BS EN 14893:2014

BSI Standards Publication

LPG equipment and accessories — Transportable Liquefied Petroleum Gas (LPG) welded steel pressure drums with a capacity between 150 litres and 1 000 litres

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National foreword

This British Standard is the UK implementation of EN 14893:2014. It supersedes BS EN 14893:2006 which is withdrawn.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 secretary.

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LPG equipment and accessories - Transportable Liquefied Petroleum Gas (LPG) welded steel pressure drums with a capacity between 150 litres and 1 000 litres

Équipements pour GPL et leurs accessoires - Fûts à pression métalliques transportables pour GPL d'une capacité comprise entre 150 litres et 1 000 litres

Flüssiggas-Geräte und Ausrüstungsteile - Ortsbewegliche, geschweißte Druckfässer aus Stahl für Flüssiggas (LPG) mit einem Fassungsraum zwischen 150 Liter und 1 000 Liter

This European Standard was approved by CEN on 5 January 2014.

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Foreword

This document (EN 14893:2014) has been prepared by Technical Committee CEN/TC 286 “LPG 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of an identical text or by endorsement, at the latest by November 2014 and conflicting national standards shall be withdrawn at the latest by November 2014.

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

This document supersedes EN 14893:2006.

The major changes in this revision include:

— an update of the terminology; and

— the addition of an environmental checklist, Annex H.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

This European Standard has been submitted for reference into:

— the RID [12]; and

— the technical annexes of the ADR [13].

NOTE These regulations take precedence over any clause of this European Standard. It is emphasized that RID/ADR/ADN are being revised regularly at intervals of two years which may lead to temporary non-compliances with the clauses of this European Standard.

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

Introduction

This European Standard 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; it does not absolve the user from their legal obligations at any stage.

Protection of the environment is a key political issue in Europe and elsewhere around the world. Protection of the environment in this document is understood in a very broad sense. The phrase is used, for example, in relation to the total life-cycle environmental aspects of a product, including expenditure of energy, and during all phases of its existence, from mining of raw materials to fabrication, packaging, distribution, use, scrapping, recycling of materials, etc. Annex H comprises an environmental checklist which highlights the clauses of this European Standard that address environmental aspects.

It is recommended that manufacturers develop an environmental management policy. For guidance, see EN ISO 14000 series, [6], [7] and [8].

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

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

All pressures are gauge unless otherwise stated.

NOTE This European Standard 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 [16].

1 Scope

This European Standard specifies the minimum requirements for the material, design, construction, workmanship, equipping, inspection and testing at manufacture of transportable, refillable welded steel pressure drums of volumes over 150 l up to and including 1 000 l for Liquefied Petroleum Gases (LPG).

Vertical and horizontal cylindrical receptacles are covered.

2 Normative references

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

EN 549, *Rubber materials for seals and diaphragms for gas appliances and gas equipment*

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

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

EN 10028-1, *Flat products made of steels for pressure purposes - Part 1: General requirements*

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

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

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

EN 10204, *Metallic products - Types of inspection documents*

EN 13175, *LPG equipment and accessories - Specification and testing for Liquefied Petroleum Gas (LPG) tank valves and fittings*

EN 13799, *LPG equipment and accessories - Contents gauges for Liquefied Petroleum Gas (LPG) pressure vessels*

EN 14717, *Welding and allied processes - Environmental check list*

EN 14894, *LPG equipment and accessories - Cylinder and drum marking*

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

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

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

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

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

EN ISO 5173, *Destructive tests on welds in metallic materials - Bend tests (ISO 5173)*

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

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

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

EN ISO 9606-1, *Qualification testing of welders - Fusion welding - Part 1: Steels (ISO 9606-1)*

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

EN ISO 11114-2, *Gas cylinders - Compatibility of cylinder and valve materials with gas contents - Part 2: Non-metallic materials (ISO 11114-2)*

EN ISO 14171, *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)*

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

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

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

EN ISO 15614-1, *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)*

EN ISO 15995, *Gas cylinders - Specifications and testing of LPG cylinder valves - Manually operated (ISO 15995)*

EN ISO 17632, *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)*

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

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

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

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

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

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

EN ISO 19232-3, *Non-destructive testing - Image quality of radiographs - Part 3: Image quality classes (ISO 19232-3)*

ANSI/ASME B1.20.1, *Pipe Threads, General Purpose (Inch)*[1)]

3 Terms and definitions

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

3.1
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 and butene with traces of other hydrocarbon gases

3.2
pressure drum
welded transportable, refillable pressure receptacle with a water capacity from 150 l up to and including 1 000 l

3.3
competent authority
authority designated as such in each country in accordance with national regulation

3.4
pressure vessel
assembly of the pressure-retaining envelope (including the openings and their closures) and non-pressure-retaining parts attached directly to it

3.5
parent material
material in the state before any specific transformation with regards to the container manufacturing process

3.6
yield strength
upper yield strength R_{eH} or, for steels that do not exhibit a definite yield, the 0,2 % proof strength

3.7
manufacturer
manufacturer of the drum, unless otherwise specified

3.8
normalised
condition resulting from heat treatment to a uniform temperature above the upper critical point (Ac3) of the steel and then cooled under controlled conditions

3.9
calculation pressure
gauge pressure used in design formulae

1) Issued by the American National Standards Institute (1983).

3.10
maintenance
minor repair, major repair or refurbishment

3.11
nominal diameter
DN
numerical designation of size, in millimetres, which is common to all components in a piping system other than components designated by outside diameters or by thread size

Note 1 to entry: It is a convenient round number for reference purposes and is only loosely related to manufacturing dimensions. The nominal size is designated by DN followed by a number.

3.12
heat treatment
solution heat treatment, quenching and artificial or natural ageing that ensures the strength values required

3.13
longitudinal weld
weld over the full length of the shell or cylindrical part of the shell, excluding welds for fittings

3.14
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.

3.15
hot forming
forming at temperatures above the maximum permissible temperature for stress relieving in accordance with the material specification

3.16
cold forming
forming at temperatures at least 30 °C below the maximum permissible temperature for stress relieving in accordance with the material specification

3.17
Ar_3
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.

3.18
filler valve
valve system for liquid fill service

3.19
fixed liquid level gauge
control device, such as a dip tube in combination with a vent valve to indicate when a predetermined liquid level has been reached or surpassed

3.20
overfill protection device
device designed to automatically reduce the filling rate to a minimal flow when the fill level reaches a predetermined amount

3.21
tare mass
mass of the empty pressure vessel, its fittings and other parts that are permanently attached to the pressure vessel

3.22
accessories
devices connected to the system whose main function is not for the storage or conveyance of LPG

Note 1 to entry: Accessories are not “service equipment” or “structural equipment” (as defined by the RID/ADR); safety and pressure accessories are also defined in the PED [14].

4 Materials

4.1 Suitability

4.1.1 Unless otherwise specified, the design temperature range shall be –20 °C to +50 °C. The materials of construction shall be suitable for operating within the envisaged temperature range. If the drum could be subjected to more severe ambient or product temperatures, the design temperature range shall be –40 °C to +50 °C.

Guidance on selection of material grades is given in Annex A.

4.1.2 All materials which are in direct contact with LPG shall not be affected or weakened by it. The materials shall be resistant to brittle fracture, within the operating range, and to stress corrosion cracking during service (see also RID/ADR Clauses 6.2.1.2.1 and 6.2.1.2.2).

4.1.3 The manufacturer shall endeavour to acquire materials and components from suppliers who have a declared environmental policy (see EN ISO 14021 [6], EN ISO 14024 [7] and EN ISO 14025 [8]).

4.1.4 Steels shall be grouped in accordance with Table 1.

4.1.5 Where additional impact testing is required, it shall be carried out in accordance with EN ISO 148-1 to achieve the impact values specified in 6.16.

4.2 Pressure retaining parts

4.2.1 Pressure-retaining materials shall be of appropriate steels conforming to EN 10028-1, EN 10028-2, EN 10028-3 or EN 10028-5. All materials shall conform to the requirements of 6.16.

4.2.2 Steels in Table 1, sub-group 2.2 shall have a carbon equivalent limited to a maximum of 0,43 % when calculated in accordance with EN 10028-5.

4.3 Non-pressure retaining parts

All materials used for non-pressure retaining parts shall be compatible with the material of pressure retaining parts. Their suitability, to be used at low temperature, shall be established by:

— testing in accordance with EN ISO 148-1 to meet the impact requirements in 6.16; or

— reference to a recognized pressure vessel European Standard or specification, e.g. EN 13445 series.

4.4 Welding consumables

4.4.1 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 drum.

4.4.2 They shall be selected from EN ISO 2560, EN ISO 14171, EN ISO 17632 or EN ISO 636, as appropriate. Suitability of the chosen consumables shall be demonstrated in accordance with 6.7.3.

4.5 Non-metallic materials (gaskets)

All non-metallic materials in contact with LPG shall be compatible with LPG and shall not distort or harden. They shall also comply with the appropriate requirements of EN 549 and EN ISO 11114-2, including resistance to ozone (where gasket/seal is exposed to atmosphere).

4.6 Certification of materials

Pressure retaining parts and non-pressure retaining parts directly welded to the drum shall be provided with material manufacturers' certificates conforming to EN 10204, certificate type 3.1. Other parts shall have certificates conforming to EN 10204, certificate type 2.2.

Table 1 — Material grouping

Group	Sub-group	Type of steel
1		Steels with a specified minimum yield strength $R_{eH} \leq 460$ N/mm^2 [a] and with analysis in %: C ≤ 0,25 Si ≤ 0,60 Mn ≤ 1,70 Mo ≤ 0,70 [b] S ≤ 0,045 *P* ≤ 0,045 Cu ≤ 0,40 [b] Ni ≤ 0,5 [b] Cr ≤ 0,3 (0,4 for castings) [b] Nb ≤ 0,05 V ≤ 0,12 [b] Ti ≤ 0,05
	1.1	Steels with a specified minimum yield strength $R_{eH} \leq 275$ N/mm^2
	1.2	Steels with a specified minimum yield strength 275 N/mm^2 < $R_{eH} \leq 360$ N/mm^2
	1.3	Normalized fine grain steels with a specified minimum yield strength $R_{eH} > 360$ N/mm^2
2		Thermomechanically treated fine grain steels and cast steels with a specified minimum yield strength $R_{eH} > 360$ N/mm^2
	2.1	Thermomechanically treated fine grain steels and cast steels with a specified minimum yield strength 360 N/mm^2 < $R_{eH} \leq 460$ N/mm^2
	2.2	Thermomechanically treated fine grain steels and cast steels with a specified minimum yield strength $R_{eH} > 460$ N/mm^2
NOTE This table is an extract from CEN ISO/TR 15608:2013 [10].		
[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 ≤ 0,75 %.		

5 Design

5.1 General

5.1.1 Drums shall be designed in such a way that they are either;

— capable of being rolled (see 5.8); or

— prevented from rolling by the provision of support and lifting arrangements or a protective frame to permit safe handling by mechanical means, transport and use.

5.1.2 Drums shall be an assembly of a cylindrical shell and two ellipsoidal or torispherical dished ends. Dished ends convex to pressure (inwardly dished ends) are not permitted.

5.1.3 Dished ends shall be made from one piece of plate.

5.1.4 No internal corrosion allowance is required for drums intended to contain LPG which is supplied to a national or international standard or other equivalent specification that complies with the limitation on corrosive contaminants specified in ISO 9162 [11].

5.1.5 Drums shall be protected against external corrosion in accordance with 8.1. No external corrosion allowance is required.

5.1.6 The 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.

5.1.7 The drum shall be designed to withstand pressure, temperature and vacuum conditions in accordance with 5.2.1, 5.2.2 and 5.2.3 and support loadings in accordance with 5.4.

5.1.8 Where necessary to reduce stress concentrations, attachments to the drum shall be welded using a backing plate.

5.1.9 A design type specification, including a fully detailed, dimensional drawing, specifications of materials and equipment (fittings) shall be produced for the completed drum.

The design of the drum should take into account minimising the use of raw materials and minimising the environmental impact in service maintenance and end of life disposal.

5.2 Design conditions

5.2.1 Calculation pressure

The drum shall be designed for a calculation pressure of not less than the test pressure of 30 bar.

5.2.2 Design temperature

Generally the design temperature range shall be –20 °C to +50 °C. However, where temperatures lower than −20 °C are envisaged, the manufacturer shall demonstrate that the material from which the pressure containing parts of the drum are constructed have properties suitable for a range of temperatures –40 °C to +50 °C in accordance with a recognized pressure vessel standard or specification, e.g. EN 13445-2 [3].

5.2.3 Vacuum conditions

Drums shall be designed to withstand vacuum conditions generated by the product during operation or other conditions, but as a minimum, this shall be equivalent to an external pressure of at least 40 kPa (0,4 bar) gauge pressure.

Suitable design methods may be applied from EN 13445-3 [4].

5.3 Calculation of thicknesses

5.3.1 Calculation

Drum thicknesses shall be calculated in accordance with Annex E.

