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BSI Standards Publication

Tanks for the transport of dangerous goods — Metallic tanks with a working pressure not exceeding 0,5 bar — Design and construction

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National foreword

This British Standard is the UK implementation of EN 13094:2015. It supersedes BS EN 13094:2008 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee AUE/18, Tanks for the transport of dangerous goods.

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

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Tanks for the transport of dangerous goods - Metallic tanks with a working pressure not exceeding 0,5 bar - Design and construction

Citernes destinées au transport de matières dangereuses - Citernes métalliques ayant une pression de service inférieure ou égale à 0,5 bar - Conception et construction

Tanks für die Beförderung gefährlicher Güter - Metalltanks mit einem Betriebsdruck von höchstens 0,5 bar - Auslegung und Bau

This European Standard was approved by CEN on 17 January 2015.

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Contents

Page

Foreword

This document (EN 13094:2015) has been prepared by Technical Committee CEN/TC 296 “Tanks for transport of dangerous goods”, the secretariat of which is held by AFNOR.

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of an identical text or by endorsement, at the latest by November 2015 and conflicting national standards shall be withdrawn at the latest by November 2015.

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 13094:2008.

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 and/or in the technical annexes of the ADR.

Compared with EN 13094:2008, the following changes are the principal modifications which have been made:

a) a new form of protection was added to 6.9.2.2;

b) subclause 6.10 was revised;

c) for the protection of service equipment mounted on top of the tank, the addition of an alternative steel and, where longitudinal and transverse members are used, additional requirements for drainage were added;

d) references were updated, in particular related to welding and NDT standards;

e) literal mistakes were corrected.

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.

1 Scope

This European Standard specifies requirements for the design and construction of metallic tanks with a maximum working pressure not exceeding 50 kPa gauge used for the transport of dangerous goods by road and rail for which Tank Code with letter “G” is given in Chapter 3.2 of ADR [2]. It also includes requirements for a system of identification of materials used in the construction of these tanks.

This European Standard specifies requirements for openings, closures and structural equipment.

NOTE 1 This document does not specify requirements for service equipment.

This European Standard is applicable to aircraft refuellers that are used on public roads. It is also applicable to inter-modal tanks (e.g. tank containers and tank swap bodies) for the transport of dangerous goods by road and rail.

NOTE 2 This document is not applicable to fixed rail tank wagons.

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 10204, *Metallic products — Types of inspection documents*

EN 12972:2007, *Tanks for transport of dangerous goods — Testing, inspection and marking of metallic tanks*

EN 13317, *Tanks for transport of dangerous goods — Service equipment for tanks — Manhole cover assembly*

EN 14025, *Tanks for the transport of dangerous goods — Metallic pressure tanks — Design and construction*

EN 14595, *Tanks for transport of dangerous goods — Service equipment for tanks — Pressure and Vacuum Breather Vent*

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

EN ISO 3834-1, *Quality requirements for fusion welding of metallic materials — Part 1: Criteria for the selection of the appropriate level of quality requirements (ISO 3834-1)*

EN ISO 3834-2, *Quality requirements for fusion welding of metallic materials — Part 2: Comprehensive quality requirements (ISO 3834-2)*

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

EN ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature (ISO 6892-1)*

EN ISO 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system (ISO 7500-1)*

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

EN ISO 9606-2, *Qualification test of welders — Fusion welding — Part 2: Aluminium and aluminium alloys (ISO 9606-2)*

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

EN ISO 10042, *Welding — Arc-welded joints in aluminium and its alloys — Quality levels for imperfections (ISO 10042)*

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 15607, *Specification and qualification of welding procedures for metallic materials — General rules (ISO 15607)*

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 15609-2, *Specification and qualification of welding procedures for metallic materials — Welding procedure specification — Part 2: Gas welding (ISO 15609-2)*

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

EN ISO 15614 (all parts), *Specification and qualification of welding procedures for metallic materials — Welding procedure test (ISO 15614, all parts)*

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

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

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

ISO 1496-3, *Series 1 freight containers — Specification and testing — Part 3: Tank containers for liquids, gases and pressurized dry bulk*

3 Terms, definitions and symbols

3.1 Terms and definitions

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

3.1.1
baffle
structure, other than a surge plate, intended to inhibit the movement of the shell contents

3.1.2
capacity
total inner volume of shell or shell compartment

Note 1 to entry: When it is impossible to fill completely the shell or shell compartment because of its shape or construction, this reduced capacity should be used for the determination of the degree of filling and for the marking of the tank.

