any stage.

Protection of the environment is a key political issue in Europe and elsewhere; for CEN/TC 286 this is covered in CEN/TS 16765, *LPG equipment and accessories — Environmental considerations for CEN/TC 286 standards*, and this Technical Specification should be read in conjunction with this document. This Technical Specification provides guidance on the environmental aspects to be considered regarding equipment and accessories produced for the LPG industry and the following is addressed:

- a) design;
- b) manufacture;
- c) packaging;
- d) use and operation;
- e) disposal.

Provisions should be restricted to a general guidance. Limit values are specified in national laws.

It is recommended that manufacturers develop an environmental management policy. For guidance see the ISO 14000 series.

It has been assumed in the drafting of this document that the execution of its provisions is entrusted to appropriately qualified and experienced people.

All pressures are gauge pressures unless otherwise stated.

NOTE This document requires measurement of material properties, dimensions and pressures. All such measurements are subject to a degree of uncertainty due to tolerances in measuring equipment, etc. It may be beneficial to refer to the leaflet “Measurement Uncertainty Leaflet (SP INFO 2000 27 uncertainty.pdf)”.

1 Scope

This document specifies requirements for the design and manufacture of static welded steel cylindrical pressure vessels, serially produced for the storage of liquefied petroleum gas (LPG) with a volume not greater than 13 m³ and for installation above or below ground.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 764-5:2014, *Pressure equipment — Part 5: Inspection documentation of metallic materials and compliance with the material specification*

EN 837-2:1997, *Pressure gauges — Part 2: Selection and installation recommendations for pressure gauges*

EN 1708-1:2010, *Welding — Basic welded joint details in steel — Part 1: Pressurized components*

EN 10025-2:2019, *Hot rolled products of structural steels — Part 2: Technical delivery conditions for non-alloy structural steels*

EN 10028-2:2017, *Flat products made of steels for pressure purposes — Part 2: Non-alloy and alloy steels with specified elevated temperature properties*

EN 10028-3:2017, *Flat products made of steels for pressure purposes — Part 3: Weldable fine grain steels, normalized*

EN 10028-5:2017, *Flat products made of steels for pressure purposes — Part 5: Weldable fine grain steels, thermomechanically rolled*

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

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

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

EN 13636:2004, *Cathodic protection of buried metallic tanks and related piping*

EN 14717:2005, *Welding and allied processes — Environmental check list*

EN 14784-1:2005, *Non-destructive testing — Industrial computed radiography with storage phosphor imaging plates — Part 1: Classification of systems*

EN ISO 16371-2:2017, *Non-destructive testing — Industrial computed radiography with storage phosphor imaging plates — Part 2: General principles for testing of metallic materials using X-rays and gamma rays (ISO 16371-2:2017, Corrected version 2018-05)*

EN ISO 636:2017, *Welding consumables — Rods, wires and deposits for tungsten inert gas welding of non-alloy and fine-grain steels — Classification (ISO 636:2017)*

EN ISO 2560:2009, *Welding consumables — Covered electrodes for manual metal arc welding of non-alloy and fine grain steels — Classification (ISO 2560:2009)*

EN ISO 3452-1:2013, *Non-destructive testing — Penetrant testing — Part 1: General principles (ISO 3452-1:2013, Corrected version 2014-05-01)*

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

EN ISO 5178:2019, *Destructive tests on welds in metallic materials — Longitudinal tensile test on weld metal in fusion welded joints (ISO 5178:2019)*

EN ISO 5817:2014, *Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections (ISO 5817:2014)*

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

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

EN ISO 9606-1:2017, *Qualification testing of welders — Fusion welding — Part 1: Steels (ISO 9606-1: 2012 including Cor 1:2012 and Cor 2:2013)*

EN ISO 9712:2012, *Non-destructive testing — Qualification and certification of NDT personnel (ISO 9712:2012)*

EN ISO 10675-1:2016, *Non-destructive testing of welds — Acceptance levels for radiographic testing — Part 1: Steel, nickel, titanium and their alloys (ISO 10675-1:2016)*

EN ISO 11666:2018, *Non-destructive testing of welds — Ultrasonic testing — Acceptance levels (ISO 11666:2018)*

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

EN ISO 14171:2016, *Welding consumables — Solid wire electrodes, tubular cored electrodes and electrode/flux combinations for submerged arc welding of non alloy and fine grain steels — Classification (ISO 14171:2016)*