5.3.2 Minimum thickness for handling

5.3.2.1 The thicknesses of the shell and ends calculated from pressure considerations (see 5.2) shall be increased if they are less than the value calculated from the following formula:

$$e_h = 2{,}5\left(D_o / T\right)^{0{,}5} \quad (1)$$

where

e_h is the minimum thickness of cylindrical shell or dished end to satisfy handling criteria, in mm;

D_o is the outside diameter of the drum, in mm;

T is the minimum value of tensile strength in the finished drum, in N/mm^2.

5.3.2.2 The minimum thickness shall not be less than 2,5 mm.

5.3.2.3 Where the materials used for shell and ends are different, the calculation shall be carried out for each component using the appropriate properties.

5.4 Support loadings

5.4.1 The drum and supports, if any, shall be designed to withstand the greater of the following:

a) a static load when the drum is filled with water; or

b) a maximum operating mass of the drum subject to 2g acceleration acting vertically down and horizontally, and 1g acting vertically up (where g is the acceleration due to gravity).

This shall be demonstrated by experimental testing or calculation in accordance with a recognized pressure vessel standard or specification, e.g. EN 13445-3.

5.4.2 Under the forces defined above, the stresses in the drum and its fastenings shall not exceed the following:

a) for general membrane stress in the shell, remote from the supports, the normal design stress as defined in E.1; and

b) for stresses local to the supports, determined either by experimental analysis or calculation/special analysis, the limits specified in accordance with a recognized pressure vessel European Standard or specification, e.g. EN 13445-3.

5.5 Lifting lug loadings

The lifting lugs shall be designed to accept the maximum loads anticipated during construction and handling in service, applying an acceleration of 2g vertically downwards and an assumed sling angle of 45°. This shall be demonstrated by experimental testing or calculation in accordance with a recognized pressure vessel standard or specification, e.g. EN 13445-3. The stress limits as specified in 5.4 apply.

The maximum anticipated load should include the full contents of the drum.

5.6 Openings

5.6.1 General

5.6.1.1 Drums shall be provided with the minimum number of openings required to satisfy the need for fittings to meet service requirements.

5.6.1.2 Openings shall be positioned and/or grouped in such a way that their fittings can be protected as required by 5.7. For drums not fixed into a protective framework, the openings shall only be located in the ends.

5.6.2 Reinforcement

Each opening shall be reinforced by a boss, pad or compensating plate welded to the shell and shall be designed in accordance with Annex E.

5.6.3 Position of welds

The welds of opening reinforcements shall be clear of longitudinal and circumferential welds and welds of other opening reinforcements by a minimum of 40 mm between the weld edges.

5.6.4 Fittings connections

5.6.4.1 All connections, except for float gauges, shall be threaded or flanged and shall not exceed DN 50.

5.6.4.2 All threads for taper threaded connections shall comply with ANSI/ASME B1.20.1.

5.6.4.3 Flanged connections shall comply with EN 1092-1.

5.6.4.4 Float gauge connections shall comply with EN 13799.

5.6.5 Fittings

Drums shall be fitted with the equipment necessary for their intended operations.

The following fittings shall be provided:

a) filler valve, in accordance with EN 13175;

b) liquid and/or vapour off-take valve, in accordance with EN 13175 or EN ISO 15995;

c) fixed liquid level gauge, in accordance with EN 13799;

d) overfill protection device, in accordance with EN 13799; and

e) liquid removal device, in accordance with EN 13175.

All or some of the above fittings may be combined to perform these functions.

5.7 Protection of fittings

5.7.1 General

Drums shall be such that all fittings are situated inside the contour of end shrouds or within a protective frame.

5.7.2 End shrouds

5.7.2.1 End shrouds for drums intended to be rolled shall have a minimum thickness of 10 mm, or 7 mm if fitted with a reinforcing ring.

5.7.2.2 The shrouds shall be attached to the receptacle by intermittent welds for at least 50 % of their circumference. Shrouds shall have holes or cutaways large enough to allow for drainage.

5.7.3 Protective frame

5.7.3.1 Where fitted, the protective frame shall be designed to allow safe handling of the assembly by mechanical means, e.g. crane, forklift truck, 3 points system.

5.7.3.2 The frame shall be a welded steel structure and shall be designed to protect the fittings against damage leading to leakage in service. This shall be demonstrated by the drop test specified in 10.4.

5.7.3.3 The drum shall be totally or partly inserted and fixed in the frame by adequate means in a vertical or horizontal position, in accordance with the manufacturer's specification.

5.7.4 Local protection

In addition to the general protection specified in 5.7.1, 5.7.2 and 5.7.3, fittings shall be provided with local protection against unauthorised access.

5.8 Rolling hoops

5.8.1 Horizontal drums which are capable of being rolled (i.e. not fitted with saddle supports or inside a frame) shall be provided with two rolling hoops to protect the pressure envelope from damage during rolling.

5.8.2 Where the hoops are fitted to the pressure retaining part of the drum they shall be attached by continuous fillet welds on both sides of the hoop. The minimum leg length of these fillet welds shall be 5 mm. If the hoop welds are going to cross the longitudinal weld then before the hoops are fitted the longitudinal weld shall be subject to non-destructive testing before the hoops are attached. The longitudinal weld shall be proven to be free of cracks by magnetic particle testing in accordance with EN ISO 17638, dye penetrant testing in accordance with EN ISO 3452-1, or other suitable techniques providing an equivalent level of detection.

5.8.3 Where the hoops are fitted to a non-pressure attachment (e.g. shroud) then intermittent welds of not less than 50 % of the circumference are permissible.

5.9 Ventilation openings

If the drum is fitted with a base ring, the ring shall incorporate ventilation openings to allow adequate circulation of air. Where a shroud is fitted with a lid, ventilation openings shall be included.

6 Workmanship and manufacture

6.1 General

6.1.1 Drums shall be manufactured according to drawings, specifications and procedures in accordance with the requirements of this European Standard.

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

6.1.3 Materials specified for the manufacture of the drums shall be worked (subject to the working instructions of the material manufacturer, if any) so that the finished drum shows both the properties necessary to meet the design intent and the requirements of this standard.

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

6.2 Environment

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

The manufacturer should endeavour to minimize wastage of materials by selecting appropriately sized materials related to the finished parts required for the 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.

6.3 Control and traceability of materials

6.3.1 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 drum can be traced to its origin. The 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.

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

6.3.3 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 drum.

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

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

6.3.6 Records of the welding consumables shall be retained.

6.4 Manufacturing tolerances

Tolerances on the dimensions, shape and minimum thickness of drums shall be in accordance with Annex B.

6.5 Acceptable weld details

6.5.1 General

Examples of welded joints are given in Annex G. Basic weld details are given in EN 1708-1 [2].

6.5.2 Longitudinal welds

Shell welds shall be either helical butt welds or longitudinal butt welds. Where a drum 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.

6.5.3 Joggle joints

6.5.3.1 Joggle joints may only be used for circumferential weld joints and shall meet the following requirements:

a) 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 nowhere less than 75 % of the original thickness);

b) the profile of the offset shall be maintained, with a smooth radius without sharp corners throughout production;

c) 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.

A recommended arrangement is shown in Annex G.

6.5.3.2 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.

6.5.3.3 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, dye penetrant testing in accordance with EN ISO 3452-1, or other suitable techniques providing an equivalent level of detection.

6.6 Formed pressure parts

6.6.1 General

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

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

The hot forming process shall be designed to minimize energy consumption and ensure the environmentally friendly disposal of insulating material and other waste.

6.6.2 Heat treatment after forming

6.6.2.1 Heat treatment after cold forming

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

Where heat treatment is applied after cold forming, this shall be by normalizing or another proven procedure.

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

The heat treatment process shall be designed to minimize energy consumption and ensure the environmentally friendly disposal of insulating material and other waste.

6.6.2.2 Heat treatment after hot forming

Where no subsequent heat treatment is intended, the forming process shall be proven, controlled and the forming process shall be completed above the Ar_3 temperature.

Where the forming temperature is less than Ar_3 or the elongation of the steel, after forming, is less than that in the material specification, formed parts shall be heat treated by normalizing or another proven procedure after hot forming in order to restore the mechanical properties to comply with the material specification.

The heat treatment process shall be designed to minimize energy consumption and ensure the environmentally friendly disposal of insulating material and other waste.

6.6.3 Testing of formed parts

6.6.3.1 For cold-formed parts not subject to heat treatment, no mechanical tests are required in respect of the forming operation, except where required by 6.6.2.1 for ends.

6.6.3.2 For all other formed parts, where the material thickness is greater than or equal to 5 mm, tests shall be 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.

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

a) 1 from the first 10 of each family, and then

b) 1 from each 1 000 units produced, but not less than 1 per 2 years.

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

a) material specification;

b) forming process;

c) heat treatment; and

d) geometrical similarity to 10 %.

6.6.4 Repeated tests

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

6.6.4.2 Where the test results from correctly tested specimens do not conform to the specification, the test shall be repeated as follows:

a) 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 conform to the specification.

b) Where one of the three impact tests fails, three further test specimens shall be taken from the test piece and tested.

6.6.4.3 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.

6.6.4.4 Any pressure part that fails to conform to 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 conform to the specification.

6.6.4.5 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.

6.6.4.6 If any of the tests on the reheat treated parts fail, the formed parts or the production batch tested shall be rejected.

Rejected parts should be processed for recycling.

6.6.5 Visual examination and control of dimensions

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

6.6.6 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 drum. In the case of production batch testing, individual formed parts shall be traceable to the production batch.

6.6.7 Inspection certificate

Certificates specified in 4.6 shall also include details of any heat treatment applied to the formed parts.

6.7 Welding

6.7.1 General

6.7.1.1 The welding procedures shall be selected by the manufacturer for the field of application. The welders and welding personnel shall be qualified for the work allocated to them.

6.7.1.2 All circumferential, helical and longitudinal welds for drums shall be by a mechanised/automatic welding process.

NOTE All further references to longitudinal welds include helical welds.

6.7.2 Welding procedure specification (WPS)

The manufacturer shall compile welding procedure specifications for each joint or family of joints in accordance with EN ISO 15609-1.

6.7.3 Qualification of WPS

Welding procedure qualification tests in accordance with EN ISO 15614-1 or EN ISO 15613 shall be carried out to approve the welding procedure specifications.

6.7.4 Qualification of welders and welding personnel

6.7.4.1 Welders shall be approved in accordance with EN ISO 9606-1. Welding personnel shall be approved in accordance with EN ISO 14732.

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

6.7.4.2 An up-to-date list of welders and welding personnel, together with their records of approval test, shall be maintained by the manufacturer.

6.7.5 Preparation of edges to be welded

6.7.5.1 The surface to be welded shall be thoroughly cleaned of oxide scale, oil, grease or other foreign substance to avoid any detrimental effect on weld quality.

6.7.5.2 The edges to be welded shall be kept in position either by mechanical means or by tack welds or by a combination of both. The tack welds shall be removed or fully fused in the weld.

6.7.5.3 In both cases, the manufacturer shall take precautions to ensure that the tack welding does not generate metallurgical or homogeneity defects.

6.7.5.4 When welding without a sealing run, the manufacturer shall ensure that the alignment and the gap of the edges to be welded will ensure the required penetration at the weld root. During the whole welding operation, the edges to be welded shall be suitably restrained so that the required weld geometry is maintained.

NOTE Material can be cut to size and shape by any mechanical or thermal cutting process or by combination of both. This can be carried out before or after forming operations.

Material off-cuts should be processed for recycling.

6.7.6 Execution of welded joints

6.7.6.1 After each weld run, any slag shall be removed and, where necessary, the weld cleaned and any surface defects removed.

6.7.6.2 Unless the welding process used provides effective and sound penetration, the second side of a welded joint shall be removed back to sound metal using a mechanical or thermal process or by grinding.

6.7.6.3 Stray arcing on pressure drum parts outside the weld preparation shall be avoided. Where it does occur accidentally, the affected area (including the heat-affected area) shall be repaired by appropriate means.

6.7.7 Attachments and supports

6.7.7.1 Attachments (whether temporary or not), including supports, shall only be welded to a part subject to pressure by qualified welders using a qualified procedure.

6.7.7.2 Attachments not subject to pressure, e.g. supports, lugs, pads, shrouds, etc. are permitted to be attached to the drum by welding provided that such attachments are made of weldable and compatible steel. Except for the shrouds (see 5.7.2), all attachment welds shall be continuous.

6.7.7.3 Any backing pad or plate which covers a pressure containing weld shall be provided with a vent hole which shall be tapped and plugged.

6.7.7.4 Temporary attachments shall be removed using a technique that does not affect the properties of the metal or the pressure part to which they are welded. The affected areas shall be dressed smooth and subjected to penetrant or magnetic particle testing, unless the areas are to be subsequently covered by further welding which shall be checked according to 6.10.2.

Temporary attachments should be retained for further use or processed for recycling.

6.7.8 Preheating

6.7.8.1 The manufacturer shall include the preheating temperature in the WPS (see 6.7.2).

NOTE The preheat temperature depends on the composition of the metal being welded, the material thickness and the heat input being used. Recommendations on preheating are given in EN 1011-2 [1].

