

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

The European Standard EN 14893:2006 has the status of a
British Standard

ICS 23.020.30

National foreword

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The UK participation in its preparation was entrusted to Technical Committee PVE/19, LPG containers and their associated fittings, which has the responsibility to:

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English Version

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 12 June 2006.

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Foreword

This document (EN 14893:2006) has been prepared by Technical Committee CEN/TC 286 "Liquefied Petroleum Gas equipment and accessories", the secretariat of which is held by NSAI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2007, and conflicting national standards shall be withdrawn at the latest by January 2007.

This European Standard has been submitted for reference into the RID and/or in the technical annexes of the ADR. Therefore the standards listed in the normative references and covering basic requirements of the RID/ADR not addressed within the present standard are normative only when the standards themselves are referred to in the RID and/or in the technical annexes of the ADR.

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

Introduction

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

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.

NOTE The maximum capacity of drums is 1 000 l. However the technical requirements of this standard can be applied for the safe design of receptacles larger than 1 000 l although these would not be classed as pressure drums under ADR.

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 referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 287-1, *Qualification test of welders - Fusion welding - Part 1: Steels*

EN 462-3, *Non-destructive testing — Image quality of radiographs — Part 3: Image quality classes for ferrous metals*

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

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

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

EN 756, *Welding consumables - Solid wires, solid wire-flux and tubular cored electrode-flux combinations for submerged arc welding of non alloy and fine grain steels - Classification*

EN 758, *Welding consumables - Tubular cored electrodes for metal arc welding with and without a gas shield of non alloy and fine grain steels - Classification*

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

EN 875, *Destructive tests on welds in metallic materials - Impact tests - Test specimen location, notch orientation and examination*

EN 876, *Destructive tests on welds in metallic materials - Longitudinal tensile test on weld metal in fusion welded joints*

EN 895, *Destructive tests on welds in metallic materials - Transverse tensile test*

EN 910, *Destructive tests on welds in metallic materials - Bend tests*

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

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

EN 1290, *Non-destructive examination of welds - Magnetic particle examination of welds*

EN 1321, *Destructive tests on welds in metallic materials - Macroscopic and microscopic examination of welds*

EN 1418, *Welding personnel – Approval testing of welding operators for fusion welding and resistance weld setters for fully mechanised and automatic welding of metallic materials*

EN 1435, *Non-destructive examination of welds - Radiographic examination of welded joints*

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EN 1668, *Welding consumables - Rods, wires and deposits for tungsten inert gas welding of non alloy and fine grain steels - Classification*

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

EN 1714, *Non-destructive examination of welds - Ultrasonic examination of welded joints*

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 10045-1, *Metallic materials — Charpy impact test — Part 1: Test method*

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

EN 13153, *Specification and testing of LPG cylinder valves - Manually operated*

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

EN 13799, *Contents gauges for LPG tanks*

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

EN ISO 2560, *Welding consumables - Covered electrodes for manual metal arc welding of non-alloy and fine grain steels - Classification (ISO 2560:2002)*

EN ISO 6520-1, *Welding and allied processes - Classification of geometric imperfections in metallic materials - Part 1: Fusion welding (ISO 6520-1:1998)*

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

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

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 15614-1:2004)*

ISO 9162, *Petroleum products - Fuels (Class F) - Liquefied Petroleum Gases - Specifications*

ANSI/ASME B1.20.1, *Pipe threads, general purpose (inch) issued by American National Standards Institute on 1983*

3 Terms and definitions

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

3.1

LPG (Liquefied Petroleum Gas)

mixture of predominantly butane or propane with traces of other hydrocarbon gases classified in accordance with UN number 1965, hydrocarbon gases mixture, liquefied, NOS or UN 1075, petroleum gases, liquefied

NOTE In some countries, UN numbers 1011 and 1978 may also be designated LPG.

3.2 yield strength

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

3.3 production-batch

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

NOTE In this context, consecutively need not imply continuous production.

3.4 cold forming

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

3.5 hot forming

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

3.6 calculation pressure

gauge pressure used in design formulae

3.7 manufacturer

manufacturer of the drum, unless otherwise specified

3.8 A_{r3}

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 The actual temperature varies with composition of the steel.

4 Materials

4.1 Suitability

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.

Steels shall be grouped in accordance with Table 1

Table 1 — Material grouping

Group	Sub-group	Type of steel
1		Steels with a specified minimum yield strength $R_{eH} \leq 460 \text{ N/mm}^2$ ^a and with analysis in % : $C \leq 0,25$ $Si \leq 0,60$ $Mn \leq 1,70$ $Mo \leq 0,70^b$ $S \leq 0,045$ $P \leq 0,045$ $Cu \leq 0,40^b$ $Ni \leq 0,5^b$ $Cr \leq 0,3$ (0,4 for castings) ^b $Nb \leq 0,05$ $V \leq 0,12^b$ $Ti \leq 0,05$
	1.1	Steels with a specified minimum yield strength $R_{eH} \leq 275 \text{ N/mm}^2$
	1.2	Steels with a specified minimum yield strength $275 \text{ N/mm}^2 < R_{eH} \leq 360 \text{ N/mm}^2$
	1.3	Normalised fine grain steels with a specified minimum yield strength $R_{eH} > 360 \text{ N/mm}^2$
2		Thermomechanically treated fine grain steels and cast steels with a specified minimum yield strength $R_{eH} > 360 \text{ N/mm}^2$
	2.1	Thermomechanically treated fine grain steels and cast steels with a specified minimum yield strength $360 \text{ N/mm}^2 < R_{eH} \leq 460 \text{ N/mm}^2$
	2.2	Thermomechanically treated fine grain steels and cast steels with a specified minimum yield strength $R_{eH} > 460 \text{ N/mm}^2$
^a	In accordance with the specification of the steel product standards, R_{eH} may be replaced by $R_{p0,2}$.	
^b	A higher value is accepted provided that $Cr + Mo + Ni + Cu + V \leq 0,75 \%$.	
NOTE	This table is an extract from CEN ISO/TR 15608:2005	

If additional impact testing is required, it shall be carried out in accordance with EN 10045-1 to achieve the impact values specified in 7.8.

4.2 Pressure retaining parts

Pressure-retaining materials shall be of appropriate steels conforming to EN 10028 parts 1, 2, 3 or 5 or shall conform to specifications agreed with the competent authority. All materials shall conform to 7.8.

Steels in sub-group 2.2 shall have a carbon equivalent limited to 0,43%, maximum, 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 capability to be used at low temperature shall be established:

- by testing in accordance with EN 10045-1 to meet the impact requirements in 7.8, or
- by reference to a recognised pressure vessel standard or specification : e.g. EN 13445.

4.4 Welding consumables

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.

They shall be selected from EN ISO 2560, EN 756, EN 758, or EN 1668 as appropriate. Suitability of the chosen consumables shall be demonstrated in accordance with 6.6.3.

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 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.

5 Design

5.1 General

Drums shall be designed such 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.

Drums shall be an assembly of a cylindrical shell and 2 ellipsoidal or torispherical dished ends. Dished ends convex to pressure (inwardly dished ends) are not permitted.

Dished ends shall be made from one piece of plate.

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For drums intended to contain LPG that complies with the limitation on corrosive contaminants specified in ISO 9162, and which is supplied to a national or international standard or other equivalent specification, no internal corrosion allowance is required.

As drums are protected against external corrosion in accordance with 9.1, no external corrosion allowance is required.

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 .

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.

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

A fully detailed, dimensional drawing shall be produced.

5.2 Design conditions

5.2.1 Calculation pressure

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

5.2.2 Design temperature

Generally the design temperature range shall be $-20\text{ }^{\circ}\text{C}$ to $50\text{ }^{\circ}\text{C}$. However, where temperatures lower than $-20\text{ }^{\circ}\text{C}$ are envisaged, the manufacturer shall demonstrate that the material from which the pressure containing parts of drum are constructed shall have properties suitable for a range of temperatures $-40\text{ }^{\circ}\text{C}$ to $50\text{ }^{\circ}\text{C}$ in accordance with a recognised pressure vessel standard or specification. e.g. EN 13445-2.

5.2.3 Vacuum conditions

The drum shall be designed to withstand a minimum internal pressure of 0,1 bar absolute.

NOTE 1 This requirement can be demonstrated by meeting the requirements of a recognised pressure vessel standard such as EN 13445-3.

NOTE 2 This requirement ensures that the drum will withstand vacuum conditions generated by the product during operation or by normal maintenance.

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:

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

Where:

e_h is the minimum thickness of cylindrical shell or dished end to satisfy handling criteria

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

In no case shall the thickness be less than 2,5 mm.