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

EN ISO 15609-1:2019, *Specification and qualification of welding procedures for metallic materials — Welding procedure specification — Part 1: Arc welding (ISO 15609-1:2019)*

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

EN ISO 15614-1:2017, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys (ISO 15614-1:2017, Corrected version 2017-10-01)*

EN ISO 17632:2015, *Welding consumables — Tubular cored electrodes for gas shielded and non-gas shielded metal arc welding of non-alloy and fine grain steels — Classification (ISO 17632:2015)*

EN ISO 17635:2016, *Non-destructive testing of welds — General rules for metallic materials (ISO 17635:2016)*

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

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

EN ISO 17637:2016, *Non-destructive testing of welds — Visual testing of fusion-welded joints (ISO 17637:2016)*

EN ISO 17638:2016, *Non-destructive testing of welds — Magnetic particle testing (ISO 17638:2016)*

EN ISO 17639:2013, *Destructive tests on welds in metallic materials — Macroscopic and microscopic examination of welds (ISO 17639:2003)*

EN ISO 17640:2018, *Non-destructive testing of welds — Ultrasonic testing — Techniques, testing levels, and assessment (ISO 17640:2018)*

EN ISO 19232-1:2013, *Non-destructive testing — Image quality of radiographs — Part 1: Determination of the image quality value using wire-type image quality indicators (ISO 19232-1:2013)*

EN ISO 19232-2:2013, *Non-destructive testing — Image quality of radiographs — Part 2: Determination of the image quality value using step/hole-type image quality indicators (ISO 19232-2:2013)*

EN ISO 23277:2015, *Non-destructive testing of welds — Penetrant testing — Acceptance levels (ISO 23277:2015)*

EN ISO 23278:2015, *Non-destructive testing of welds — Magnetic particle testing — Acceptance levels (ISO 23278:2015)*

EN ISO 23279:2017, *Non-destructive testing of welds — Ultrasonic testing — Characterization of discontinuities in welds (ISO 23279:2017)*

ISO 9162:2013, *Petroleum products — Fuels (class F) — Liquefied petroleum gases — Specifications*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp/ui>

Note 1 to entry: See CEN/TS 16769.

3.1 General terms

3.1.1

Liquefied Petroleum Gas

LPG

low pressure liquefied gas composed of one or more light hydrocarbons which are assigned to UN 1011, UN 1075, UN 1965, UN 1969 or UN 1978 only and which consists mainly of propane, propene, butane, butane isomers, butene with traces of other hydrocarbon gases

3.1.2**serially produced pressure vessels**

more than one vessel manufactured in the same factory to a common design using the same material and manufacturing procedure and produced with no major interruption within a given period of time

3.1.3**manufacturer**

individual or organization responsible for the design, fabrication, testing, installation where relevant, and compliance with the requirements of the relevant product standard, whether executed by him or a subcontractor

Note 1 to entry: The manufacturer can subcontract one or more of the abovementioned tasks under its responsibility.

Note 2 to entry: In EU member states the manufacturer is responsible for compliance with the Pressure Equipment Directive 2014/68/EU. For those manufacturers outside of the EU their authorized representative inside the EU assumes this responsibility.

3.1.4**yield strength**

upper yield strength R_{eH} or, for steels that do not exhibit a definite yield, the 0,2 % proof strength $R_{p0,2}$

3.1.5**design pressure**

pressure used for the calculation of the minimum wall thickness

3.1.6**climatic area**

geographic area agreed or defined by the relevant national authorities, or other bodies, responsible for defining the design conditions for LPG storage pressure vessels, in the country(ies) where the pressure vessel is intended to be operated

Note 1 to entry: The area is used to define the reference temperature for design pressure and filling.

3.1.7**hot forming**

forming at temperatures above the maximum permissible temperature for stress relieving in accordance with the material specification

3.1.8**cold forming**

forming at temperatures not less than 25 °C below the maximum permissible temperature for stress relieving, in accordance with the applicable material specifications

3.1.9**Ar₃**

critical point, on the iron-iron carbide equilibrium diagram, representing the temperature at the end of transformation of austenite to ferrite on cooling of the steel

Note 1 to entry: The actual temperature varies with composition of the steel.

3.1.10

production-batch

group of pressure parts or finished pressure vessels, made consecutively by the same manufacturer using the same manufacturing techniques to the same design, nominal size and material specifications on the same production machinery and subject to the same heat treatment conditions

Note 1 to entry: In this context, consecutively need not imply continuous production.