The preheating process shall be designed to minimize energy consumption and ensure the environmentally friendly disposal of insulating material and other waste.

6.7.8.2 No welding shall be carried out when the temperature of the parent metal near the joint is less than 5 °C.

6.8 Post weld heat treatment

Post weld heat treatment is not required.

6.9 Repairs

6.9.1 Repairs of surface imperfections in the parent metal

6.9.1.1 If surface imperfections are only superficial, such as accidental arc strikes, tool marks, oxy-acetylene cutting marks, the imperfections may be removed by grinding so that the ground area has a taper with the adjoining surfaces. The grinding shall be followed by inspection for surface imperfections.

6.9.1.2 The thickness at the repair shall be checked to ensure that the design requirements are met.

6.9.1.3 Where the imperfections reduce the thickness of the wall below the minimum design thickness, no repair shall be carried out and the drum shall be rejected.

6.9.2 Repair of weld imperfections

6.9.2.1 Weld imperfections not meeting the acceptance criteria (see Annex D) shall be repaired or the drum rejected.

6.9.2.2 Imperfections shall be repaired by both removing and reinstating the complete weld or by local repair depending on the extent of the imperfections.

6.9.2.3 If the remaining thickness is not within acceptable tolerances, repairs shall be carried out.

6.9.2.4 Repairs shall be carried out using a qualified WPS in accordance with 6.7.2 or with a specific qualified repair procedure. When the weld procedure is used for the repair, the qualification of a new weld procedure is not required.

6.9.2.5 The repair shall be carried out by a qualified welder or operator.

6.9.2.6 Repaired areas shall be non-destructively examined in the same manner as the initial weld and shall meet the requirements of 6.10. Where the result of the examination is not satisfactory, a further repair is not permitted.

6.9.2.7 The manufacturer shall keep records of all weld repairs.

Any parts that are going to be scrapped should be processed for recycling.

6.10 Examination of welds

6.10.1 Visual examination of welds

6.10.1.1 On completion of welding, all welded joints shall be visually examined for surface imperfections in accordance with EN ISO 17637 and any imperfections shall be assessed against the criteria in Annex D. The surface examined shall be well illuminated and shall be free from grease, dirt, scale, residue or protective coating of any kind.

6.10.1.2 Unacceptable imperfections shall be repaired in accordance with 6.9 or the drum shall be rejected.

It is recommended that visual examination is supplemented by magnetic particle, dye penetrant testing or other suitable means that demonstrate an equivalent level of safety in case of doubt (see 6.11.4 and 6.11.5).

6.10.2 Non-destructive testing (NDT)

6.10.2.1 Radiographic and/or ultrasonic examination of longitudinal or helical shell welds shall be carried out in accordance with 6.11.2 and 6.11.3 to the extent specified in Table 2.

Any imperfections shall be assessed using the criteria in Annex D.

6.10.2.2 In the case of steel groups 1.1, 1.2 and 1.3, where the weld joint coefficient is 1, the extent of NDT on longitudinal welds may be reduced from 100 % to 10 % when satisfactory experience is achieved.

NOTE Satisfactory experience is defined as successful production, without any unacceptable imperfections, of 25 drums or 60 m of weld, whichever is the greater.

If there is a change in welding procedure or following a break in production of more than 4 weeks, the criteria for satisfactory experience shall be re-established.

6.10.2.3 10 % of the aggregate length of all welds attaching nozzles, branches and compensating plates to the shell and ends, and 10 % of all other attachment welds to pressure components, shall be examined for imperfections by magnetic particle, dye penetrant techniques and/or other means of examination that demonstrate an equivalent level of detection (see 6.11.4 or 6.11.5).

It is recommended that the manufacturer produces a location drawing of the examined areas.

6.10.2.4 100 % of the lifting lug attachment welds shall be examined for imperfections by magnetic particle, dye penetrant techniques and/or other means of examination that demonstrate an equivalent level of detection (see 6.11.4 or 6.11.5).

Table 2 — Extent of non-destructive testing on longitudinal welds and weld joint coefficients

Steel group (see Table 1)	**2.1, 2.2**	**1.1, 1.2, 1.3**	**1.1, 1.2, 1.3, 2.1, 2.2**
Extent of NDT [a]	100 %	100 % then 10 % [b, c]	10 %
Weld joint coefficient	1	1	0,85

[a] The percentage relates to the percentage of welds of each individual drum.

[b] Limited to fully mechanised and/or automatic welding process where at least the weld head and the welding consumable movement is mechanised.

[c] First figure: initially; second figure: after satisfactory experience. See 6.10.2.2.

6.11 Non-destructive testing techniques

6.11.1 General

Guidance on the choice of non-destructive tests for welds is given in EN ISO 17635 [9]. Other methods and techniques may be used provided the same level of imperfection detection is achieved.

6.11.2 Radiographic techniques

6.11.2.1 Radiographic examination shall be carried out in accordance with EN ISO 17636-1 and EN ISO 17636-2.

6.11.2.2 Radiographic sensitivity shall be determined in accordance with EN ISO 19232-3 or with other techniques that achieve comparable sensitivities.

6.11.2.3 Each section of weld radiographed shall have symbols affixed to identify the following:

a) job or workpiece serial number, order number or similar distinctive reference number;

b) joint;

c) section of the joint; and

d) outer edges of the weld.

It is recommended that these are marked with arrows or other symbols alongside but clear of the edges to clearly mark their positions.

6.11.2.4 Where radiographs are required of the entire length of a weld, sufficient overlap shall be provided to ensure that the radiographs cover the whole of the weld and each radiograph shall exhibit a number near each end.

6.11.2.5 Radiographs of repair welds shall be clearly identified, e.g. “R1”.

NOTE The location of the weld can be identified for instance with a letter “L” for a longitudinal weld, “C” for a circumferential weld, with the addition of a numeral (1, 2, 3, etc.) to indicate whether the weld was the first, second, third, etc., of that type.

6.11.3 Ultrasonic techniques

6.11.3.1 Ultrasonic examination techniques shall conform to EN ISO 17640.

6.11.3.2 Before carrying out ultrasonic examination of welds, the adjacent parent metal shall be ultrasonically examined to establish the thickness of the material and to locate any imperfections, which may prevent effective examination of the weld.

6.11.4 Magnetic particle techniques

6.11.4.1 Magnetic particle inspection techniques shall be in accordance with EN ISO 17638.

6.11.4.2 Care shall be taken to avoid damage to surfaces by misuse of the magnetic equipment and if such damage occurs, it shall be repaired in accordance with 6.9.1.

6.11.5 Dye penetrant techniques

Dye penetrant examination of welds shall be carried out in accordance with EN ISO 3452-1.

6.12 Marking for all non-destructive testing techniques

Marks shall be made alongside welds to provide reference points with respect to the test report (see 12.2 i)).

6.13 Qualification of personnel

Testing personnel shall be qualified to EN ISO 9712.

6.14 Acceptance criteria

6.14.1 Imperfections found by non-destructive testing shall be assessed using the criteria in Annex D.

6.14.2 When isolated unacceptable imperfections are found during non-destructive testing, two additional areas of the weld containing the imperfection shall be examined by the same method. If further unacceptable imperfections are found, then the weld seam shall be examined 100 % and the acceptance criteria applied to the 100 % examination.

6.14.3 If a recurrence of the same type of unacceptable imperfections (continuous or multiple) is found in a weld when the whole of a weld is inspected as required by 6.14.2, then the drum produced immediately before and after the drum being examined shall have the equivalent welds examined.

6.14.4 If no unacceptable imperfections are found in the appropriate welds of those two drums, no further special examinations are required.

6.14.5 If unacceptable imperfections are found in either the preceding or following drum, then further drums in sequence, both before and after the drums containing unacceptable imperfections, shall be assessed in accordance with 6.14.2 and 6.14.3 until a drum with no unacceptable imperfection is found. Where 6.10.2.2 is applicable, satisfactory experience shall be re-established during subsequent production.

Any drum that is to be scrapped should be processed for recycling.

6.15 Production test plates (coupon plates)

6.15.1 For each month of production and for each longitudinal welding process the number of test plates shall be as follows:

a) 1 test plate from 0 m to 60 m;

b) 1 test plate from 60 m to 360 m;

c) 1 test plate from 360 m to 1 860 m; and

d) 1 test plate from 1 860 m to 9 360 m.

6.15.2 Test plates on longitudinal welds shall, wherever practicable, be attached to the shell plate on one end of the welds so that the edges to be welded in the test plate are a continuation and duplication of the corresponding edges of the drum weld. The test plates shall be welded continuously with the welding of the corresponding longitudinal seam so that the welding procedure and technique are the same. When it is necessary to weld the test plates separately, such as in the case of circumferential joints, the welding procedure used shall replicate that used in the construction of the drum.

6.15.3 The test plates shall be of sufficient size to provide the required specimens, including an allowance for retests.

The type and number of specimens taken from the test plate is specified in Table 3.

Testing shall be carried out in accordance with the following European Standards:

— Bend tests, EN ISO 5173;

— Macro examination, EN ISO 17639;

— Impact tests, EN ISO 9016;

— Longitudinal tensile test, EN ISO 5178; and

— Transverse tensile test, EN ISO 4136.

Table 3 — Number of test specimens

Steel group (see Table 1)	**1.1, 1.2 and 1.3**		**2.1 and 2.2**	
Parent metal thickness, *e*	$e \leq 12$	$e > 12$	$e \leq 12$	$e > 12$
Face bend test	1	—	1	—
Root bend test	1	—	1	—
Macro examination	1	1	1	—
Impact test: weld deposit	3[a]	3	3[a]	3
Impact test: heat affected zone	—	3	—	3
Longitudinal weld tensile test	—	—	—	1[b]
Transverse tensile test	—	—	—	1
It is permissible to apply non-destructive testing on the test plate prior to cutting the test specimens in order that they are selected from sound areas.				
[a] Not required for thicknesses less than 5 mm. [b] Where difficulty is experienced in obtaining an all weld metal test, this may be replaced by a full chemical analysis of the weld metal.				

6.15.4 A test record shall be prepared showing the test results compared with the specified requirements.

6.15.5 Where individual bend test results do not conform to the specified requirements, the reasons for the failure shall be investigated and, if no unacceptable imperfections are found, two further bend tests shall be made. If any of the retest results fail to conform, then the welds represented by the test plate shall be deemed not to be in conformance with this European Standard.

Following completion of the tests, test plates and coupons should be processed for recycling.

6.16 Impact tests

6.16.1 Tests shall be carried out in accordance with EN ISO 9016 with a V-shaped notch, perpendicular to the surface of the test specimen.

6.16.2 Impact-energy tests are not required on welds with a parent plate thickness less than 5 mm.

6.16.3 For plates under 10 mm but not less than 5 mm thick, test specimens with cross sectional dimensions of 10 mm by the thickness of the parent plate shall be used.

Machining to either 7,5 mm or 5 mm may be permitted, if required.

6.16.4 If the thickness of the parent plate is ≤ 10 mm, tests shall be carried out on three test specimens with the notch at the centre of the weld and three test specimens with the notch at the centre of the heat affected zone (with the V-notch crossing the fusion boundary at the centre of the specimen).

6.16.5 If the thickness of the parent plate is > 10 mm, tests shall be carried out on three test specimens from the centre of the weld and three test specimens from the heat affected zone (with the V-notch crossing the fusion boundary at the centre of the specimen).

6.16.6 The average value obtained from each set of three test specimens shall be not less than 34 J/cm^2. Not more than one of the individual values shall be below 34 J/cm^2 and shall in no case be less than 24 J/cm^2. This shall apply to specimens taken at the centre of the weld and in the heat-affected zone.

6.16.7 The normal test temperature shall be –20 °C but for drums that may be subjected to temperatures below –20 °C, as defined in 4.1, impact testing shall be carried out at a temperature of –40 °C.

Following completion of the tests, test plates and coupons should be processed for recycling.

7 Initial inspection and testing

7.1 General

Following completion, the following inspections and tests shall be undertaken.

For batches:

— Verification of mechanical characteristics and homogeneity of material in accordance with 6.3.

— Verification of minimum wall thickness in accordance with 6.4 with reference to Annex B.

— Verification of the conformity with the design type specification and the requirements of this standard.

For all drums:

— Hydraulic pressure test in accordance with 7.2.

— Inspection and assessment of manufacturing defects in accordance with 6.4 and 6.9.

— Inspection of the markings on the drums in accordance with Clause 9.

— Leak tightness test in accordance with 7.4.

— Inspection of the neck threads in accordance with 7.5.

— Inspection of the external and internal conditions in accordance with 7.5.

— Establishment of tare mass in accordance with 7.6.

— Lifting lug test in accordance with 7.3.

The manufacturer shall demonstrate full compliance with the relevant requirements (above) before the authorized body applies their stamp or issues the compliance certification.

7.2 Pressure test

7.2.1 Each drum shall be hydraulically tested, at its calculation pressure, in accordance with Annex C. There shall be no signs of leakage or cracks and show no pressure drop with the drum isolated from the pressure supply. After the test, the drum shall exhibit no sign of permanent distortion.