If 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

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

- 1) static load when the drum is filled with water.
- 2) 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 recognised pressure vessel standard or specification, e.g. EN 13445-3.

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;
- b) for stresses local to the supports, determined either by experimental analysis or calculation/special analysis – the limits specified in accordance with a recognised pressure vessel 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 recognised pressure vessel standard or specification, e.g. EN 13445-3. Stress limits as specified in 5.4 apply.

5.6 Openings

5.6.1 General

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

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 be located in the ends only.

5.6.2 Reinforcement

Each opening shall be reinforced by a boss, pad or compensating plate attached by welding and 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

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

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

Flanged connections shall comply with EN 1092-1.

Float gauge connections shall comply with EN 13799.

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

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.

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

5.7.3 Protective frame

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

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 12.4

The drum shall be totally or partly inserted and fixed in the frame by adequate means in a vertical or horizontal position.

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

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.

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.

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

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

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

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.

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

6.2 Control and traceability of materials

The manufacturer shall maintain a system of identification for the material used in fabrication in order that all material for pressure parts in the completed 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.

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

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

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

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

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

Records of the welding consumables shall be retained.

6.3 Manufacturing tolerances

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

6.4 Acceptable weld details

6.4.1 General

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

6.4.2 Longitudinal welds

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

6.4.3 Joggle joints

6.4.3.1 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 round 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.

NOTE Recommended arrangement is shown in Annex G.

6.4.3.2 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.

6.4.3.3 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 1290 or penetrant testing in accordance with EN 571-1.

6.5 Formed pressure parts

6.5.1 General

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

Ends shall be made from one piece of plate.

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

6.5.2 Heat treatment after forming

6.5.2.1 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 normalising 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.

6.5.2.2 Heat treatment after hot forming

If no subsequent heat treatment is intended, the forming process shall be proven, controlled and the forming process shall be completed above the A_{r3} temperature.

If the forming temperature is less than A_{r3} or the elongation of the steel, after forming, is less than that in the material specification, formed parts shall be heat treated by normalising or another proven procedure after hot forming in order to restore the mechanical properties to comply with the material specification.

6.5.3 Testing of formed parts

For cold-formed parts not subject to heat treatment, no mechanical tests are required in respect of the forming operation except where required by 6.5.2.1 for ends.

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

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

- 1 from the first 10 of each family, and then,
- 1 from each 1 000 units produced, but not less than 1 per 2 years.

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 %.

6.5.4 Repeated tests

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

Where the test results from correctly tested specimens do not 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.

The mean value of these six individual test results shall meet the specification. No more than two individual values shall fall below the minimum value and, of these two; one shall be at least 70 % of the minimum value.

Any pressure part 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.

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

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

6.5.5 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.

6.5.6 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.

6.5.7 Test certificate

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

6.6 Welding

6.6.1 General

Welding shall conform to the following:

- a) 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.
- b) 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.

6.6.2 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.

6.6.3 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.

6.6.4 Qualification of welders and welding personnel

Welders shall be approved in accordance with EN 287-1 and welding personnel with EN 1418.

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

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

6.6.5 Preparation of edges to be welded

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

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.

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.

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

When welding without a sealing run, the manufacturer shall ensure that the alignment and the gap of the edges to be welded will assure 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.

6.6.6 Execution of welded joints

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

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.

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.

6.6.7 Attachments and supports

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

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 the shrouds (see 5.7.2) all attachment welds shall be continuous.

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

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 7.2.

6.6.8 Preheating

6.6.8.1 The manufacturer shall include the preheating temperature in the WPS.

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.

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

6.7 Post weld heat treatment

Post weld heat treatment is not required.

6.8 Repairs

6.8.1 Repairs of surface imperfections in the parent metal

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.

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

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.

6.8.2 Repair of weld imperfections

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

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

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

Repairs shall be carried out using a qualified WPS in accordance with 6.6.2 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.

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

Repaired areas shall be non-destructively examined in the same manner as the initial weld and shall meet the requirements of Clause 7. Where the result of the examination is not satisfactory, a further repair is not permitted.

The manufacturer shall keep records of all weld repairs.

7 Inspection and testing

7.1 Visual examination of welds

On completion of welding, all welded joints shall be visually examined for surface imperfections in accordance with EN 970 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.

Unacceptable imperfections shall be repaired in accordance with 6.8 or the drum shall be rejected.

NOTE It is recommended that visual examination is supplemented by magnetic particle or penetrant testing in case of doubt (see 7.3.4 and 7.3.5).

7.2 Non-destructive testing (NDT)

7.2.1 Radiographic and/or ultrasonic examination of longitudinal or helical shell welds shall be carried out in accordance with 7.3.2 and 7.3.3 to the extent specified in Table 2. Any imperfections shall be assessed using the criteria in Annex D.

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 7.2.2.			

7.2.2 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.

7.2.3 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 and/or penetrant techniques, see 7.3.4 or 7.3.5.

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

7.2.4 100% of the lifting lug attachment welds shall be examined for imperfections by magnetic particle and/or penetrant techniques, see 7.3.4 or 7.3.5.

7.3 Non-destructive testing techniques

7.3.1 General

Guidance on the choice of non-destructive tests for welds is given in EN 12062. Other methods and techniques may be used provided the same level of imperfection detection is achieved.

7.3.2 Radiographic techniques

Radiographic examination shall be carried out in accordance with EN 1435.

Radiographic sensitivity shall be determined in accordance with EN 462-3 or with other techniques that achieve comparable sensitivities.

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

- job or workpiece serial number, order number or similar distinctive reference number;
- joint;
- section of the joint;
- outer edges of the weld.

NOTE 1 It is recommended that these are marked with arrows or other symbols alongside but clear of the edges to clearly mark their positions.

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.

Radiographs of repair welds shall be clearly identified e.g. "R1".

NOTE 2 The location of the weld may 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.

7.3.3 Ultrasonic techniques

Ultrasonic examination techniques shall conform to EN 1714.

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.

7.3.4 Magnetic particle techniques

Magnetic particle inspection techniques shall be in accordance with EN 1290.

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 6.8.1.

7.3.5 Penetrant techniques

Penetrant examination of welds shall be carried out in accordance with EN 571-1.

7.4 Marking for all non-destructive testing techniques

Marks shall be made alongside welds to provide reference points for the accurate location of the seam with respect to the test report [see 13.2 (i)].

7.5 Qualification of personnel

Testing personnel shall be qualified to EN 473.

7.6 Acceptance criteria

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

7.6.2 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.

7.6.3 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 7.6.2, then the drum produced immediately before and after the drum being examined shall have the equivalent welds examined.

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

7.6.5 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 7.6.2 and 7.6.3 until a drum with no unacceptable imperfection is found. Where 7.2.2 is applicable, satisfactory experience shall be re-established during subsequent production.

7.7 Production test plates (coupon plates)

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

- 1 test plate from 0 m to 60 m;
- 1 test plate from 60 m to 360 m;
- 1 test plate from 360 m to 1 860 m;
- 1 test plate from 1 860 m to 9 360 m.

7.7.2 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 duplicate that used in the construction of the drum.

7.7.3 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 .

Table 3 — Number of test specimens

Steel group (see Table 1)	Dimensions in mm			
	1.1, 1.2 and 1.3		2.1 and 2.2	
Parent metal thickness, e	e ≤ 12	e > 12	e ≤ 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

NOTE 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.

Testing shall be carried out in accordance with the following standards:

- Bend tests EN 910;
- Macro examination EN 1321;
- Impact tests EN 875;
- Longitudinal tensile test EN 876;
- Transverse tensile test EN 895.

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

7.7.5 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 standard.

7.8 Impact tests

Tests shall be carried out in accordance with EN 875 with a V-shaped notch, perpendicular to the surface of the test specimen.

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

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.

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

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).

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).

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.

The normal test temperature shall be $-20 \text{ }^\circ\text{C}$ but for drums that may be subjected to temperatures below $-20 \text{ }^\circ\text{C}$, as defined in 4.1, impact testing shall be carried out at a temperature of $-40 \text{ }^\circ\text{C}$.

8 Final assessment

8.1 Pressure test

Drums shall be hydraulically tested in accordance with Annex C. There shall be no signs of leakage or plastic deformation 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.

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

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

The minimum pressure applied during the test shall be 30 bar. However, 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} .

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.

8.2 Lifting lugs

For drums designed to be handled by their lifting lugs, each lifting point shall be subjected to a lift test at the maximum gross weight. These tests may be carried out by attaching external weights to the drum.

8.3 Final examination

Drums designed and constructed in accordance with this standard shall be subject to an external and internal examination for compliance with the requirements of the construction drawings.

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

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.

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

9 Surface treatment and finishing

9.1 General

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;
- periods between periodic inspections/maintenance.