3.2 Terms for coatings

3.2.1

coating material

product, in liquid, paste or powder form, that, when applied to a substrate, forms a layer possessing protective, decorative and/or other specific properties

[SOURCE: EN ISO 4618:2014, 2.51, modified – The original Note 1 to entry is not reproduced here.]

3.2.2

coating

layer formed from a single or multiple application of a coating material to a substrate

[SOURCE: EN ISO 4618:2014, 2.50.1]

3.2.3

coating process

method of application of a coating material to a substrate

[SOURCE: EN ISO 4618:2014, 2.53]

4 Materials

4.1 Environmental

The manufacturer shall endeavour to acquire materials and components from suppliers who have a declared environmental policy; see CEN/TS 16765, EN ISO 14021, EN ISO 14024 and EN ISO 14025.

4.2 Shells and ends

4.2.1 Materials for shells and ends shall be selected from the range of steels specified in EN 10028-2:2017, EN 10028-3:2017 or EN 10028-5:2017.

Other equivalent material specifications which have either European materials approval or have been subjected to a particular material appraisal may be used.

4.2.2 In all cases the materials used shall comply with the following:

- the chemical composition and mechanical properties shall meet the requirements of either Group 1 or Group 2, as defined in Table 1 — Material grouping;
- the minimum specified ultimate tensile strength shall not exceed 700 MPa;
- the minimum elongation after fracture shall be 14 %;
- the impact properties shall be not less than 27 J at the minimum design temperature or shall meet the requirements for low temperature design as detailed in EN 13445-2.

4.2.3 Steels shall be grouped in accordance with Table 1 — Material grouping.

4.2.4 Where materials subject to particular material appraisal have been used, satisfactory properties following welding shall be demonstrated by production weld test plates, see 9.7.

Table 1 — Material grouping

Group	Sub-group	Type of steel
1		Steels with a specified minimum yield strength $R_{eH} \leq 460$ MPa ^a and with analysis in percent: C $\leq 0,25$ Si $\leq 0,60$ Mn $\leq 1,70$ Mo $\leq 0,70$ ^b S $\leq 0,045$ P $\leq 0,045$ Cu $\leq 0,40$ ^b Ni $\leq 0,5$ ^b Cr $\leq 0,3$ (0,4 for castings) ^b Nb $\leq 0,05$ V $\leq 0,12$ ^b Ti $\leq 0,05$
	1.1	Steels with a specified minimum yield strength $R_{eH} \leq 275$ MPa
	1.2	Steels with a specified minimum yield strength $275 \text{ MPa} < R_{eH} \leq 360$ MPa
	1.3	Normalized fine grain steels with a specified minimum yield strength $R_{eH} > 360$ MPa
2		Thermomechanically treated fine grain steels and cast steels with a specified minimum yield strength $R_{eH} > 360$ MPa
	2.1	Thermomechanically treated fine grain steels and cast steels with a specified minimum yield strength $360 \text{ MPa} < R_{eH} \leq 460$ MPa
^a In accordance with the specification of the steel product standards, R_{eH} may be replaced by $R_{p0,2}$.		
^b A higher value is accepted provided that $Cr + Mo + Ni + Cu + V \leq 0,75$ %.		
NOTE This table is based on CEN ISO/TR 15608.		

4.3 Pressure parts other than shell or ends

Materials for pressure parts, other than shells and ends, shall comply with the appropriate harmonized European Standard for the material, or a similar specification which has European materials approval or particular material appraisal.

Examples of standards which may be used include EN 10222-2 (Forgings), EN 10216-2 (Seamless tubes), EN 10217 series (Welded tubes) and EN 10273 (Bars).

Materials shall also meet the requirements of 4.2.2 and 4.2.3 and 4.2.4.

4.4 Parts welded to the pressure vessel

Non-pressure retaining parts that are directly welded to the pressure retaining parts shall be made from suitable materials selected from EN 10025-2:2019 or a material which is compatible with the pressure retaining part material.

In all cases, the material shall meet the requirements of 4.2.

4.5 Welding consumables

The welding consumables shall be such that they are capable of giving consistent welds with properties at least equal to those specified for the parent materials of the finished pressure vessel.