7.2.2 The pressurization shall be carried out under controlled conditions with appropriate safety precautions.

7.2.3 Drums, which have been repaired subsequent to the pressure test, shall be subjected to a further test after completion of repairs, unless otherwise agreed.

7.2.4 The minimum pressure applied during the test shall be 30 bar. Calculations shall be made to ensure the stress occurring at the actual test pressure does not exceed 77 % of the material yield strength R_{eH}.

7.2.5 The duration of the test shall allow sufficient time for an examination to check for signs of leakage or general plastic deformation of the drum, but shall be not less than 10 min.

7.3 Lifting lug test

For drums designed to be handled by their lifting lugs, each lifting lug shall be subjected to a lift test at the maximum gross weight (if the design allows lifting by one lug, it shall be tested at 2,0 × the maximum gross weight). These tests may be carried out by attaching external weights to the drum.

7.4 Final examination of drum

7.4.1 Drums designed and constructed in accordance with this European Standard shall be subject to an external and internal examination for compliance with the requirements of the construction drawings and this standard. This examination shall include checks (both visual and using a test gauge) of the connection neck threads.

7.4.2 This inspection shall be undertaken after removal of any internal debris and complete drying of the drum.

7.4.3 If, due to the size of the openings, an internal examination is not possible upon completion of the drum, the manufacturer shall ensure that the internal surfaces are examined prior to their final assembly.

7.4.4 The final examination shall be performed following completion of all welding activities and any post weld heat treatment, but before application of any coating.

7.5 Leak tightness test

After mounting of the fittings, each drum shall be subjected to a leak tightness test at a minimum pressure of 6 bar using dry air, nitrogen or LPG. All joints shall be tested for leaks using proprietary leak detection fluid or by methods of equal sensitivity.

7.6 Tare mass

Each drum shall be weighed in order to determine the tare mass to an accuracy of 1 %. The tare mass shall include all permanent accessories and fittings, including coatings and the permanently attached protective frame, where applicable.

7.7 Verification on conformity

For each batch checks should be undertaken to ensure conformity with both the design type specification and the requirements of this standard.

8 Surface treatment and finishing

8.1 General

8.1.1 Drums shall be protected so as to prevent external corrosion arising from atmospheric exposure by the application of a protective coating system. The actual system applied shall take into account:

— environmental burdens caused by the corrosion protection coatings (alternatives such as solvent-free coatings shall be considered);

— local operating environment; and

— periods between periodic inspections/maintenance.

8.1.2 Details of the actual system used, expected life and coating maintenance recommendations shall be included in the operating instructions (see 12.2).

8.2 Finishing operations

The following finishing operations shall be carried out on drums following the final visual examination detailed in 7.4:

a) protection of all flanges and nozzles against impact and oxidation; and

b) protection of inner surface against oxidation from the atmosphere and against any introduction of foreign matter. This type of protection shall take into account the possible over pressure caused by high ambient temperatures and the possible partial vacuum conditions.

NOTE Finishing operations are all operations carried out after the drum has been pressure tested and before shipment/transport. The aim is to protect the drum from impact and contamination during transport, prior to use.

Any packaging and protection used during storage/transport of the finished products should be selected to have the minimum environmental impact, i.e. use of recyclable or bio-degradable materials, minimum use of energy.

9 Marking

Drum details shall be marked on a corrosion resistant nameplate or other appropriate permanently attached non-pressure part.

The markings shall conform to the requirements of this standard and EN 14894.

NOTE The marking of transportable pressure vessels is regulated by RID/ADR and the European Directive on Transportable Pressure Equipment 2010/35/EU [15] includes additional marking requirements (including π-marking), both of which take precedence over any clause in this European Standard.

10 Conformity assessment

10.1 General

10.1.1 Drums manufactured according to this standard are subject to a conformity assessment system consisting of the prototype and design variant testing, approval of the design type and the production testing with the initial inspection and testing of batches and all pressure drums manufactured according to the design type.

NOTE Detailed regulations on the conformity assessment system and the approval for manufacture of pressure receptacles are outlined in RID [12] and ADR [13].

10.1.2 Records shall be kept of the type approval testing.

10.1.3 Any subsequent change in design which would result in an increase in calculated wall thickness, change in material thickness specified, material specification or weld procedure shall require a further set of tests. No further tests are required if the length varies by not more than 20 % or the diameter is reduced by not more than 5 %.

10.2 Fatigue test

10.2.1 The drum shall be filled with a non-corrosive liquid and subjected to successive applications of hydraulic pressure.

10.2.2 The test shall be carried out at an upper cyclic pressure equal to the test pressure.

10.2.3 The value of the lower cyclic pressure shall not exceed 10 % of the upper cyclic pressure.

10.2.4 The drum shall be subjected to 12 000 cycles.

10.2.5 The frequency of pressure cycling shall not exceed 0,25 Hz (15 cycles/min). The temperature measured on the outside surface of the cylinder shall not exceed 50 °C during the test.

10.2.6 There shall be no leakage from the drum.

10.3 Burst test

A drum representative of the design (which may be the drum used for the fatigue test) shall be subjected to a hydraulic burst test. The pressure shall be raised at a rate not exceeding 5 bar per minute. The design shall pass if the burst is not less than 67,5 bar. The final burst shall be without fragmentation.

10.4 Drop test

The drum, including any fittings protection frame, shall be subject to a drop test from a height of 1,2 m on to a flat surface. The orientation of the drum shall be such that the fittings protection (shroud or frame) strikes the surface in a position or direction considered to be the weakest. The drum shall be part filled with water to give the maximum gross operating mass and it shall be pressurized to 6 bar. Following the test, there shall be no leakage from the drum, fittings or their joints.

10.5 Lifting lugs

For drums designed to be handled by their lifting lugs, each lifting lug shall be subjected to a lift test at two times the gross operating weight. On completion of the test, the lugs and attachment welds shall be examined and shall not show cracks or distortion.

These tests may be carried out by attaching external weights to the drum.

Following completion of the tests, the drum should be processed for recycling.

11 Design type testing

Any new design of drum shall successfully undergo the following tests using prototype drums which are representative for the design:

a) fatigue test in accordance with 10.2;

b) burst test in accordance with 10.3;

c) drop test in accordance with 10.4;

d) lifting test in accordance with 10.5.

12 Records and documentation

12.1 Records to be obtained by the manufacturer

The manufacturer shall obtain the following documentation:

a) certificates showing the chemical analysis and details of the mechanical properties of the steels used in the construction of the pressure retaining parts of the drums;

b) certificate for formed parts in accordance with EN 10204, where required.

12.2 Documents to be provided by the manufacturer

The manufacturer shall provide the following:

a) design documents, including a fully dimensioned drawing, material specifications, design calculations etc.;

b) records of any heat treatment applied;

c) records of mechanical tests;

d) records of visual examination and dimensional checks on formed parts;

e) welding procedure specifications and welding procedure tests results;

f) up-to-date list of welders and records of their approval tests;

g) records of any weld repairs;

h) record of the result of the hydraulic pressure test;

i) radiographs where taken or results of other non-destructive tests in accordance with 6.10.2;

j) certificate of conformity to this European Standard;

k) operating instructions;

l) records of type approval tests.

Annex A
(informative)

Guidance on selection of material grades

This annex lists some of the material grades from the standards specified in Clause 4 that can be used for fabricating the drum.

The steel group as defined in Table 1 is also listed for each of the grades.

Table A.1 — Steel grades

Specification	Grade	Yield strength[a]	Tensile strength[b]	Minimum impact values (V-notched test pieces in the transverse direction)			Elongation after fracture[d]	Steel group
		R_{eH} N/mm^2	R_m N/mm^2	Toughness J/cm^2	Energy[c] J	Test temperature °C	%	
EN 10028-2	P235GH	235	360	34	27	0	25	St 1.1
	P265GH	265	410	34	27	0	23	St 1.1
	P295GH	295	460	34	27	0	22	St 1.2
	P355GH	355	510	34	27	0	21	St 1.2
EN 10028-3	P275N	275	390	37,5	30	−20	24	St 1.1
	P275NL1			34	27	−40		St 1.1
	P275NL2			34	27	−50		St 1.1
	P355N	355	490	37,5	30	−20	22	St 1.2
	P355NL1			34	27	−40		St 1.2
	P355NL2			34	27	−50		St 1.2
	P460N	460	570	37,5	30	−20	17	St 1.3
	P460NL1			34	27	−40		St 1.3
	P460NL2			34	27	−50		St 1.3

[a] The values of R_{eH} only apply to thicknesses up to 16 mm.

[b] The values of R_m are the specified minimum values.

[c] The impact absorbed energy values refer to a standard 10 mm × 10 mm specimen.

[d] $L_o = 5{,}65\sqrt{S_o}$ in accordance with EN ISO 6892-1 [5].

Annex B
(normative)

Tolerances on drums

B.1 Mean external diameter

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

B.2 Out of roundness

Out of roundness, *O*, the ratio of the difference between the maximum and minimum and the mean diameter, as defined by:

$$\frac{D_{max} - D_{min}}{0{,}5\left[D_{max} + D_{min}\right]} \quad \text{(B.1)}$$

shall not exceed 1,5 % of the specified external diameter with a maximum (in millimetres) of:

$$\frac{(D + 1\,250)}{200} \quad \text{(B.2)}$$

These tolerances shall apply to the cylindrical shell, including the straight flange length on the dished ends.

NOTE The determination of the out of roundness need not consider the elastic deformation due to the dead-mass of the drum.

At nozzle positions, a greater out of roundness may be permitted if it can be justified by calculation or strain gauge measurement.

Single dents or knuckles shall be smooth and their depth, which is the deviation from the surface of the shell, shall not exceed 1 % of their length or 2 % of their width respectively.

Greater dents and knuckles are permissible provided they have been proven acceptable by calculation or strain gauge measurements.

B.3 Deviation from the straight line

The deviation from the straight line shall not be more than 0,5 % of the total cylindrical length of the drum.

B.4 Irregularities in circular profile

B.4.1 Irregularities in circular profile shall not exceed the following:

— 2 % of the gauge length (checked by a 20° gauge, see Figure F.1 a)); or

— 2,5 % of the gauge length (checked by a 20° gauge) where the length of the irregularities along the length of the cylinder does not exceed the lesser of one quarter of the length of the shell strake between two circumferential seams, or 1,0 m.

B.4.2 If either of the above is exceeded, proof by calculation or strain gauge measurement shall be required to show that the stresses are permissible.

B.4.3 If irregularity in the profile occurs at the welded seam and is associated with “flats” adjacent to the weld, the irregularity in profile or “peaking” shall not exceed *e*/3 (see Figure F.1), where *e* is the wall thickness.

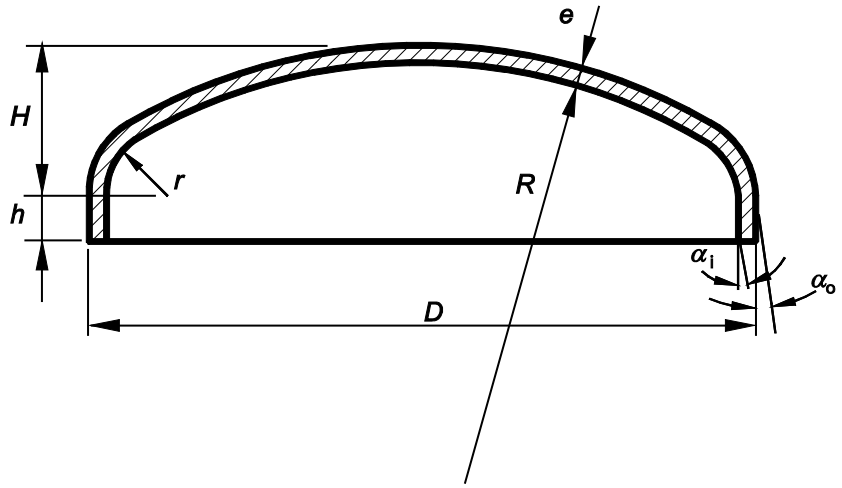
NOTE A suitable conservative method of measurement (covering peaking and ovality) is described in informative Annex F. Other types of gauges such as bridge gauges or needle gauges are also acceptable.

B.5 Thickness tolerance

The thickness of the material after forming shall be not less than the thickness determined in Annex E.

B.6 Profile

The dished ends shall be within the tolerances specified in Table B.1 for the elements shown in Figure B.1. The crown radius shall not be greater than the value specified in the design and the knuckle radius shall not be less than the value specified in the design.