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

9.2 Finishing operations

The following finishing operations shall be carried out on drums:

- final examination (see 8.3);
- protection of all flanges and nozzles against impact and oxidation;
- 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 due to water vapour condensation.

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 installation.

10 Fittings

10.1 General

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

The following fittings shall be provided:

- Filler valve, in accordance with EN 13175,
- Liquid and/or vapour off-take valve, in accordance with EN 13175 or EN 13153,
- Liquid level gauge, in accordance with EN 13799,
- Overfill indication or protection device, in accordance with EN 13799,

— Liquid removal device, in accordance with EN 13175.

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

10.2 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.

10.3 Protective frame

Where the drum is designed to be inserted in a protective frame, this shall be done according to the manufacturer's specification.

10.4 Tare weight

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

11 Marking

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

The markings shall conform with the requirements of EN 14894.

12 Prototype testing

12.1 General

Drums representative of the design shall be submitted to the following type tests.

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 %.

Tests shall be conducted according to the procedures described below.

12.2 Fatigue test

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

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

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

The drum shall be subjected to 12 000 cycles.

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.

There shall be no leakage from the drum.

12.3 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.

12.4 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 pressurised to 6 bar. Following the test, there shall be no leakage from the drum, fittings or their joints.

12.5 Lifting lugs

For drums designed to be handled by their lifting lugs, each lifting lug shall be subjected to a lift test at 2 x the gross operating weight. On completion of the test, the lugs and attachment welds shall be examined and shall not show cracks or distortion.

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

13 Records and documentation

13.1 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.

13.2 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 7.2;
- 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 may 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 R_{eH} N/mm ²	Tensile strength ^b R_m N/mm ²	Minimum impact values (V-notched test pieces in the transverse direction)			Elongation after fracture ^d %	Steel group
				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 x 10 mm specimen.
^d $L_0 = 5,65\sqrt{S_0}$ in accordance with EN 10002-1

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:

$$\left[\frac{D_{\max} - D_{\min}}{D_{\max} + D_{\min}} \right]$$

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

$$\frac{(D + 1\,250)}{200}$$

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

NOTE 1 The determination of the out of roundness need not consider the elastic deformation due to the dead-weight of the drum.

NOTE 2 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.

NOTE 3 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

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 stroke between two circumferential seams, or 1,0 m.

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

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.

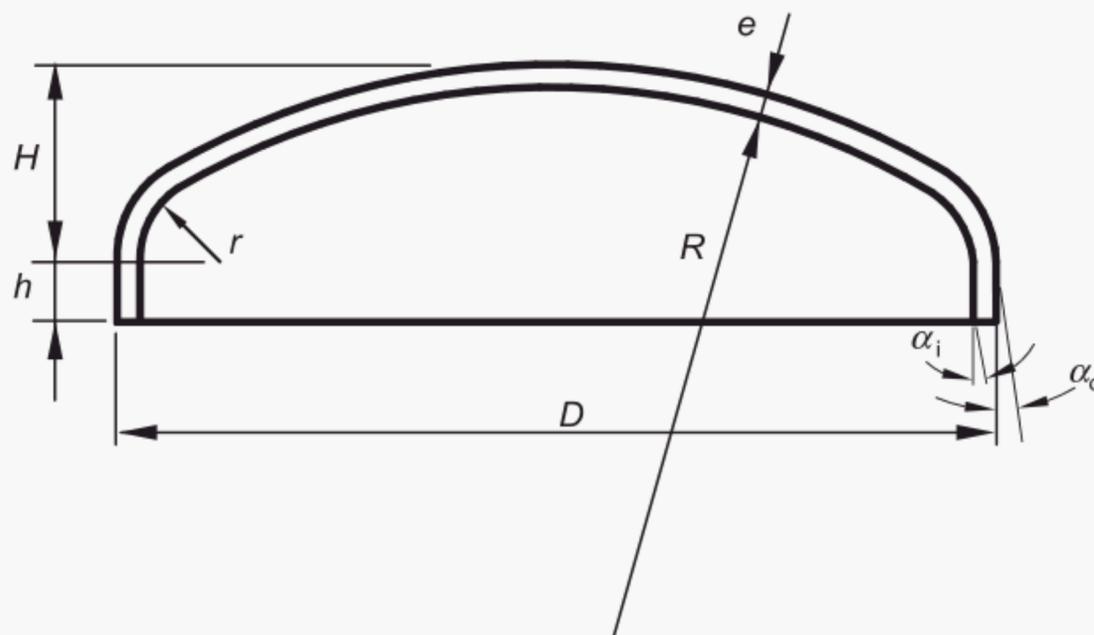
NOTE A suitable conservative method of measurement (covering peaking and ovality) is described in informative Annex F. Other types of gauges such as bridge gauges or needle gauges are also acceptable.

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 (πD)
- O is the out of roundness $\frac{2(D_{\max} - D_{\min})}{(D_{\max} + D_{\min})}$
- 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	$D \leq 1\,000$ mm	$\pm 0,4\%$	Special manufacturing conditions may require smaller tolerances.
	$D > 1\,000$ mm	$\pm 0,3\%$	
O		1%	Special manufacturing conditions may require smaller tolerances.
H		-0 +0,015D or +10 mm, which ever is the greater	The tolerance shall not fall below zero.
$e \leq 10$ mm		-0,3 mm	The actual wall thickness shall not fall below that specified beyond the tolerance given.
$e > 10$ mm		-0,5 mm	
α_i		$\leq 2^\circ$	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.
α_o		$\leq 5^\circ$	

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

NOTE 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 8.1) 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.

Annex D (normative)

Imperfections

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
Localised (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, which ever 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 - $0,3t$

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

Imperfection	EN ISO 6520-1 reference	Acceptance limit for detectable imperfection
Tungsten inclusions	3041	As for porosity, see 2011
Copper inclusions	3042	Not permitted
Lack of fusion (side, root or inter-run)	401	Not permitted
Incomplete penetration	402	Not permitted
Slag inclusions (all)	301	Not permitted when occurring at the surface (shall be removed by grinding for example)
Flux inclusions (all)	302	
Oxide inclusions (all)	303	
Metallic inclusions (all)	304	
Lack of penetration	402	Not permitted
Undercut	5011 5012	$t \geq 16 \text{ mm}$ $h = 0,5 \text{ mm}$ long imperfections $6 \text{ mm} \leq t < 16 \text{ mm}$ $h = 0,3 \text{ mm}$ long imperfections $h = 0,5 \text{ mm}$ short imperfections $t < 8 \text{ mm}$ $h = 0,3 \text{ mm}$ 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 : $h = 1 \text{ mm}$
Root concavity	515	a smooth transition is required
Excessive penetration	504	$h = 1 \text{ mm} + 0,6b$ maximum 4 mm
Excessive convexity	503	$h = 1 \text{ mm} + 0,15b$ smooth transition is required
Excess weld metal	502	$h = 1 \text{ mm} + 0,15b$ smooth transition is required
Excessive asymmetry of fillet weld	512	$h = 2 \text{ mm} + 0,15a$
Irregular surface	514 509 511 513 517	Reinforcement to be of continuous and regular shape with complete filling of groove
Overlap	506	Not permitted

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

Imperfection	EN ISO 6520-1 reference	Acceptance limit for detectable imperfection
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.
Arc Strike	610	Grind smooth, accept subject to thickness and crack detection test in accordance with 7.3.
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)
NOTE	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 than 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 $e_{\min} = \frac{pD_o}{2fz + p}$

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:

$$r \geq 0,06D_i$$

$$r \geq 3e$$

$$e \leq 0,08D_i$$

$$e \geq 0,001D_i$$

$$R \leq D_o$$

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

$$e_s = \frac{pR}{2fz - 0,5p}$$

$$e_y = \frac{Cp(0,75R + 0,2D_i)}{f} \text{ and}$$

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

where

$$f_b = R_{eH} / 1,5 \text{ for all materials.}$$

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

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

Ellipsoidal ends shall be designed as nominally equivalent torispherical ends with