The welding consumables shall be selected from EN ISO 2560:2009, EN ISO 14171:2016, EN ISO 17632:2015 or EN ISO 636:2017, as appropriate. Suitability of the chosen consumables shall be demonstrated in accordance with 7.7.3.

4.6 Inspection documents for materials

The pressure vessel manufacturer shall obtain inspection documents showing the chemical analysis and details of the mechanical properties of the steel supplied for the construction of the pressure vessel, the documents shall be in accordance with EN 764-5:2014. The documents shall include, or be supplemented by, the material manufacturer's documented affirmation of compliance to the material specification.

NOTE Annex 1 Essential Safety Requirement 4.3 of the PED gives specific requirements for material manufacturers and their quality management systems.

4.7 Non-metallic materials (gaskets)

Non-metallic materials shall be compatible with both phases of LPG over the full range of pressures and temperatures anticipated in service.

5 Design

5.1 General

Pressure vessel shell thicknesses shall be calculated in accordance with Annex E.

No internal corrosion allowance is required for pressure vessels intended to contain LPG which complies with ISO 9162:2013 and is supplied to a national or international standard or other equivalent specification.

No external corrosion allowance is required for pressure vessels protected against external corrosion in accordance with Clause 10.

The appropriate weld joint coefficient for the material used and the level of non-destructive testing to be adopted shall be selected in accordance with Table 2.

The pressure vessel shall be designed to withstand the forces of pressure, vacuum conditions and liquid load in accordance with 5.3, 5.4 and 5.5.

For underground pressure vessels, the weight of the surrounding ground in the operating condition and loadings from anti-flotation devices shall be taken into account.

Where necessary, attachments to the pressure vessel shall be welded using a backing plate.

A fully detailed, dimensional drawing shall be produced.

The design of the pressure vessel should take account of the following:

- required vaporization capacity;
- footprint of the pressure vessel to minimize land use;
- minimizing the use of materials;
- profile of the pressure vessel;
- fittings required for the pressure vessel;
- minimizing the environmental impact of in service maintenance and end of life disposal;
- efficient transport of finished product.

5.2 Temperature

The design temperature range shall be $-20\text{ }^{\circ}\text{C}$ to $50\text{ }^{\circ}\text{C}$. However, if temperatures lower than $-20\text{ }^{\circ}\text{C}$ (including lowering of temperatures due to the vaporization of the LPG) are envisaged, the manufacturer shall demonstrate that the material from which the pressure containing parts of the pressure vessel are constructed shall have properties suitable for a range of temperatures $-40\text{ }^{\circ}\text{C}$ to $50\text{ }^{\circ}\text{C}$ in accordance with EN 13445-2:2014.

5.3 Pressure

The design pressure, p (see 3.1.5), shall not be less than the maximum allowable pressure.

For underground pressure vessels, it shall be selected taking into account:

- the pressure developed by the LPG at the maximum soil temperature at 1 m depth; and
- the maximum pressure of the LPG delivered into the pressure vessel.

Recommended pressures for various climatic areas are given in Annex A.

5.4 Vacuum conditions

The pressure vessel shall be designed to withstand a minimum internal pressure of 0,3 bar absolute.

This shall be demonstrated by calculation in accordance with EN 13445-3:2014. The applicable tolerances for vacuum condition shall be in accordance with EN 13445-3:2014, 8.5.1 where these are more onerous than B.2.

This requirement should ensure that the pressure vessel will withstand vacuum conditions generated by the product during operation or normal maintenance.

5.5 Support loadings

For above ground pressure vessels, the pressure vessel and supports shall be designed to withstand the load when the pressure vessel is filled with water.

For underground pressure vessels, the pressure vessel and its supports shall be designed to withstand the greater of:

- the operating mass plus the mass of the backfill above the pressure vessel;
- the load from its supports when the pressure vessel is filled with water.

This shall be demonstrated by calculation in accordance with EN 13445-3:2014 or by experimental testing.

5.6 Lifting lugs loadings

The lifting lugs shall be designed to accept the maximum loads anticipated during construction and handling. This shall be demonstrated by calculation in accordance with EN 13445-3:2014 or experimental testing.

6 Openings

6.1 General

Pressure vessels shall be provided with an adequate number of openings to satisfy the need for fittings to meet service requirements. Openings using screwed or flanged connections shall be positioned such that they remain accessible after installation.

6.2 Reinforcement

Each opening shall be reinforced by a boss, pad or compensating plate attached by welding and designed in accordance with E.3.