Key

R is the crown radius
r is the knuckle radius
H is the dish height
h is the straight flange
e is the wall thickness
D is the external diameter
c is the circumference
O is the out of roundness, see B.2
α_i is the deviation of the bore from cylindrical shape - inner side
α_o is the deviation of the bore from cylindrical shape - outer side

Figure B.1 — Example of dished end

Table B.1 — Dished end tolerances

Elements		Tolerance of the element	Notes
c	D = 1 000 mm D > 1 000 mm	±0,4 % ±0,3 %	Special manufacturing conditions may require smaller tolerances.
O		1 %	Special manufacturing conditions may require smaller tolerances.
H		−0 +0,015D or +10 mm, whichever is the greater	The tolerance shall not fall below zero.
e = 10 mm e > 10 mm		−0,3 mm −0,5 mm	The actual wall thickness shall not fall below that specified beyond the tolerance given.
α_i α_o		≤ 2° ≤ 5°	In the case of ends where the outer side angle is influenced by the forming operation, the deviation of the straight flange from the cylindrical shape shall be measured only on the inner side of the end.

B.7 Surface alignment

The root faces of the weld preparations shall be aligned within the tolerances permitted by the welding procedure specification. The components shall be aligned as indicated on the construction drawings, as follows:

a) for longitudinal joints in the cylindrical shells, the surfaces of adjacent plates shall be aligned to the following tolerances:

   1) for plate thickness e up to and including 10 mm: 1 mm;

   2) for plate thickness e above 10 mm: 10 % of thickness.

b) for circumferential joints the surfaces of adjacent plates shall be in alignment with the following tolerance:

   1) 10 % of the thinner part plus 1 mm.

B.8 Attachments, nozzles and fittings

All pads, reinforcing plates, lugs, brackets, supports and other attachments shall fit closely to the shell, and the gap at all exposed edges to be welded shall not exceed 2 mm.

Except where specific dimensions are shown on the fully dimensioned drawing, the maximum gap between the outside of any nozzle and the inside edge of the hole in the shell, flange, reinforcing ring or backing ring shall not exceed 1,5 mm for openings less than or equal to 300 mm diameter and 3 mm for openings greater than 300 mm. To achieve this gap, it is permissible to machine over a sufficient length of the outside diameter of the drum or nozzle to accommodate the attachment to which it is to be welded. This machined length shall not extend beyond the toes or edges of the attachment welds, and shall not reduce the nozzle wall thickness to a value less than the design thickness.

Annex C
(normative)

Hydraulic pressure test

C.1 Temporary fittings

All temporary pipes and connections and blanking devices shall be designed to withstand the standard test pressure.

Jointing materials for flanged joints shall be of the same type as those to be used in service.

C.2 Pressure gauges

Pressure gauges shall be selected in accordance with EN 837-2. The gauge shall have an accuracy equal to or better than 1,6 % of the reading. The test pressure of the drum shall give a reading on the gauge between 50 % and 90 % of full scale deflection.

Alternative methods of pressure measurement can be used providing they achieve equivalent levels of accuracy.

C.3 Pressurising agent

Water shall normally be used as the pressurising agent. Care shall be taken to ensure the drum is positioned such that entrapped air is vented.

To avoid the risk of freezing, the temperature of the water during the test should be not less than 7 °C.

C.4 Avoidance of shocks

No drum undergoing pressure testing shall be subjected to any form of impact or pulsation loading.

C.5 Test procedure

The pressure in the drum shall be gradually and regularly increased until the test pressure (see 7.2) is reached. The required test pressure shall be maintained for not less than 10 min.

On completion of the hydraulic test, release of pressure shall be gradual and from the top of the drum. Adequate venting shall be provided to ensure that the vacuum rating of the drum is not exceeded.

After draining, any residual water shall be removed by appropriate means.

The fluid used for the hydraulic test should be recycled for further use or disposed of with due regard to the environment.

Annex D
(normative)

Imperfections of welded joints

Table D.1 specifies the acceptance criteria for imperfections in welded joints.

Table D.1 — Imperfection levels in butt-welds detected by NDT methods

Imperfection	EN ISO 6520-1 **reference**	**Acceptance limit for detectable imperfection**
Cracks and lamellar tears	100	Not permitted
Porosity	2011	d = 0,3t maximum 4 mm
Uniformly distributed porosity	2012	- For any individual gas pore, see 2011 - Not permitted if the total projected surface porosity exceeds 2 % of the considered projected surface of weld [a]
Localized (clustered) porosity	2013	- For any individual gas pore, see 2011 - Not permitted if the total projected surface porosity exceeds 4 % of the considered projected surface of the weld, whichever is the greatest of the two following areas: - area 1) an envelope surrounding all the pores - area 2) a circle with a diameter corresponding to the weld width
Linear porosity	2014	Same as for uniformly distributed pores, see 2012, but the distance between two pores (Δl) shall always be greater than twice the diameter of the bigger one, and not less than 4 mm (to ensure that there is no chance of having a lack of fusion)
Elongated cavity	2015	l = 0,3t, maximum 5 mm; and w = 2 mm
Wormhole	2016	Same as for elongated cavity, see 2015
Shrinkage cavity	202	l = 0,3t, maximum 4 mm; and w = 2 mm Not permitted when occurring at a stop or restart
Slag and flux inclusions and oxide inclusions (Parallel to the weld axis)	301 302 303	w = 0,3t, maximum 3 mm In case of several linear slag inclusions with a distance between two of them less than twice the longest of them, the total length shall be considered a defect
Slag and flux inclusions (random, not parallel to weld axis)	3012 3013 3022 3023	Individual length, maximum - 0,3t
Tungsten inclusions	3041	As for porosity, see 2011

Imperfection	EN ISO 6520-1 **reference**	**Acceptance limit for detectable imperfection**
Copper inclusions	3042	Not permitted
Lack of fusion (side, root or inter-run)	401	Not permitted
Incomplete penetration	402	Not permitted
Slag inclusions (all) Flux inclusions (all) Oxide inclusions (all) Metallic inclusions (all)	301 302 303 304	Not permitted when occurring at the surface (shall be removed by grinding for example)
Lack of penetration	402	Not permitted
Undercut	5011 5012	$t \geq 16$ mm $h = 0,5$ mm long imperfections 6 mm $\leq t < 16$ mm $h = 0,3$ mm long imperfections $h = 0,5$ mm short imperfections $t < 8$ mm $h = 0,3$ mm short imperfections
Local protrusion	5041	Occasional local protrusion exceeding h (see 504) is permitted with a maximum that shall be related to the operating conditions
Shrinkage groove	5013	Long imperfections[b]: not permitted Short imperfections[c]: $h = 1$ mm
Root concavity	515	A smooth transition is required
Excessive penetration	504	$h = 1$ mm + 0,6b maximum 4 mm
Excessive convexity	503	$h = 1$ mm + 0,15b smooth transition is required
Excess weld metal	502	$h = 1$ mm + 0,15b smooth transition is required
Excessive asymmetry of fillet weld	512	$h = 2$ mm + 0,15a
Irregular surface	514 509 511 513 517	Reinforcement to be of continuous and regular shape with complete filling of groove
Overlap	506	Not permitted
Linear misalignment (surface)	507	See B.7
Spatter	602	Spatter shall be removed from all pressure parts and from both load carrying attachment weld. Isolated, non-systematic spatter may however be permitted on components made from steel St 1.

Imperfection	EN ISO 6520-1 **reference**	**Acceptance limit for detectable imperfection**
Arc Strike	601	Grind smooth, accept subject to thickness and crack detection test in accordance with 6.11
Spatter	602	
Tungsten spatter	6021	
Torn surface	603	
Grinding mark	604	
Chipping mark	605	
Under flushing	606	Not permitted, any local under flushing shall be related to the design characteristics (calculated thickness = minimum thickness for base material) (Thickness shall be measured by ultrasonic method in case of doubt)
a is normal fillet weld throat thickness *b* is width of weld reinforcement *d* is diameter of pore *h* is height of imperfections		*l* is length of imperfection *t* is wall or plate thickness *w* is width of imperfection
[a] Area is the maximum length of weld affected multiplied by the local width of weld. [b] Long imperfections: one or more imperfections of total length greater then 25 mm in any 100 mm length of the weld or a maximum of 25 % for a weld shorter than 100 mm. [c] Short imperfections: one or more imperfections of length not greater than 25 mm in any 100 mm length of weld or a maximum of 25 % of the weld length for a weld shorter than 100 mm.		

Annex E
(normative)

Design formulae for drums

E.1 Allowable stresses

R_{eH} is the upper yield strength specified in the material standard.

Nominal design stress, $f = 0,77\ R_{eH}$.

E.2 Design formulae

E.2.1 General

Drums shall be designed using the formulae given in E.2.2 to E.2.4.

NOTE The resulting thickness is a minimum thickness and does not take into account the provision of any corrosion allowance or minimum handling thicknesses required by 5.3.2.

E.2.2 Cylindrical shell calculation

The minimum thickness:

$$e_{min} = \frac{p_c D_o}{2fZ + p_c} \tag{E.1}$$

where

D_o is the outside diameter of shell;

p is the calculation pressure;

z is the weld joint coefficient (1,0 or 0,85 as appropriate);

f is the nominal design stress.

E.2.3 Torispherical end calculation

The following rules only apply to ends for which:

$r \geq 0,06 D_i$

$r \geq 3e$

$e \leq 0,08 D_i$

$e \geq 0,001 D_i$

$R \leq D_o$

The minimum thickness e is the greatest of e_s, e_y and e_b where

$$e_s = \frac{p_c R}{2fZ - 0{,}5p_c} \tag{E.2}$$

$$e_y = \frac{Cp(0{,}75R + 0{,}2D_i)}{f} \tag{E.3}$$

and

$$e_b = [0{,}75R + 0{,}2D_i]\left[\frac{p_c}{111f_b}\left(\frac{D_i}{r}\right)^{0{,}825}\right]^{\left(\frac{1}{1{,}5}\right)} \tag{E.4}$$

where

$f_b = R_{eH}/1{,}5$ for all materials;

where

D_o is the outside diameter of the shell;

p is the calculation pressure;

z is the weld joint coefficient, = 1,0 for one piece ends;

f is the nominal design stress;

f_b is the design stress for buckling calculation;

C is a factor determined from Figure E.1 or by calculation (see E.2.5);

e is the required thickness of the end;

e_s is the minimum thickness of end to limit membrane stress in central part;

e_y is the minimum thickness of knuckle to avoid axisymmetric yielding;

e_b is the minimum thickness of knuckle to avoid buckling;

D_i is the inside diameter of the end;

R is the inside radius of curvature of central part of the torispherical end;

r is the inside radius of the knuckle.

It is permissible to reduce the thickness of the spherical part of the end to the value e_s over a circular area that shall not come closer to the knuckle than the distance $\sqrt{R \times e}$.

Any straight cylindrical flange shall meet the requirements of E.2.2 for a cylinder, unless its length is no greater than $0{,}2\sqrt{D_i \times e}$, in which case it may be the same thickness as the knuckle.

E.2.4 Ellipsoidal end calculation

An ellipsoidal end is defined as one made in such a way as to produce a truly semi-ellipsoidal shape without distinct spherical and knuckle radii.

The design method converts these ends to equivalent torispheres which are calculated in accordance with E.2.3.

These rules apply only to ends for which

$1{,}7 < K < 2{,}2$ and $z = 1$

Ellipsoidal ends shall be designed as nominally equivalent torispherical ends with:

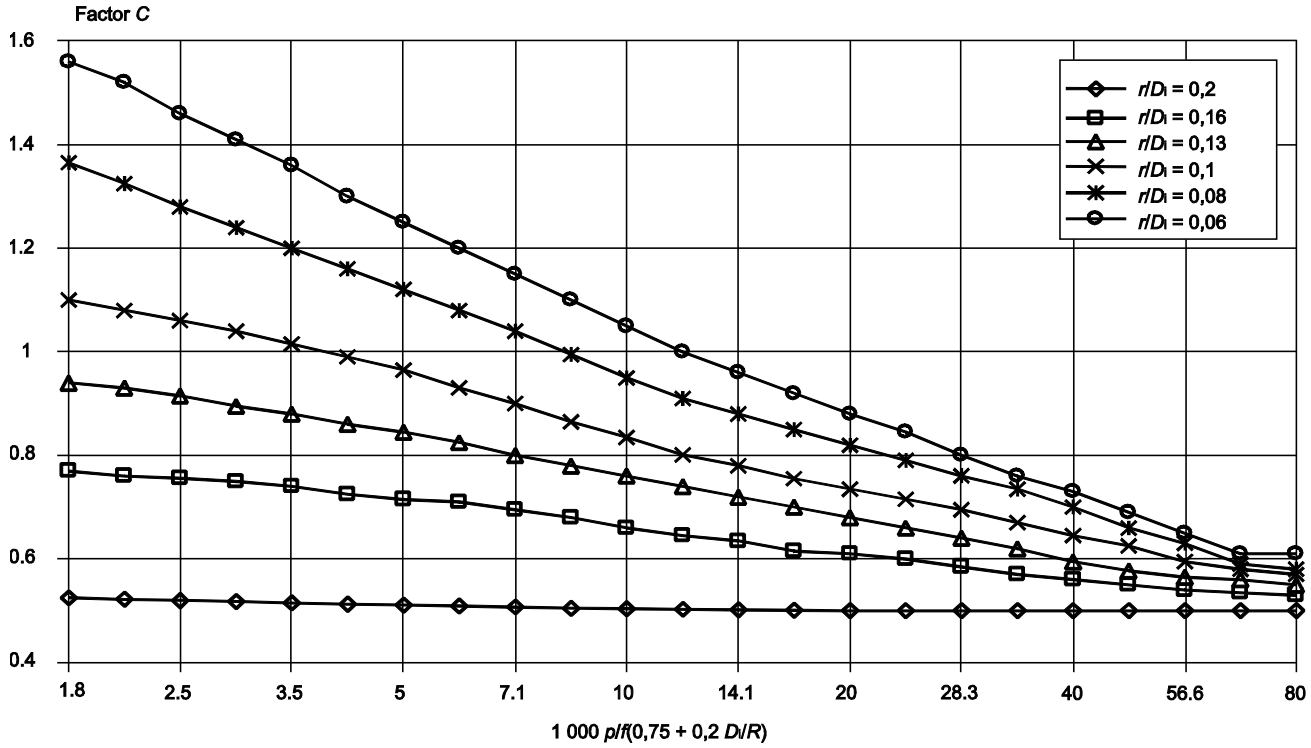
$$r = \left[\frac{0{,}5}{K} - 0{,}08\right] D_i \tag{E.5}$$

$$R = \left[0{,}44K + 0{,}02\right] D_i \tag{E.6}$$

where

$K = D_i/2h_i$ and is the shape factor for ellipsoidal ends;

h_i is the inside height of the ellipsoidal end.