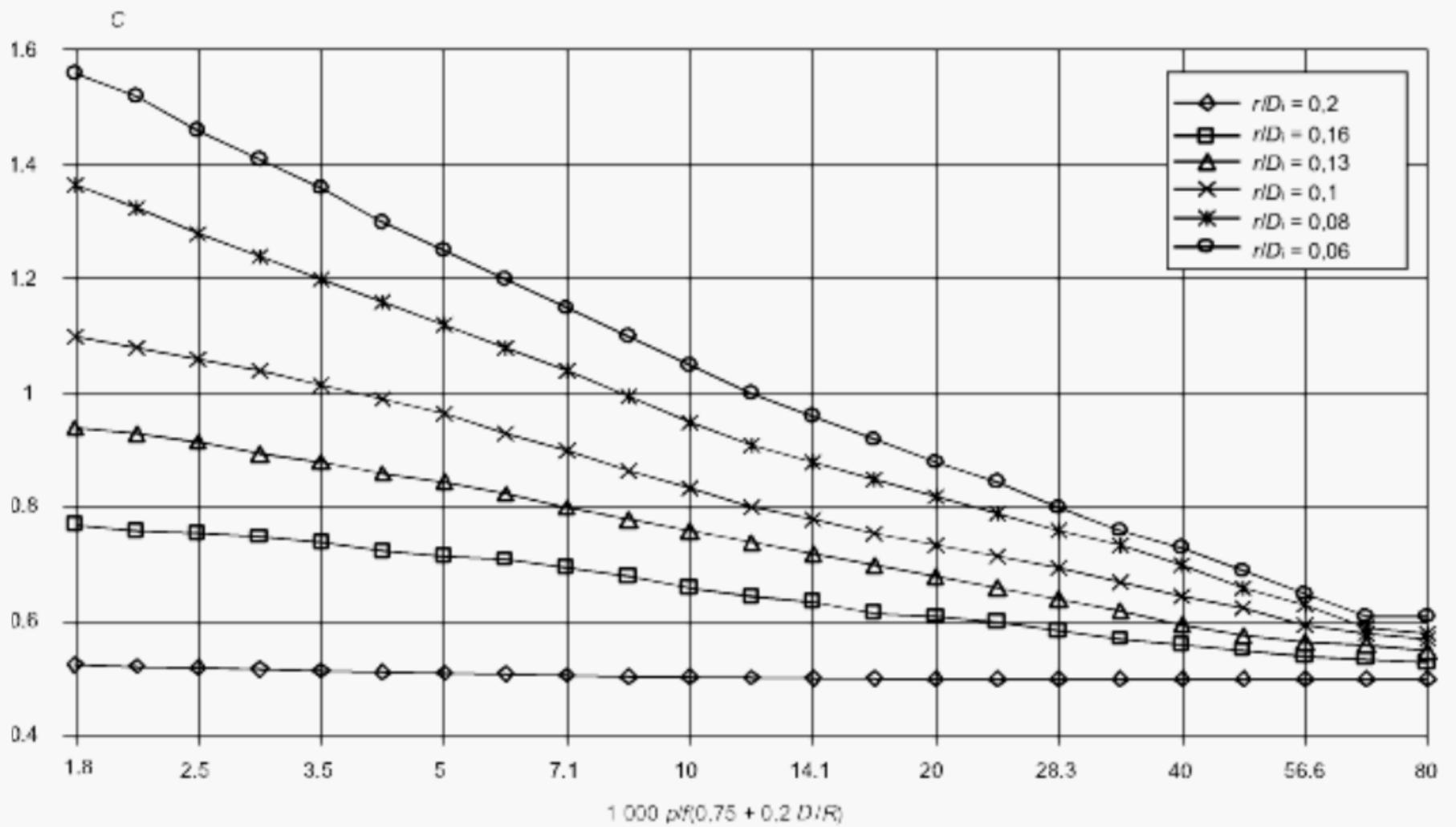
$$r = \left[\frac{0,5}{K} - 0,08 \right] D_i$$

$$R = [0,44K + 0,02] D_i$$

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

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

$$Z = \log (1/Y)$$

$$X = r/D_i$$

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

For $X = 0,2$

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

For $X = 0,1$

$$C_{0,1} = (-0,1833Z^3 + 1,0383Z^2 - 1,2943Z + 0,837) \times N$$

For $X = 0,06$

$$C_{0,06} = (-0,3635Z^3 + 2,2124Z^2 - 3,2937Z + 1,8873) \times N$$

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

$$C = 10\{(0,2 - X)C_{0,1} + (X - 0,1)C_{0,2}\}$$

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

$$C = 25\{(0,1 - X)C_{0,06} + (X - 0,06)C_{0,1}\}$$

E.3 Nozzle re-enforcement

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, $\frac{d_i}{2r_{im}} \leq 1$

b) dished ends, $\frac{d_i}{2r_{im}} \leq 0,6$

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

$$l_m = \sqrt{(2r_{im} + e_m)e_m}$$

where:

for shells $r_{im} = D_o/2 - e_m$

for torispherical ends $r_{im} = r_{ih}$, and

for ellipsoidal ends $r_{im} = D_i \left[\frac{0,22D_i}{h_i} + 0,02 \right]$

where:

D_o is the outside diameter of shell or dished end

D_i 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). 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 a);

- b) by set-on welded compensating plates as shown in Figure E.3 b);
 c) by set-on or set-in welded branches as shown in Figure E.3 c).

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. 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:

$$p \left[A_p + 0,5(A_{fm} + A_{fb} + A_{fp}) \right] \leq f A_{fm} + f_p A_{fp} + f_b A_{fb}$$

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 shall be used.

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

$$l_p \leq l_m$$

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.3 c) where the lengths contributing to the reinforcement shall be not more than l_m , for the shell (see E.3.3), and

$$l_b = \sqrt{(d_{ob} - e_b)e_b}$$

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 c)] shall be

$$l_{bi} = 0,5 l_b$$

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:

$$e_p \leq e_m \text{ and } l_p \leq l_m$$

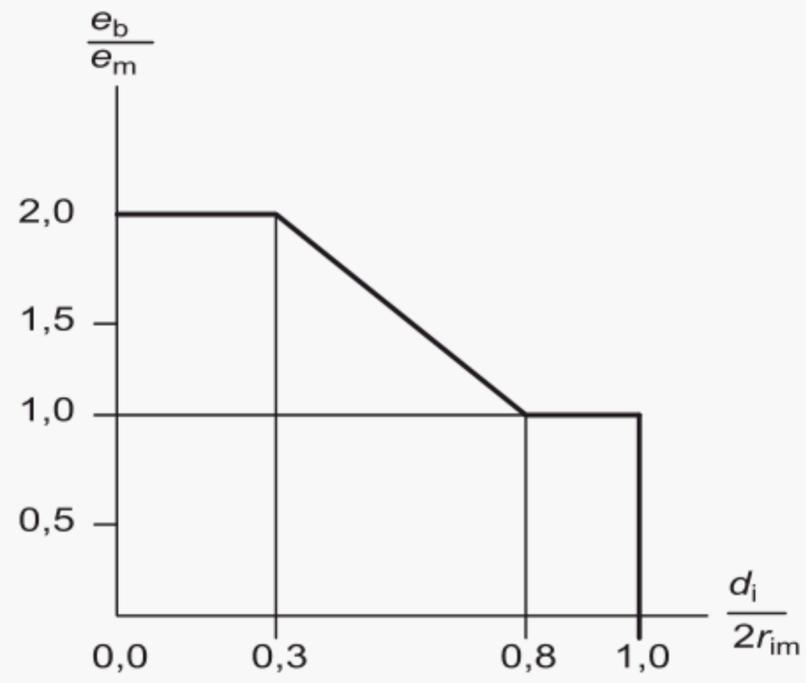
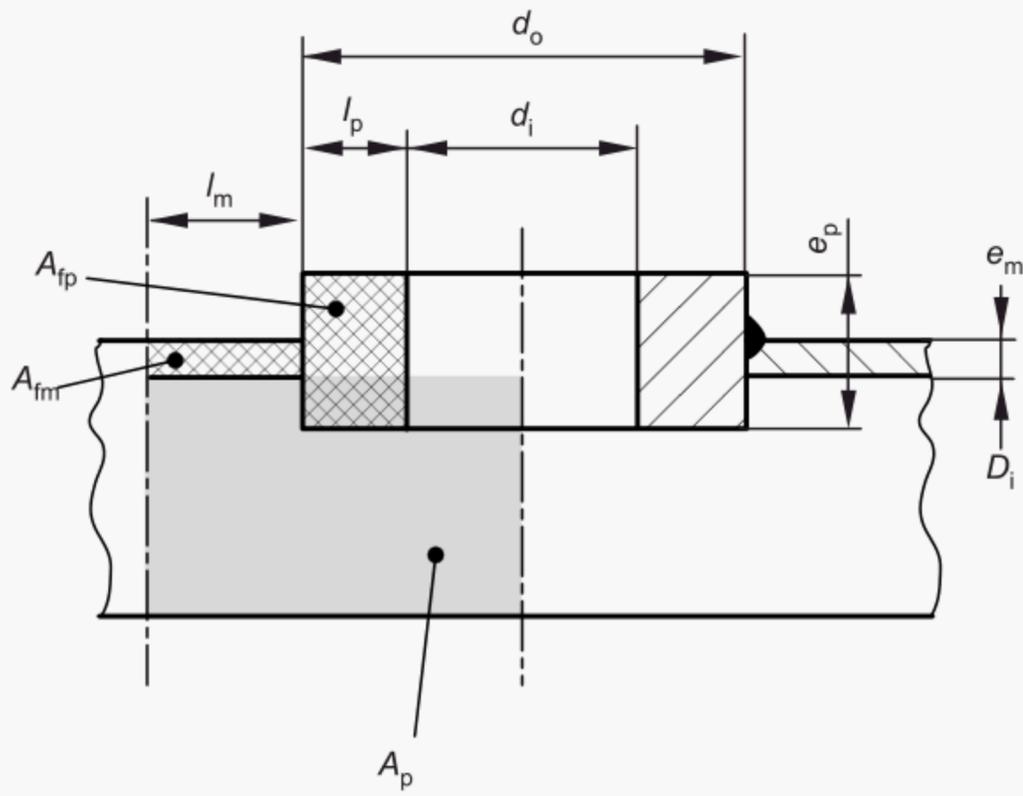