3.1.3
competent authority
authority or authorities or any other body or bodies designated as such in each country and in each specific case in accordance with domestic law

Note 1 to entry: Attention is drawn to ADR [2] and to the OTIF regulations (commonly referred to as RID) [3] in respect of Competent Authorities.

3.1.4
maximum working pressure
highest of the four pressures P_d, P_r, P_v and P_{ts}

3.1.5
partition
hermetically sealed dividing wall between adjacent compartments in compartmented tanks

3.1.6
section modulus
second moment of area of a structure (and, where appropriate, its associated shell) about its neutral axis divided by the maximum distance from the neutral axis to the extreme fibre of the section used in the calculation

3.1.7
shell
sheathing containing the substance carried (including the openings and their closures)

3.1.8
specific resilience
integral of the applied force and the measured deflection of a test piece up to the point at which the test bar punctures the test piece, as indicated by the point of maximum force

3.1.9
global resilience
ability of a shell with multiple divisions or surge plates to withstand a sideways impact with a beam

3.1.10
mild steel
steel with a guaranteed minimum tensile strength of 360 N/mm^2 to 490 N/mm^2 and a guaranteed minimum elongation at fracture conforming to the requirement for steel specified in 5.2.2.3.1

3.1.11
reference steel
steel with a tensile strength of 370 N/mm^2 and an elongation after fracture of 27 %

3.1.12
surge plate
non-hermetically sealed wall in tanks or compartments of shells intended to reduce the effect of surge, mounted at right angles to the direction of travel, having an area of at least 70 % of the cross-sectional area of the shells where the surge plate is located

3.1.13
test pressure
highest effective pressure which arises in the tank during the pressure test

3.1.14
maximum design mass
sum of the tare of the tank and the maximum permissible load for which the tank is designed

3.2 Symbols

For the purposes of this document, the following symbols apply.

A percentage (%) elongation after fracture

A_1 minimum percentage (%) elongation after fracture of the metal used (see 6.9.1)

B pitch circle diameter or, if elliptical, average of major and minor diameters, in millimetres (mm)

c distance from the start of a knuckle bend to the edge of a shell, in millimetres (mm)

NOTE 1 This is used for the attachment of a dished end to a shell.

e shell thickness, in millimetres (mm)

e_c thickness of a flat closure, in millimetres (mm)

e_d thickness of a domed closure, in millimetres (mm)

e_f thickness of a tank end or partition, in millimetres (mm)

e_{rs} thickness of a reinforcing section, in millimetres (mm)

e_r thickness of an opening flange, in millimetres (mm)

e_{rd} thickness of a domed closure flange, in millimetres (mm)

e_v adopted thickness of a shell, in millimetres (mm)

$e_{v, min}$ minimum thickness of a shell according to 6.9.1, in millimetres (mm)

e_0 minimum thickness of shell in reference steel, in millimetres (mm)

e_1 thickness of the thickest part of a shell, in millimetres (mm)

e_2 thickness of the thinner part of the metal used, in millimetres (mm)

g acceleration due to gravity, in metres per second squared (m/s^2)

NOTE 2 The value of g is 9,81 m/s^2.

L overlap of a lapped joint, in millimetres (mm)

L_c length of reinforcing piece, in millimetres (mm)

L_r length of reinforcing ring, in millimetres (mm)

L_0 initial gauge length of the test piece used in the tensile test, in millimetres (mm)

l length of transition between plates of different thickness, in millimetres (mm)

l_1 length of overlap of swaged edge, in millimetres (mm)

l_2 length of weld at base of swaged joint, in millimetres (mm)