Key

C Factor *C*

Figure E.1 — Torispherical end design

E.2.5 Formulae for calculating *C*

Y = min [e/R ; 0,04]

Z = log (1/Y)

$X = r/D_i$

$$N = \left[1{,}006 - \frac{1}{6{,}2 + (90Y)^4}\right] \quad \text{(E.7)}$$

For $X = 0{,}2$

$$C_{0,2} = \max\left\{\left(0{,}56 - 1{,}94Y - 82{,}5Y^2\right) \times 0{,}95; 0{,}5\right\} \quad \text{(E.8)}$$

For $X = 0{,}1$

$$C_{0,1} = \left[-0{,}183\,3Z^3 + 1{,}038\,3Z^2 - 1{,}294\,3Z + 0{,}837\right] \times N \quad \text{(E.9)}$$

For $X = 0{,}06$

$$C_{0,06} = \left[-0{,}363\,5Z^3 + 2{,}212\,4Z^2 - 3{,}293\,7Z + 1{,}887\,3\right] \times N \quad \text{(E.10)}$$

For $0{,}1 < X < 0{,}2$

$$C = 10\{(0{,}2 - X)C_{0,1} + (X - 0{,}1)C_{0,2}\} \quad \text{(E.11)}$$

For $0{,}06 < X < 0{,}1$

$$C = 25\{(0{,}1 - X)C_{0,06} + (X - 0{,}06)C_{0,1}\} \quad \text{(E.12)}$$

E.3 Nozzle reinforcement

E.3.1 General

The design method specified in this subclause is limited to the compensation of openings which conform to the geometric limitations specified.

The design method specified in this subclause only applies to cylindrical shells, and dished ends having circular or elliptical openings, where the assumptions and conditions specified in E.3.2 and E.3.9 are satisfied.

E.3.2 Size of openings

Size of openings shall be limited as follows:

a) cylindrical shells

$$\frac{d_i}{2r_{im}} \leq 1 \quad \text{(E.13)}$$

b) dished ends

$$\frac{d_i}{2r_{im}} \leq 0,6 \tag{E.14}$$

where

d_i is the inside diameter of opening or branch;

r_{im} is the inside radius of main body (shell or end).

In all cases, the ratio of branch thickness to main body thickness e_b/e_m shall comply with the limits of Figure E.2.

E.3.3 Distance between openings or branches

The distance between openings or branches, measured from the outside of the branches, pads, or compensation plates shall be not less than 2 l_m, where

$$l_m = \sqrt{(2r_{im} + e_m)e_m} \tag{E.15}$$

where

for shells:

$$r_{im} = D_o/2 - e_m \tag{E.16}$$

for torispherical ends:

$$r_{im} = r_{ih} \tag{E.17}$$

and

for ellipsoidal ends:

$$r_{im} = d_{is}\left[\frac{0,22d_{is}}{h_i} + 0,02\right] \tag{E.18}$$

where

D_o is the outside diameter of shell or dished end;

d_{is} is the inside diameter of shell or straight flange of dished end;

e_m is the actual thickness of the main body (shell or end) less any thinning allowance;

h_i is the inside height of an ellipsoidal end;

l_m is the length of the main body considered as effective compensation measured along the wall centreline from the edge of the opening or outside of the branch;

r_{im} is the inside radius of the main body (shell or end);

r_{ih} is the inside radius of the spherical shell, or spherical portion of the torispherical end.

E.3.4 Openings and branches

Openings and branches and their reinforcements in dished ends shall be located entirely within the spherical portion of the torisphere or for elliptical ends within a circle with a diameter of 0,6 times the outside diameter of the end.

E.3.5 Cylindrical shells and dished ends with openings

Cylindrical shells and dished ends with openings shall be reinforced where necessary.

The reinforcement area of the main body with openings cannot be calculated directly but shall be assumed in the first instance. That assumption may be verified by means of the method described in E.3.6 to E.3.14. The applied method is based on calculated thickness for pressure derived from E.2.2 for cylindrical shells and from E.2.3 for dished ends and leads to relationships between a pressure loaded area A_p and stress loaded cross sectional area A_f (see Figure E.3, Figure E.4 and Figure E.5). The calculation may need to be repeated using a corrected assumption of the reinforcement area.

E.3.6 Shell reinforcement

The reinforcement of the main body can be obtained by the following measures:

a) by set-in welded pads (see Figure E.3);

b) by set-on welded compensating plates (see Figure E.4);

c) by set-on or set-in welded branches (see Figure E.5).

E.3.7 Extent of reinforcement

Where necessary, sufficient reinforcement shall be provided in all planes through the axis of the opening branch.

E.3.8 Elliptical openings

In the case of elliptical openings, the ratio between the major and the minor axis shall not exceed 1:4. For elliptical openings in cylindrical shells, the axis along the length of the shell shall be taken as the diameter for design purposes.

E.3.9 Welded branches

Set on or set in welded branches, fillet welded only, may be considered as reinforcement where they are in accordance with Figure E.3, Figure E.4 and Figure E.5. Each fillet shall have a throat thickness not less than 0,7 times the drum wall thickness.

E.3.10 Compensating plates

Reinforcement of openings by compensating plates is not limited by size. However, the effective width of such plates shall be calculated using only the main shell thickness, not the combined thickness.

E.3.11 Reinforcement — General

All openings shall satisfy the following general relationship:

$$p\left[A_p + 0{,}5(A_{fm} + A_{fb} + A_{fp})\right] \leq fA_{fm} + f_p A_{fp} + f_b A_{fb} \qquad \text{(E.19)}$$

where

p is the calculation pressure;

A_p is the pressure loaded area;

A_{fb} is the cross sectional area of compensation in branch;

A_{fm} is the cross sectional area of compensation in main body (shell or end);

A_{fp} is the cross sectional area of compensation in pad;

f is the nominal design stress of the main body (shell or end);

f_b is the nominal design stress of the branch or f, whichever is the lesser;

f_p is the nominal design stress of the pad or reinforcing plate or f, whichever is the least.

E.3.12 Reinforcement by pads

Only pads of the set-in welded type in accordance with Figure E.3, Figure E.4 and Figure E.5 shall be used.

The width of the pads l_p considered as contributing to the reinforcement shall not exceed l_m.

$$l_p \leq l_m \tag{E.20}$$

where

l_m is the length of main body considered as effective compensation measured along the wall centreline from the edge of the opening or outside of the branch.

The value of e_p used in the determination of A_{fp} shall not exceed twice $e_{m,}$

where

l_p is the maximum length of pad or reinforcing plate considered to be effective as compensation, measured along the pad or plate centreline from the edge of the opening or outside of the branch;

e_p is the thickness of pad or reinforcing plate;

e_m is the actual thickness of main body (shell or end), less any thinning allowance.

E.3.13 Reinforcement by branches

The wall thickness of branches (nozzles) shall, if necessary, be in excess of the thickness calculated to withstand internal pressure for a length l_b measured from the exterior wall of the main body. This requirement is independent of any reinforcement provided by fitting compensating plates.

E.3.14 Branch connections normal to the drum wall

For branch connections normal to the drum wall, the areas A_p , A_{fb} , A_{fm} , and A_{fp} shall be determined in accordance with Figure E.5, where the lengths contributing to the reinforcement shall be not more than l_m, for the shell (see E.3.3), and

$$l_b = \sqrt{(d_{ob} - e_b)e_b} \tag{E.21}$$

where

l_b is the external length of branch considered as effective compensation measured from the outside of the main body;

d_{ob} is the outside diameter of branch;

e_b is the actual thickness of the branch less any thinning allowance.

The maximum value to be used in the calculation of the part extending inside, if any, in the case of set-through branches [Figure E.3] shall be

$$l_{bi} = 0{,}5\ l_b \tag{E.22}$$

where

l_{bi} is the internal length of the branch considered as effective compensation, measured from the inside surface of the main body.

The dimensions of the compensating plate to be used in the calculation shall be:

$$e_p \leq e_m \text{ and } l_p \leq l_m \tag{E.23}$$

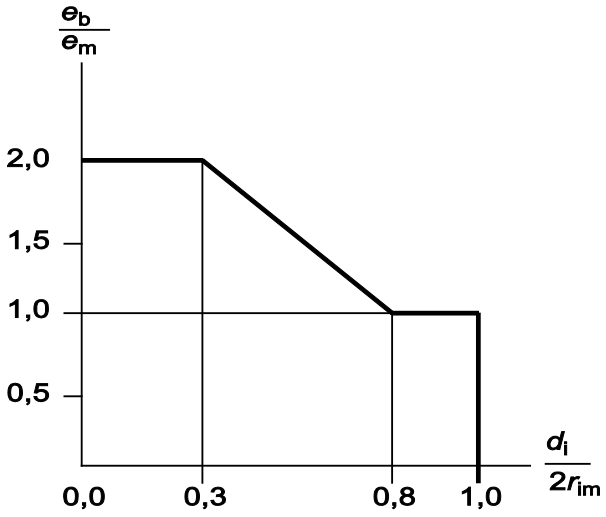
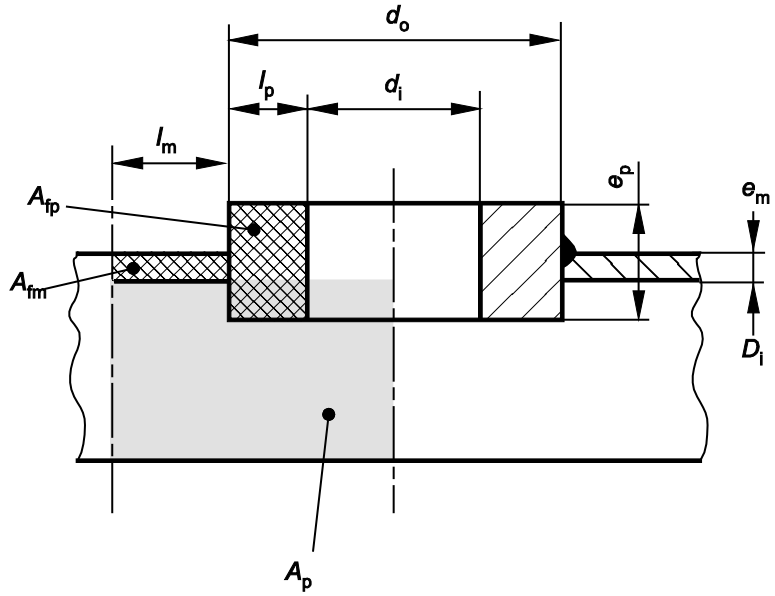