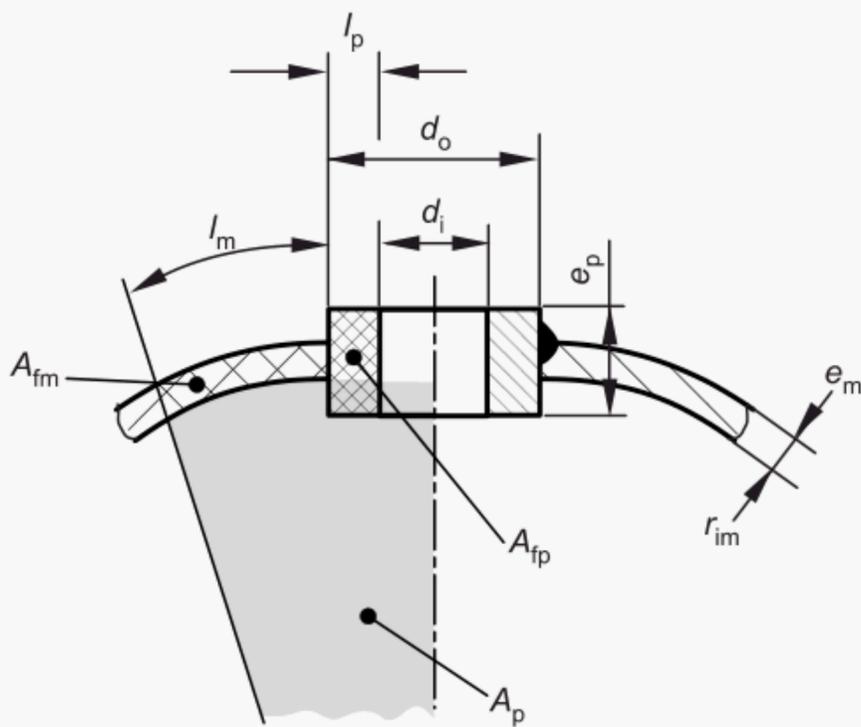
Figure E.2 —Maximum branch to body thickness ratio



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

$$A_{fm} = e_m l_m$$

$$A_{fp} = e_p l_p$$



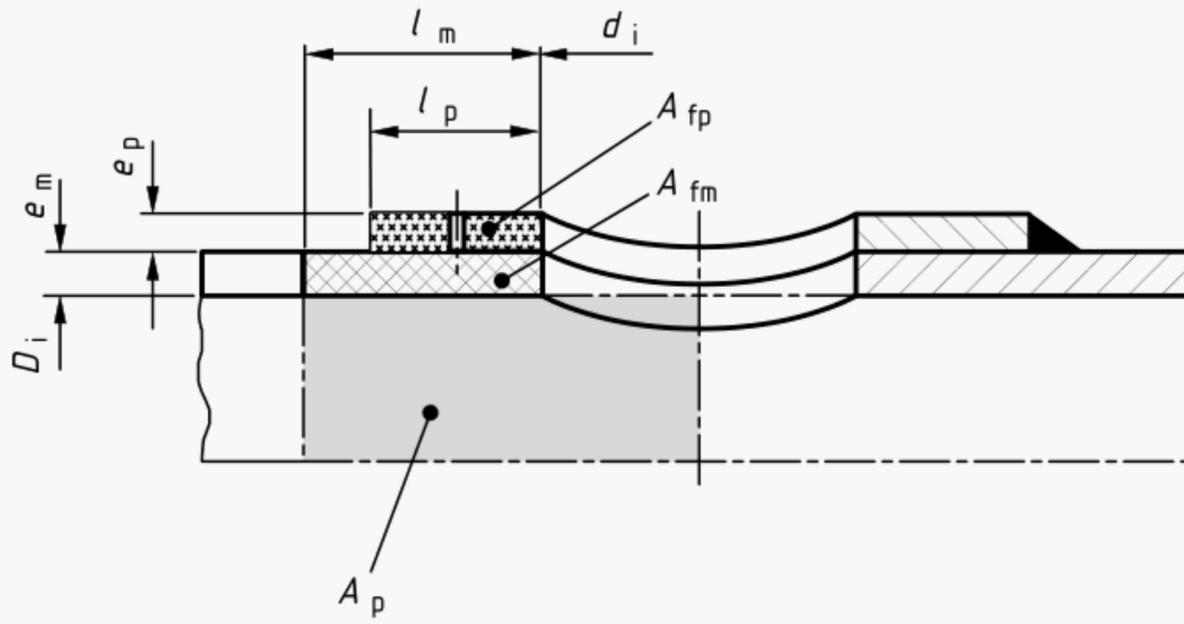
$$A_p = \frac{r_{im}}{2} \left(l_m + \frac{d_o}{2} \right)$$

$$A_{fm} = e_m l_m$$

$$A_{fp} = e_p l_p$$

a) Reinforcement by pads

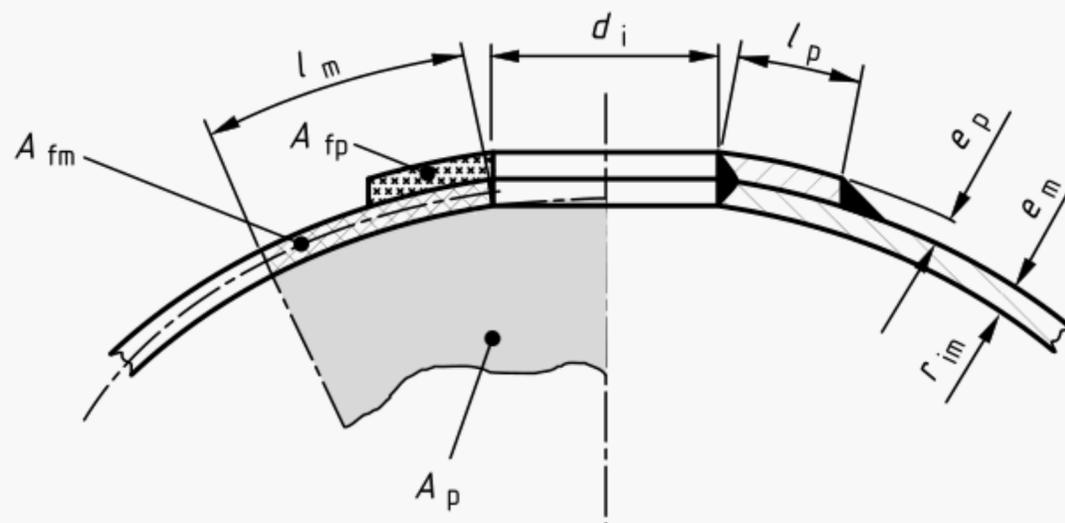
Figure E.3 — Design of openings – Cylindrical shells with isolated openings