6.3 Position of welds and openings

The welds of openings shall be clear of longitudinal and circumferential welds and welds of other openings as measured between the weld edges by not less than the smaller of:

- twice the thickness of the shell or head (as appropriate); or
- 40 mm.

7 Workmanship and manufacture

7.1 General

Pressure vessels shall be manufactured according to drawings and specifications in accordance with the requirements of this document and good engineering practice.

The manufacturer shall be responsible for the competence, training and supervision of its staff.

The forming, welding and heat treatment performed by the manufacturer shall ensure that the material properties in the finished pressure vessel meet the requirements of the design and this document.

The manufacturer shall have a defined organization for the control of manufacturing operations, which includes special processes such as forming, welding and heat treatment.

7.2 Environment

The environmental impact of welding and allied processes shall be assessed in accordance with EN 14717:2005.

The manufacturer should endeavour to minimize wastage of material by selecting appropriately sized materials related to the finished parts required for manufacture. Unavoidable waste/scrap material should be recycled.

Noise levels from the production process should be evaluated and measures put into place to minimize the impact upon the external environment.

7.3 Control and traceability of materials

The manufacturer shall maintain a system of identification for the material used in fabrication in order that all material for pressure parts in the completed pressure vessel can be traced to its origin. The traceability system shall incorporate procedures for verifying the identity of material as received from the supplier via the material manufacturer's test certificates and/or acceptance tests.

The manufacturer shall ensure that the material used complies with that specified in the design and/or the drawings.

In laying out and cutting the material, the material identification mark shall be so located as to be:

- a) clearly visible when the pressure part is completed; or
- b) traceable by operation of a documented system which ensures material traceability for all materials in the completed pressure vessel.

Where the material identification mark is unavoidably cut out during manufacture of a pressure part, it should be transferred by the pressure part manufacturer, to another part of this component. The transfer of the mark should be carried out by a person designated by the manufacturer.

When identification on materials is transferred, the method of stamping or marking shall not have any detrimental effect on the specified material properties.

Records of the welding consumables used shall be retained.

7.4 Manufacturing tolerances

Tolerances on the shape of pressure vessels shall be in accordance with Annex B.

7.5 Acceptable weld details

7.5.1 General

Basic weld details shall be in accordance with EN 1708-1:2010. Recommended weld details are given in Annex G.

7.5.2 Longitudinal welds

Shell welds shall be either helical butt welds or longitudinal butt welds. Where a pressure vessel is made from more than one shell strake, the longitudinal weld seams of adjacent strakes shall be staggered by at least 100 mm. This spacing shall be measured between weld edges.

7.5.3 Joggle joints

7.5.3.1 Joggle joints shall meet the following requirements:

- the offset section which forms the weld backing shall be a close fit within its mating section around the entire circumference (machining of the spigot of the offset section is permissible provided that the thickness remaining as backing material is not less than 75 % of the original thickness at any point);
- the profile of the offset shall be maintained, with a smooth radius without sharp corners throughout production;
- on completion of the welding the weld shall have a smooth profile and shall fill the groove to the full thickness of the plate being joined.

Recommended arrangement for joggle joints is shown in Figure G.2.

7.5.3.2 When the flange section of the dished end is joggled, the joggle shall be sufficiently clear of the knuckle radius to ensure that the edge of the circumferential weld is at least 12 mm clear of the knuckle.

7.5.3.3 When a strake edge is joggled the longitudinal or helical weld shall be ground flush internally and externally for a distance of approximately 50 mm prior to joggling with no reduction of plate thickness. On completion of the joggling, the area of the weld shall be proven to be free of cracks by magnetic particle testing in accordance with EN ISO 17638:2016 or penetrant testing in accordance with EN ISO 3452-1:2013.

7.6 Formed pressure parts

7.6.1 General

Formed pressure parts shall be either cold formed or hot formed.

Ends shall be made from one piece of plate.

Plates used for formed parts shall comply with 4.2.

The work-piece temperature during hot forming shall not exceed 1 050 °C.

7.6.2 Heat treatment after forming

7.6.2.1 Environment

Where heat treatment is performed the process shall be designed to minimize energy consumption and the use of coolants, and ensure the environmentally friendly disposal of insulating material and other waste.

Where formed parts are supplied as components, reference shall be made to 4.2.