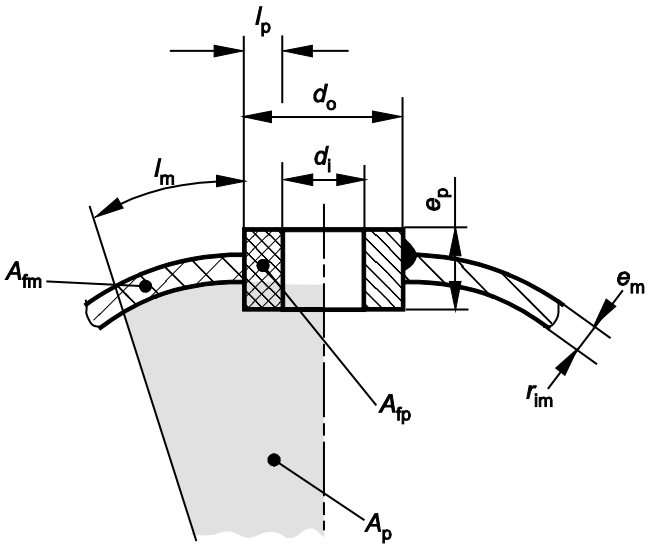
Figure E.2 — Maximum branch to body thickness ratio



$$A_p = \frac{D_i}{2}\left(l_m + \frac{d_o}{2}\right)$$

$$A_{\mathrm{fm}} = e_{\mathrm{m}}\, l_{\mathrm{m}}$$

$$A_{fp} = e_p\, l_p$$

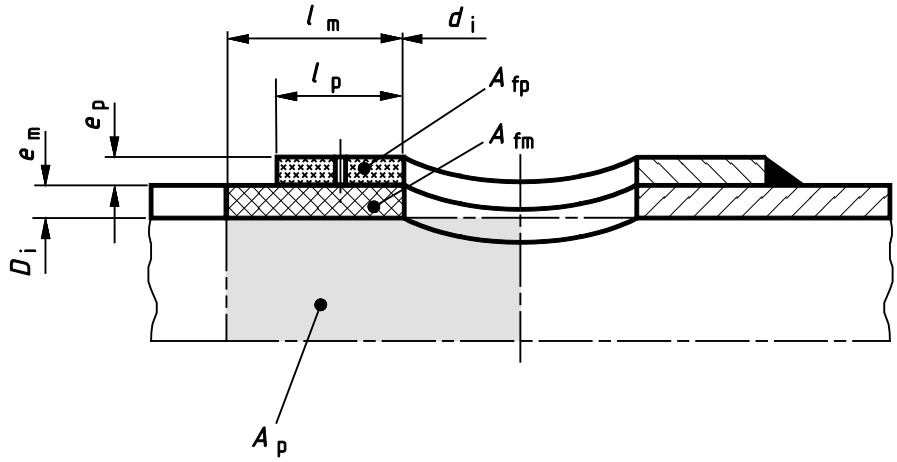


$$A_p = \frac{r_{im}}{2}\left(l_m + \frac{d_o}{2}\right)$$

$$A_{fm} = e_m\, l_m$$

$$A_{\mathrm{fp}} = e_{\mathrm{p}}\, l_{\mathrm{p}}$$

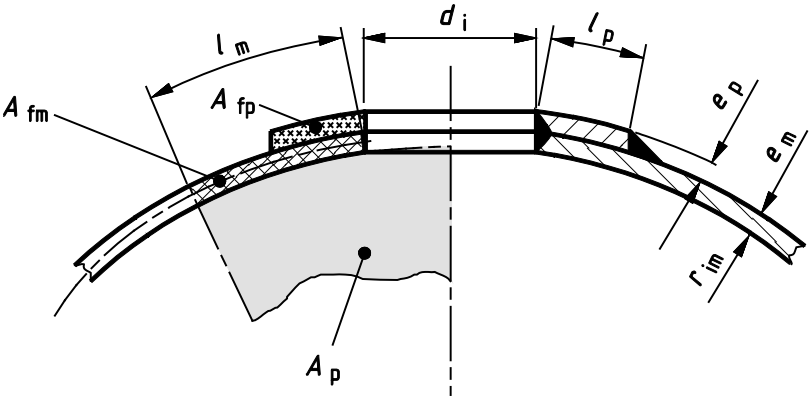
Figure E.3 — Design of openings — Cylindrical shells with isolated openings — Reinforcement by pads



$$A_p = \frac{D_i}{2}\left(l_m + \frac{d_i}{2}\right)$$

$$A_{fm} = e_m\ l_m$$

$$A_{fp} = e_p\ l_p$$

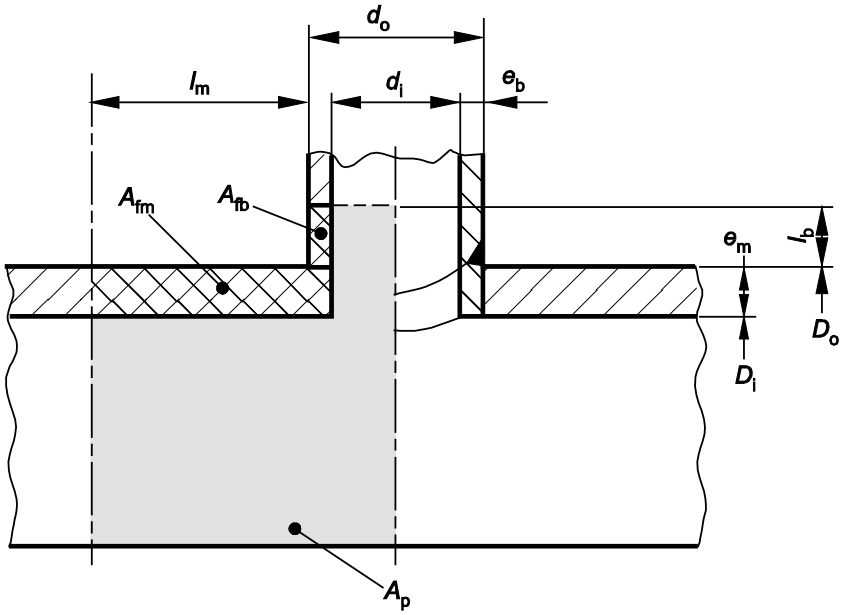


$$A_p = \frac{r_{im}}{2}\left(l_m + \frac{d_i}{2}\right)$$

$$A_{fm} = e_m\ l_m$$

$$A_{fp} = e_p\ l_p$$

Figure E.4 — Design of openings — Cylindrical shells with isolated openings — Reinforcement by compensating plates



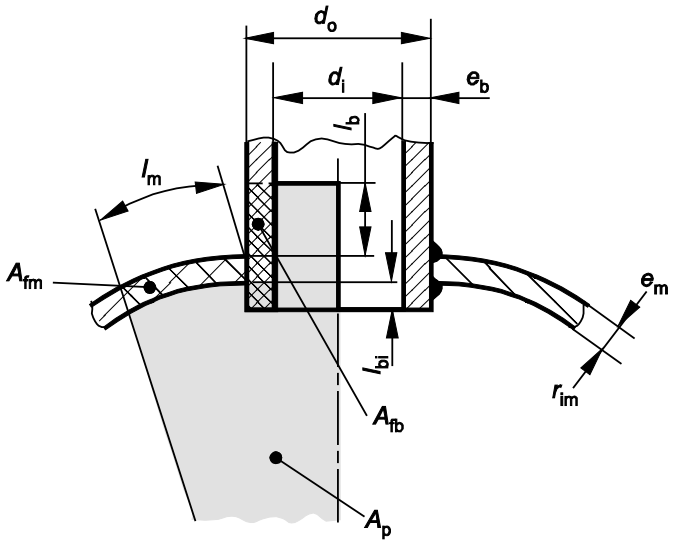
$$A_p = \frac{D_i}{2}\left(l_m + \frac{d_o}{2}\right) + \frac{d_i}{2}\left(l_b + e_m\right)$$

$A_{fm} = e_m l_m$ (set in)

$A_{fm} = e_m\left(l_m + e_b\right)$ (set on)

$A_{fb} = e_b\left(l_b + e_m\right)$ (set in)

$A_{fb} = e_b\ l_b$ (set on)



$$A_p = \frac{r_{im}}{2}\left(l_m + \frac{d_o}{2}\right) + \frac{d_i}{2}\left(l_b + e_m\right)$$

$A_{pm} = e_m\ l_m$

$A_{fp} = e_b\left(l_b + e_m + l_{bi}\right)$

Figure E.5 — Design of openings — Cylindrical shells with isolated openings — Reinforcement by branches

Annex F
(informative)

Measurement of shell peaking

F.1 Profile gauge

To enable peaking to be measured, a profile gauge should be made for each size of drum to be examined. Details of the gauge are given in Figure F.1 a).

The minimum inner arc length should be $0{,}175D_o$ (20° of arc), where D_o is the external diameter of the drum. This diameter should be checked by measurement of the actual drum.

However, for some drums the calculated arc length may not extend beyond the flats. Because of this, it is required that the minimum arc length of the gauge should be sufficient to clear the flats.

The recommended width of the weld cut is 28 mm but this may need to be increased to ensure that the cut out is clear of the weld [see Figure F.1 a)].

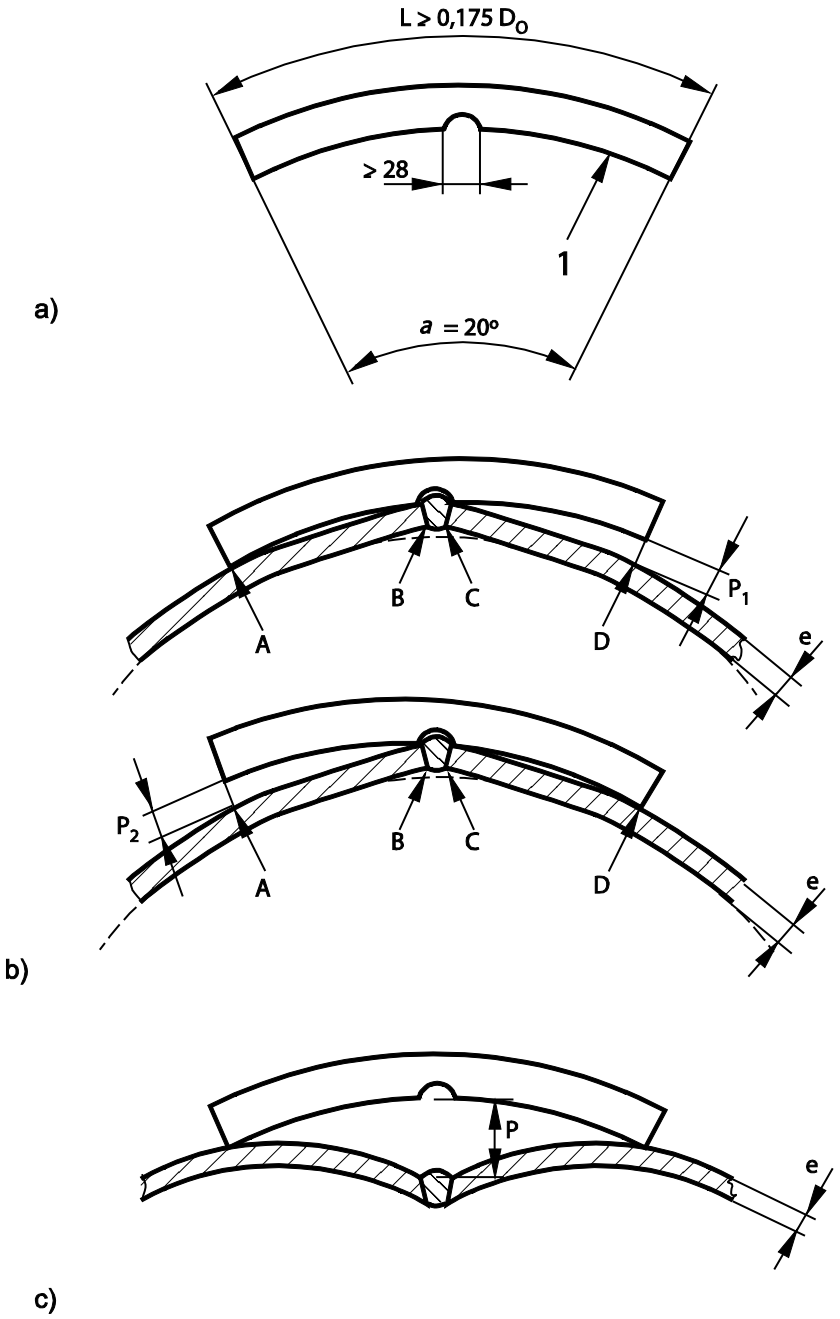
F.2 Peaking survey

The approximate zone of the maximum peaking should be determined by taking readings at intervals of approximately 250 mm along the longitudinal welds using the profile gauge. When this has been found, the maximum peaking P should be determined by accurate measurement of P_1 and P_2 [see Figure F.1 b) and Figure F.1 c)]. Care should be taken to ensure that the gauge makes contact with the shell at points indicated in the note to Figure F.1.

It may be beneficial to make a taper gauge as shown in Figure F.2, for checking P_1 and P_2.

Approximate dimensions of the flats should be measured at the point of maximum peaking and recorded.

For Figure F.1 b) the gauge should touch the shell at point A and as near to point B as possible. Likewise, when the gauge touches point D it should be as near as possible to point C. If there is a significant high spot between points A and B or between points D and C in Figure F.1 c) then this method may overestimate the peaking and in this case a plaster cast should be made to verify the amount of peaking. Also, note that points A and D should be clear of any flats.