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

$$A_{fm} = e_m l_m$$

$$A_{fp} = e_p l_p$$



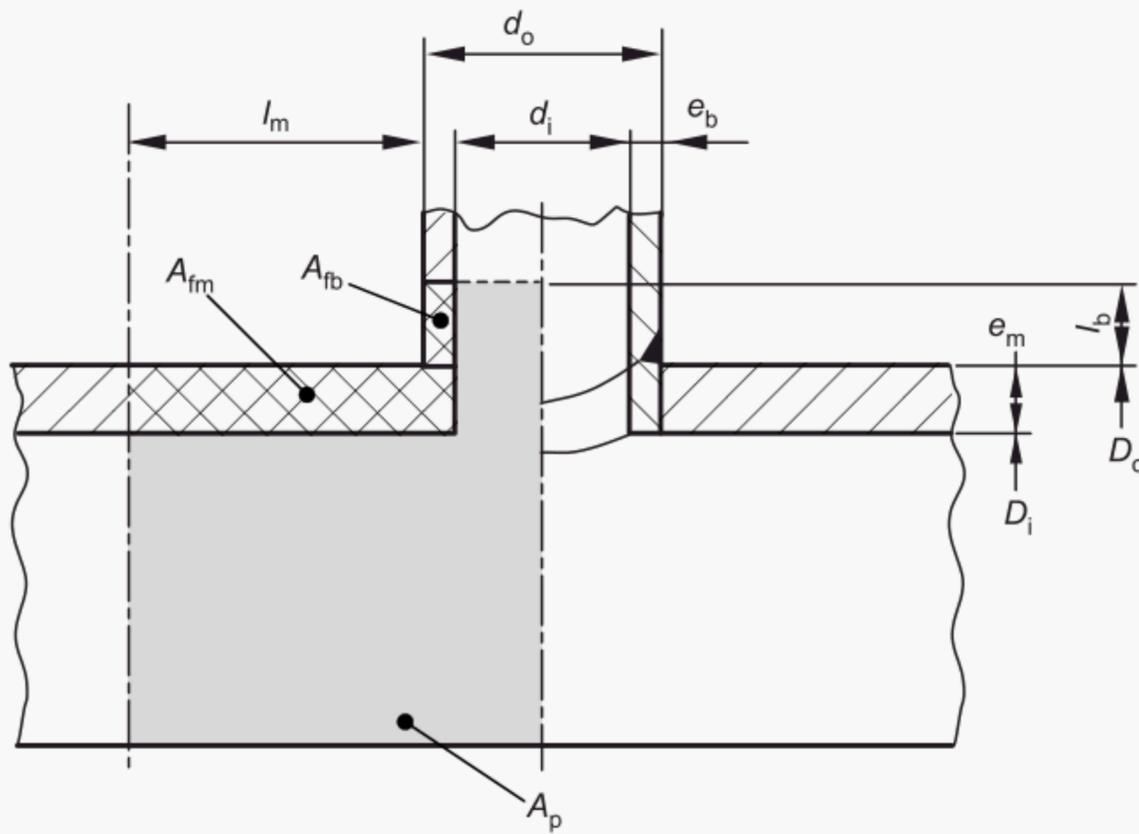
$$A_p = \frac{r_{im}}{2} \left(l_m + \frac{d_i}{2} \right)$$

$$A_{fm} = e_m l_m$$

$$A_{fp} = e_p l_p$$

b) Reinforcement by compensating plates

Figure E.3 — Design of openings – Cylindrical shells with isolated openings (continued)



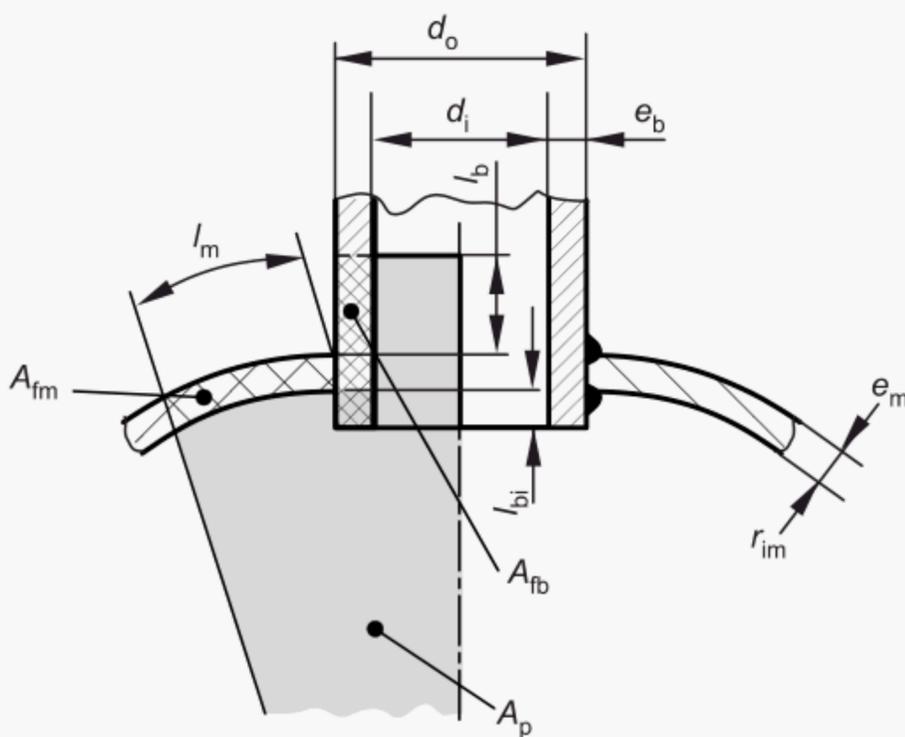
$$A_p = \frac{D_i}{2} \left(l_m + \frac{d_o}{2} \right) + \frac{d_i}{2} (l_b + e_m)$$

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

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

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

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



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

$$A_{fm} = e_m l_m$$

$$A_{fb} = e_b (l_b + e_m + l_{bi})$$

c) Reinforcement by branches

Figure E.3 — Design of openings – Cylindrical shells with isolated openings (concluded)

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 require to be increased to ensure that the cut out is clear of the weld [see Figure F.1 a)].