7.6.2.2 Heat treatment after cold forming of flat products

Cold formed ends shall be heat treated after forming, unless it can be demonstrated that the properties specified in 4.2 are met, or a burst test on a prototype pressure vessel demonstrates that the formed component is not the weakest part of the pressure vessel.

Where heat treatment is applied after cold forming, this shall be by normalizing to achieve the required material properties.

NOTE The base material manufacturer's test certificate can be taken as an indication or recommendation for the type of heat treatment required.

7.6.2.3 Heat treatment after hot forming

If no subsequent heat treatment is intended, the forming process shall be proven, controlled and meet the requirements of 7.6.1.

If the forming temperature is less than A_{r3} or the elongation at fracture of the steel, after forming, is less than that specified in 4.2, formed parts shall be heat treated by normalizing or another qualified procedure after hot forming in order to restore the mechanical properties to comply with 4.2.

7.6.3 Testing of formed parts

For cold-formed parts not subject to heat treatment, no mechanical tests are required in respect of the forming operation except where required by 7.6.2.2 for ends.

All other formed parts where the material thickness is greater than or equal to 5 mm, shall have tests carried out after the last forming operation or any heat treatment, to demonstrate conformity to the material specification. Test pieces shall be taken from an excess length, or a redundant piece of the formed part, or from a separate piece formed by the same procedure. The test pieces, taken in accordance with the material specification, shall consist of one tensile and three impact specimens.

In the case of formed ends, the test pieces shall be taken from sample ends selected as follows:

- one from the first ten of each family; and then
- one from each 1 000 units produced, but not less than one per two years.

Ends belong to a family when they have the following characteristics in common:

- material specification;
- forming process;
- heat treatment; and
- geometrical similarity to $\pm 10\%$.

7.6.4 Repeated tests

Where an unsatisfactory test result is due to poor testing technique or to a defect limited to one specimen, the test may be repeated.

Where the test results from correctly tested specimens do not comply with the specification, the test shall be repeated as follows:

- where the tensile or bend test fails, the test shall be repeated with two further specimens taken from the test piece. These two results shall then comply with the specification;
- where one of the three impact tests fail, three further test specimens shall be taken from the test piece and tested. The mean value of these six individual test results shall meet the specification. No more than two individual values shall fall below the minimum value and, of these two; one shall be at least 70 % of the minimum value.

Any pressure part, which fails to comply with the specification, shall be rejected. The testing shall be repeated on two other formed parts of the same production-batch where the test results shall comply with the specification.

Where the results of the repeated tests fail to meet the specification, the formed parts and the test pieces may be subject to one further heat treatment and the tests repeated.

If any of the tests on the re-heat treated parts fail, the formed parts or production-batch shall be rejected.

7.6.5 Visual examination and dimensional check

Formed parts, which require certificates according to EN 10204:2004, shall be subject to visual examination and dimensional check in the delivered condition by the manufacturer. The results of the visual examination and the dimensional check shall be certified by the manufacturer and included with the EN 10204:2004 certificate.

7.6.6 Marking

Formed parts shall be marked in such a manner that the material and the manufacturer of the formed parts can be identified during manufacture of the pressure vessel. In the case of production-batch testing, individual formed parts shall be traceable to the production-batch.

7.6.7 Test certificate

Product certificates for formed parts shall include details of any heat treatment applied.

7.7 Welding

7.7.1 General

Welding shall comply with the following:

- the welding procedures shall be selected by the manufacturer for the field of application and the welders and welding personnel shall be qualified for the work allocated to them;
- longitudinal welds shall be by a mechanized/automatic welding process. All circumferential welds for pressure vessels with diameter less than or equal to 1 250 mm shall be by a mechanized/automatic welding process.

7.7.2 Welding procedure specification (WPS)

The manufacturer shall compile welding procedure specifications for all joints in accordance with EN ISO 15609-1:2019.

7.7.3 Qualification of WPS

Welding procedure specifications shall be qualified by tests in accordance with EN ISO 15614-1:2017 or EN ISO 15613:2004.

7.7.4 Qualification of welders and welding operators

Welders shall be qualified in accordance with EN ISO 9606-1:2017 and welding operators with EN ISO 14732:2013. For the application of this document under the PED for pressure equipment of categories II, III and IV the revalidation in accordance with route 9.3 c) of EN ISO 9606-1:2017 and route 5.3 c) of EN ISO 14732:2013 is not permitted.

NOTE The training, supervision and control of welders and welding operators is the responsibility of the manufacturer.