Key

a) 20° gauge details

b) measurement of outside peaking

c) measurement of inward peaking

NOTE In b) and c), main peaking $P = \frac{P_1 + P_2}{4}$

Figure F.1 — Measurement of shell peaking

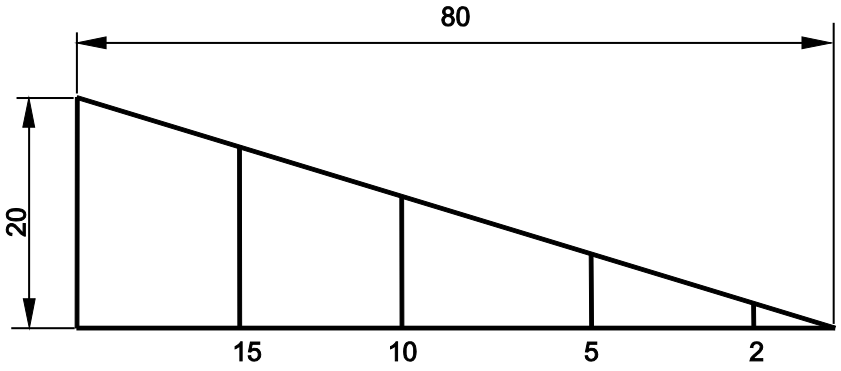


Figure F.2 — Taper gauge

Annex G
(informative)

Examples of welded joints

Examples of weld joints are shown in Figure G.1, Figure G.2, Figure G.3, Figure G.4 and Figure G.5.

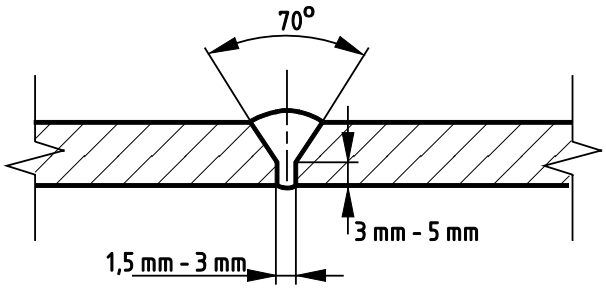
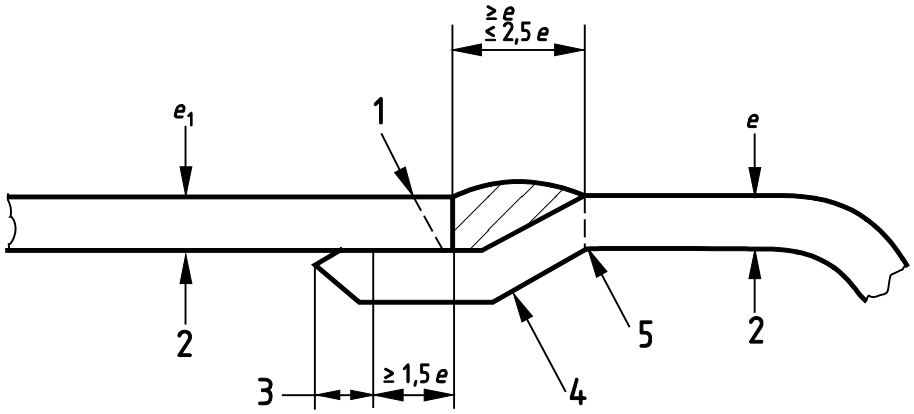


Figure G.1 — V-butt weld



Key

1 bevel optional
2 inside diameter
3 as desired
4 depth of offset = e_1
5 avoid sharp break

Figure G.2 — Joggle joint

NOTE The dimension limits (i.e. ≥ *e*, ≤ 2,5*e*) apply to weld preparation only.

The finished weld shall have a smooth profile and shall completely fill the grooves to the full thickness of the plates being joined. See 6.5.3.

The offset section that forms the weld backing shall be a close fit within the mating section round its entire circumference. This can be achieved by machining the spigot of the offset section, provided the thickness remaining as backing material is not less than 75 % of the original thickness.

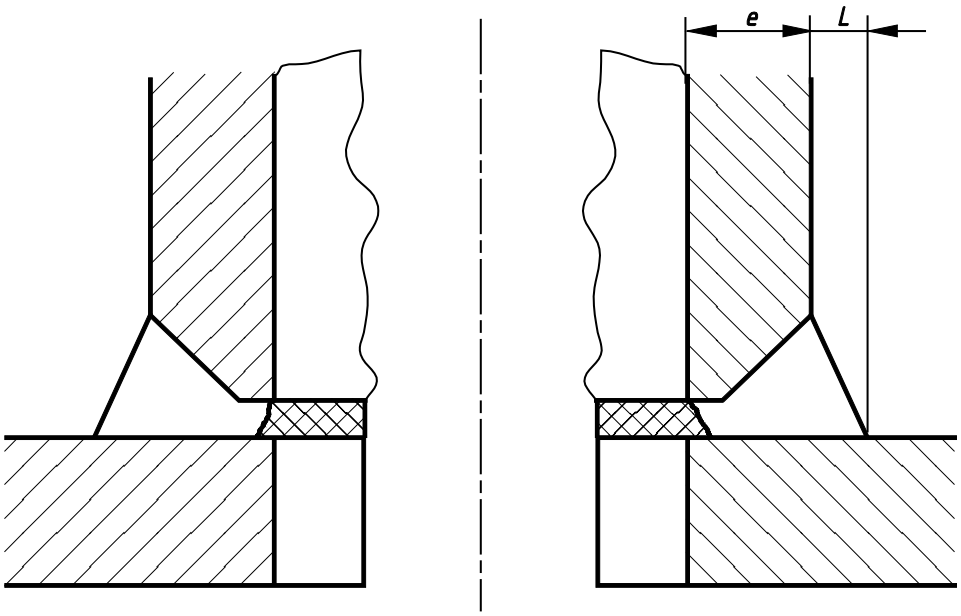


Figure G.3 — Nozzle joints: set-on

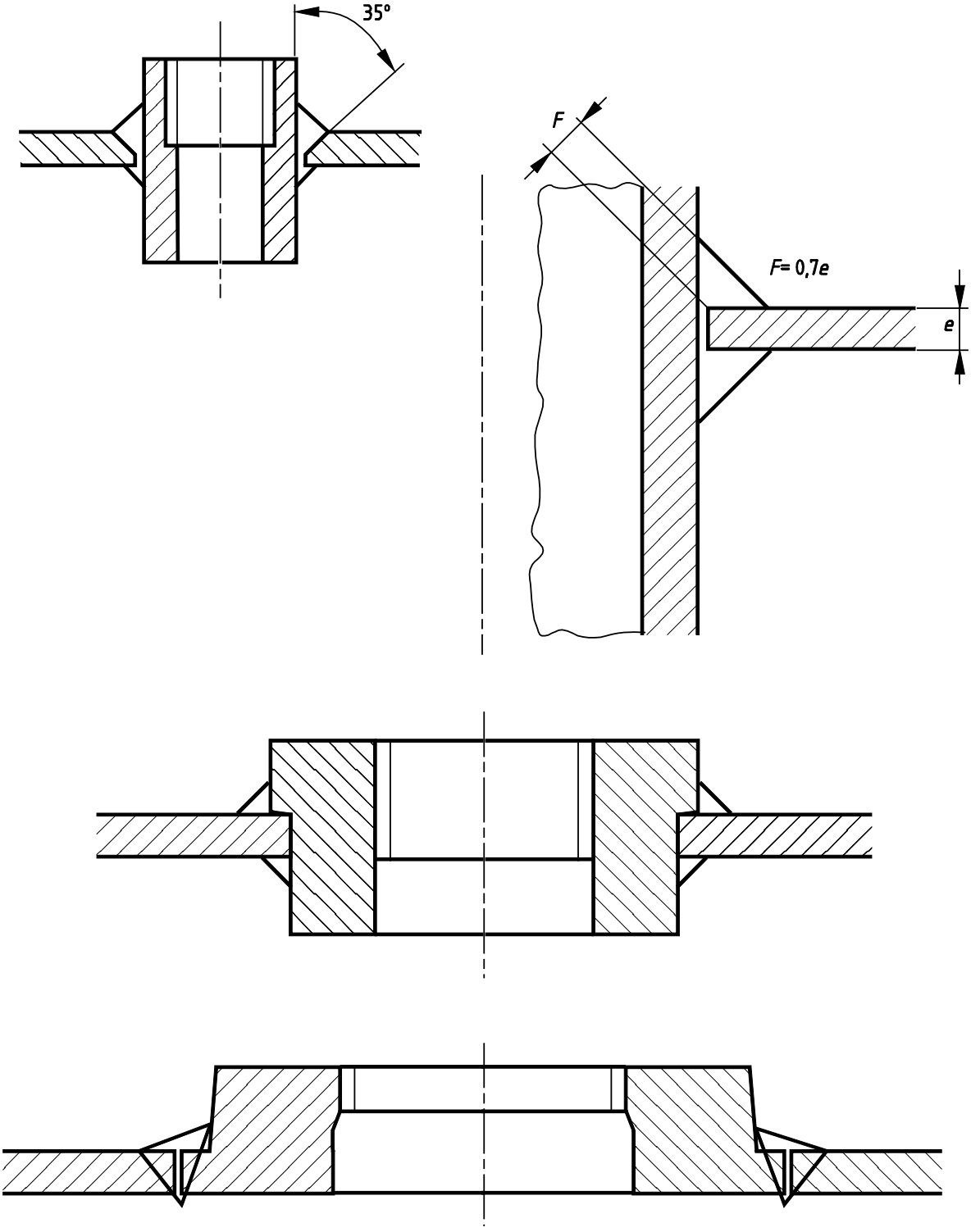


Figure G.4 — Nozzle joints: set-in

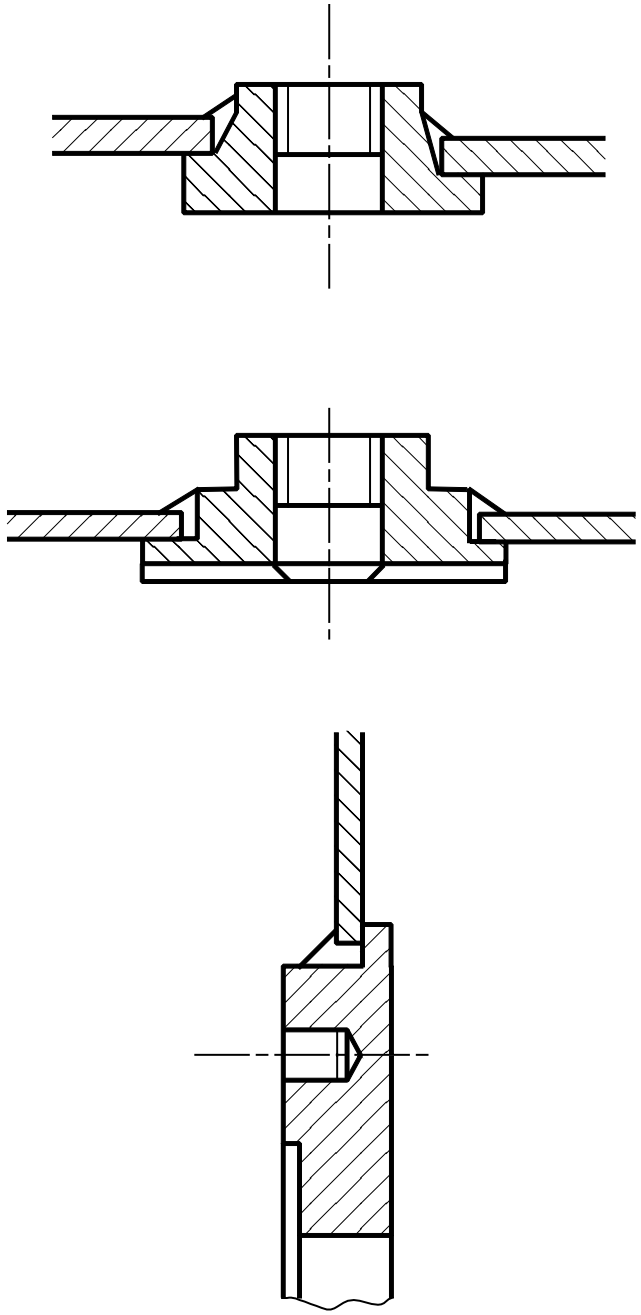


Figure G.5 — Nozzle joints: integral backing

Annex H
(informative)

Environmental checklist

Environmental Aspect	Stages of the life cycle										All stages
	Acquisition		Production		Use			End-of-Life			
	Raw materials and energy	Pre-manufactured materials and components	Production	Packaging	Use	Maintenance and repair	Use of additional products	Reuse / Material and Energy Recovery	Incineration without energy recovery	Deposition	Transportation
Inputs											
Materials	4.1.1	4.1.1	5.1.9 6.2	8.2		5.1	5.1	5.1 6.14.5 6.15.5 6.16.7 10.5		6.9	
Water			7.2 C.5								
Energy	4.1.1	4.1.1	5.1.9 6.2 6.6.2 6.7.8	8.2							5.1
Land					5.1						
Outputs											
Emissions to air			7.5								
Discharges to water											
Discharges to soil											
Waste			5.1.9 6.6.4 6.7.5 6.7.7 8.1.1	5.2 8.2				7.3		5.1	
Noise, vibration, radiation, heat losses			6.2 6.6.1 6.6.2.1 6.6.2.2								5.1
Other relevant aspects											
Risk to the environment from accidents or unintended use			Intro 1		11						
Customer information					11						
Comments:											

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