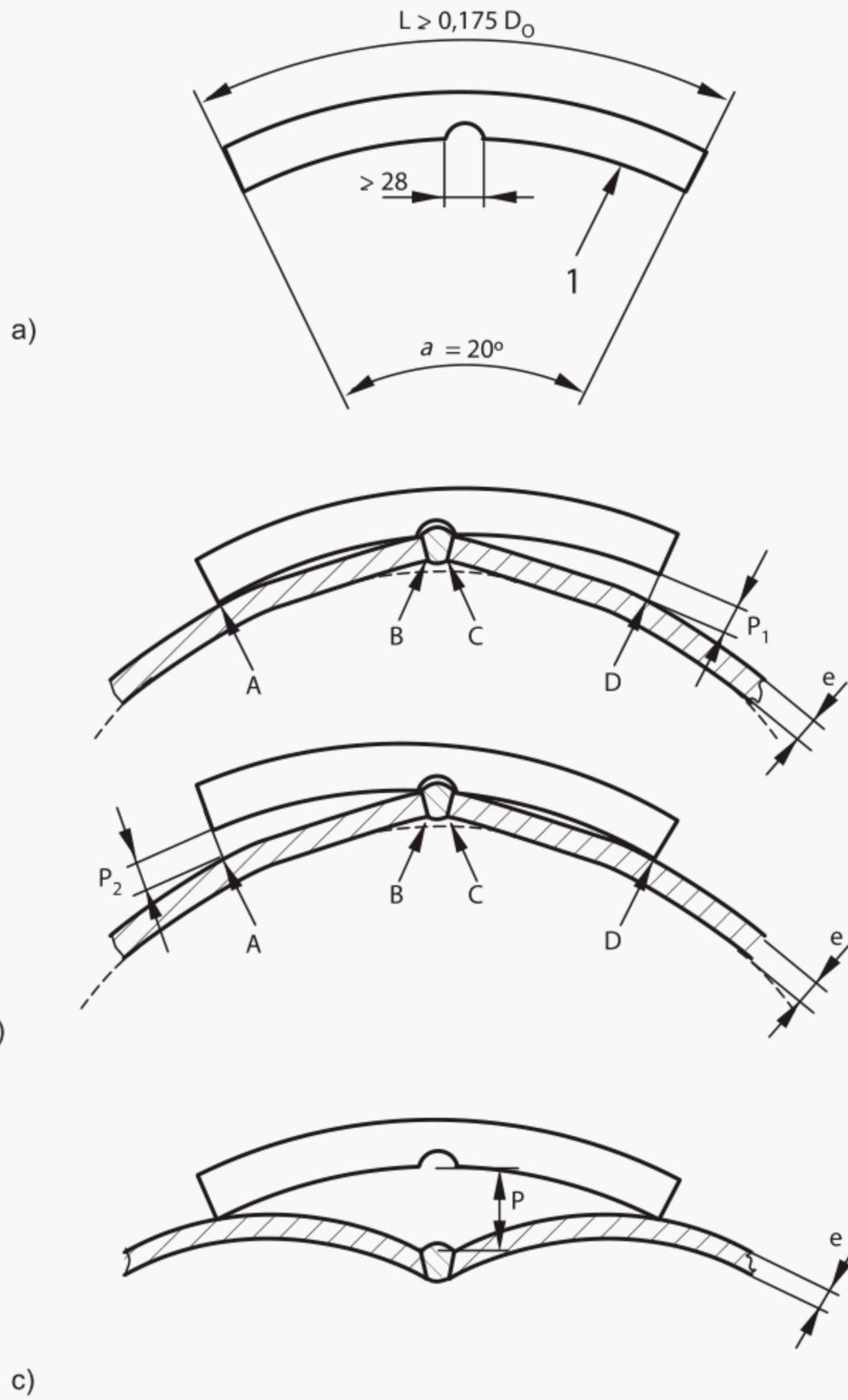
F.2 Peaking survey

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

Dimensions in mm

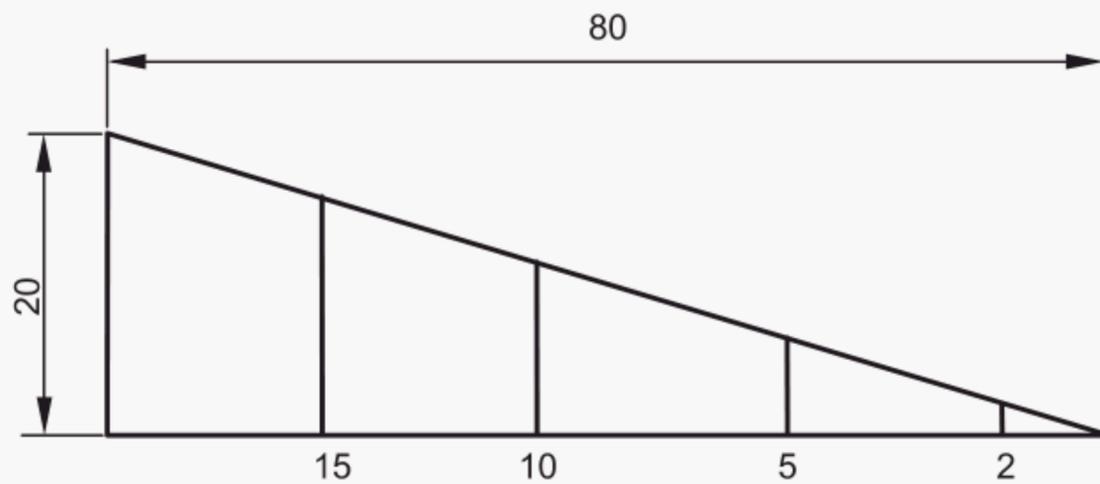


Figure F.2 — Taper gauge

Annex G (informative)

Examples of welded joints

Examples of weld joints are shown in Figure G.1 to Figure G.5 .

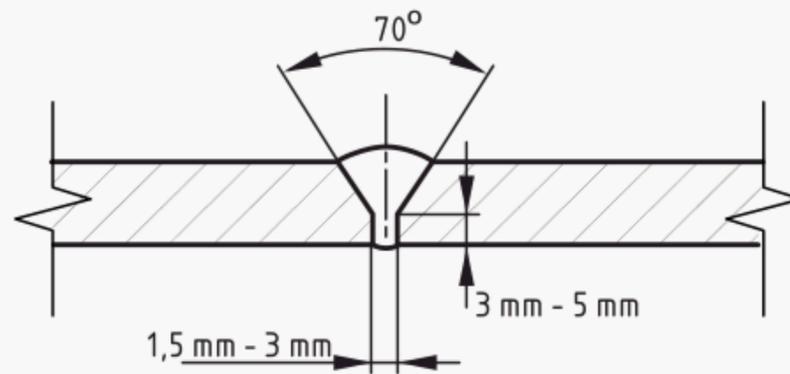
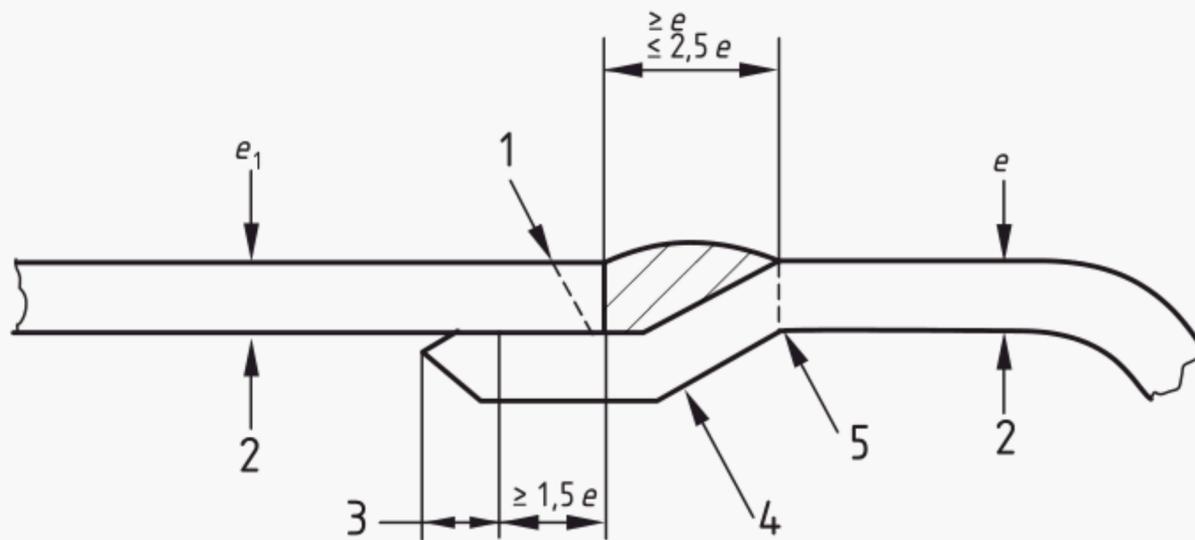


Figure G.1 — V-butt weld



Key

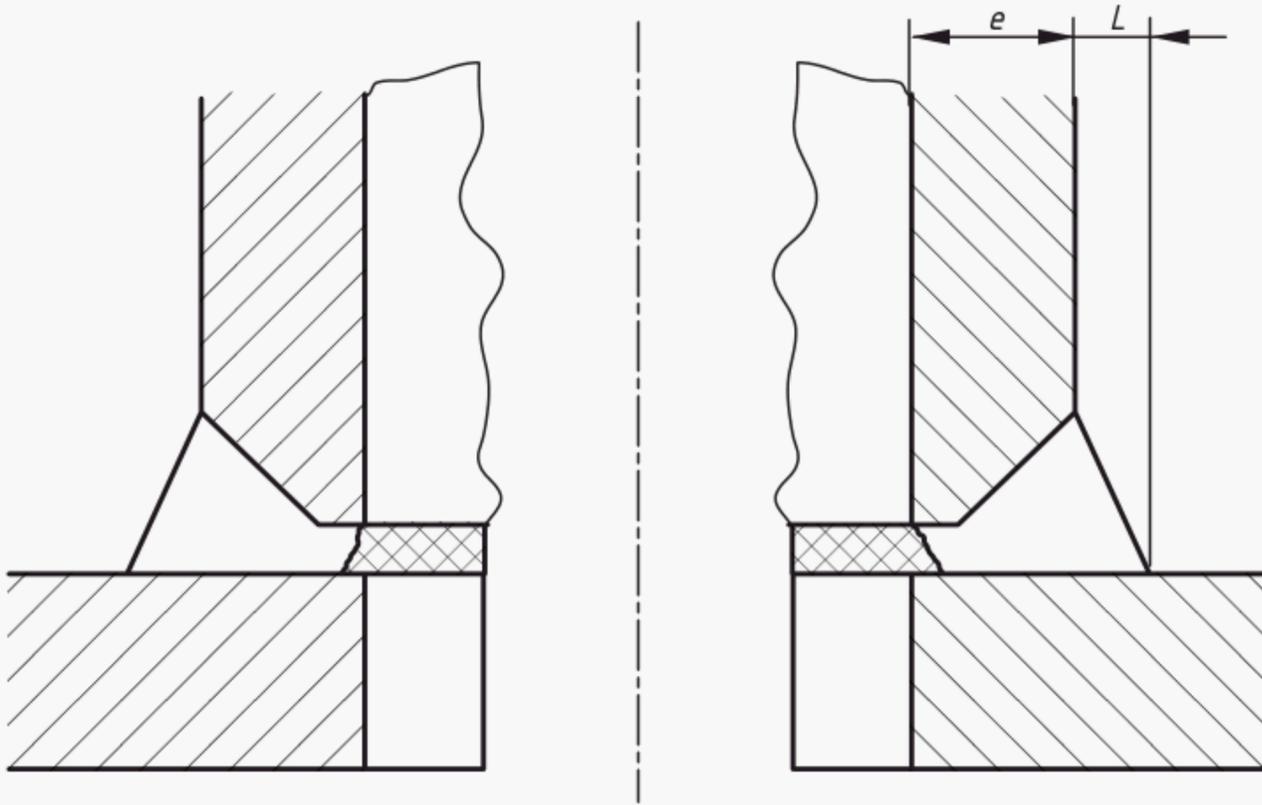
- 1 Bevel optional
- 2 Inside diameter
- 3 As desired
- 4 Depth of offset = e_1
- 5 Avoid sharp break

Figure G.2 — Joggle joint

NOTE The dimension limits (i.e. $\geq e, \leq 2,5e$) 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 6.4.3

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.

**Key**

$L = e/3$ minimum but not less than 6 mm.

Figure G.3 — Nozzle joints: set-on

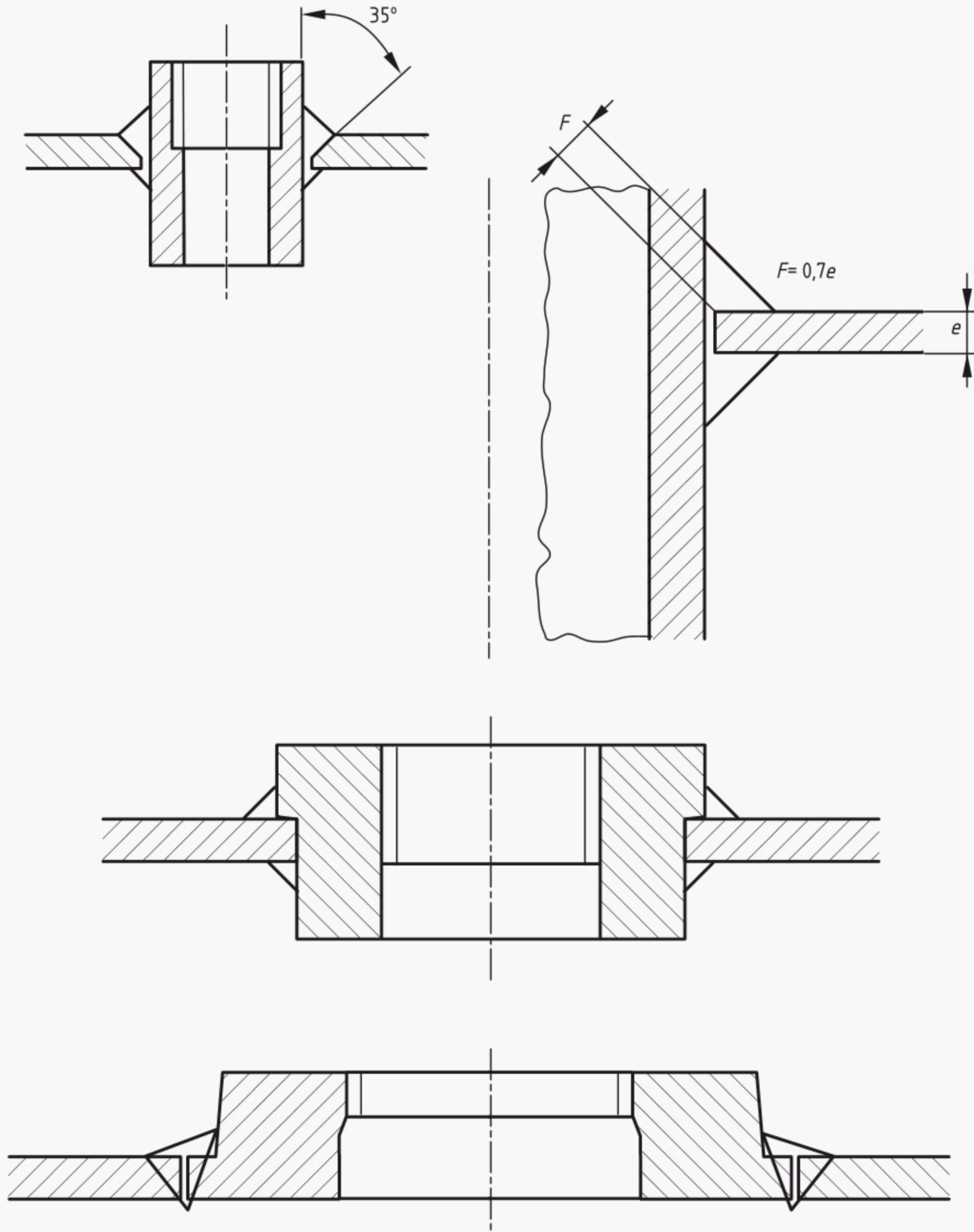


Figure G.4 — Nozzle joints: set-in

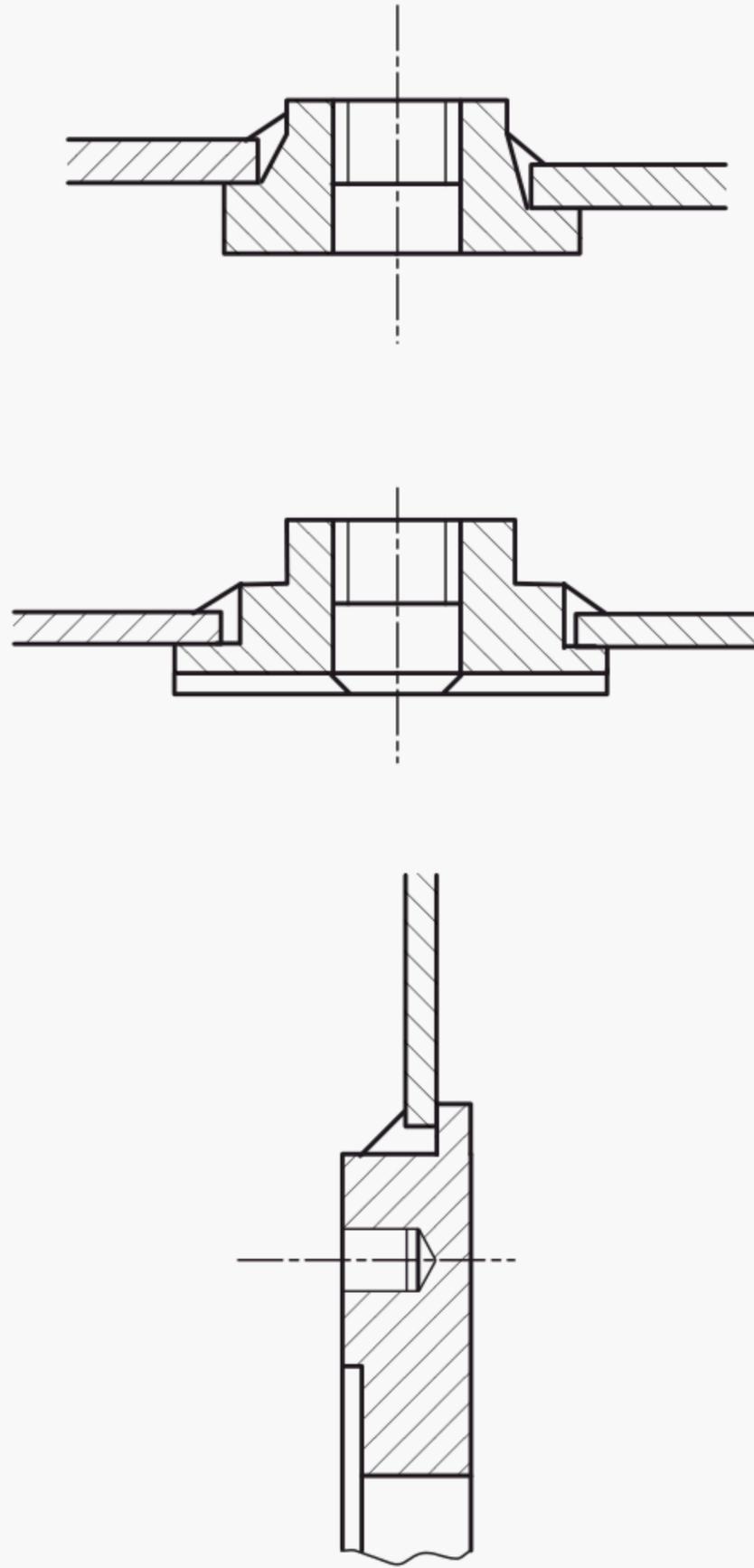


Figure G.5 — Nozzle joints: integral backing

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- [2] EN 10002-1, *Metallic materials - Tensile testing - Part 1: Method of test at ambient temperature*
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- [4] EN 13445-2, *Unfired pressure vessels - Part 2: Materials*
- [5] EN 13445-3, *Unfired pressure vessels - Part 3: Design*
- [6] CEN ISO/TR 15608:2005, *Welding — Guidelines for a metallic materials grouping system (ISO/TR 15608:2005)*