N	safety factor
P_d	highest effective pressure allowed in a shell during discharge (“maximum discharge pressure allowed”), in MegaPascals (MPa)
P_r	highest effective pressure allowed in a shell during filling (“maximum filling pressure allowed”), in MegaPascals (MPa)
P_{ts}	opening pressure of the breather device, in MegaPascals (MPa)
P_v	effective pressure to which a shell is subjected by the substance carried (including such extraneous gases as it might contain) at the design temperature, in MegaPascals (MPa)
P_x	design pressure of tank, in MegaPascals (MPa)
R	internal radius of a domed closure, in millimetres (mm)
R_d	determined tensile strength, in Newtons per square millimetre (N/mm^2)
R_e	apparent yield strength for steels having a clearly defined yield point or guaranteed 0,2 % proof strength for steels with no clearly defined yield point (1 % proof strength for austenitic steels) Newtons per square millimetre (N/mm^2)
R_{et}	apparent yield strength for steels having a clearly defined yield point or guaranteed 0,2 % proof strength for steels with no clearly defined yield point (1 % proof strength for austenitic steels) at minimum design temperature Newtons per square millimetre (N/mm^2)
R_m	tensile strength, in Newtons per square millimetre (N/mm^2)
R_{mt}	tensile strength at minimum design temperature, in Newtons per square millimetre (N/mm^2)
R_{m1}	minimum tensile strength of the metal used, in Newtons per square millimetre (N/mm^2)
S_B	total tensile area, in square millimetres (mm^2)
S_0	initial cross-sectional area of a test piece used in the tensile test, in square millimetres (mm^2)
w	effective depth of fillet weld (i.e. distance from the surface of the weld to the minimum penetration point of the molten metal into the base material)
Z_0	minimum section modulus in reference steel, in cubic centimetres (cm^3)
Z_1	minimum section modulus in the metal used, in cubic centimetres (cm^3)
σ_c	design stress for cover material, according to 6.8, in Newtons per square millimetre (N/mm^2)
σ_r	design stress for flange material, according to 6.8, in Newtons per square millimetre (N/mm^2)

4 Breather device and safety device

Tanks shall be equipped with a breather device fitted with a safety device to prevent the contents from spilling out if the tank overturns in accordance with EN 14595. For compartmented tanks, each compartment shall be equipped so.

5 Materials

5.1 General

5.1.1 The designer shall select the materials to be used in the construction of the tank using ferritic steel, austenitic steel, austenitic-ferritic stainless steel or aluminium alloy material standards published by a national or international standards body or otherwise approved by the competent authority. The material shall in any case meet the requirements specified in 5.2.

5.1.2 Materials used in the construction of shells shall be suitable for shaping. Materials shall be deemed unsuitable if, even though they meet the material requirements of this European Standard, the degree of shaping required by a particular shell design generates cracking or other signs of distress in the shell material.

5.1.3 Materials shall be used that are known to be resistant to brittle fracture and to stress corrosion cracking.

5.1.4 When tested in accordance with the appropriate clauses of EN ISO 15614-1, the properties of materials used in the fabrication of welded shells shall not be less than the minimum values specified for the material selected in accordance with 5.1.1 throughout the welded area after welding without post-weld heat treatment.

5.2 Material properties

5.2.1 Impact strength

Ferritic steel materials shall be tested in accordance with EN ISO 148-1 using a V-shaped notch, and shall have an impact strength of not less than 34 J/cm^2 at –20 °C (or at the minimum design temperature where this is lower). Impact tests shall be carried out on sheets of materials, or on their weld seams, where the sheet thickness is more than 5 mm.

5.2.2 Yield strength, tensile strength and elongation after fracture

5.2.2.1 General

5.2.2.1.1 The values of A, R_e and R_m to be used shall be the minimum values specified for the material selected in accordance with the relevant standard for the material with the exception of 5.2.2.1.2 and 5.2.2.1.3.

5.2.2.1.2 When austenitic steels are used, the value of R_e used in the calculation may exceed the minimum value in accordance with the relevant standard for the material specified for the material selected provided that:

— the higher values are attested in a certificate 3.1 issued in accordance with EN 10204;

— the value of R_e used in the calculation does not exceed 1,15 multiplied by the value of R_e as specified for the material selected in accordance with the relevant standard for the material.

5.2.2.1.3 When fine-grained steels are used, the value of R_e shall not exceed 460 N/mm^2 and the value of R_m shall not exceed 725 N/mm^2 in accordance with the specifications of the relevant standard for the material.

5.2.2.2 Yield strength and tensile strength

Steels with a ratio of R_e/R_m exceeding 0,85 shall not be used in the construction of welded tanks. The values specified in certificate 3.1 issued in accordance with EN 10204 shall be used to determine the R_e/R_m ratio.

5.2.2.3 Elongation after fracture

5.2.2.3.1 The material shall be tested in accordance with EN ISO 6892-1. The percentage elongation after fracture, A, shall be not less than:

— 16 % for fine grained steels;

— 20 % for other steels;

— 12 % for aluminium alloys.

5.2.2.3.2 Additionally, for steel, the percentage elongation after fracture, A, shall be not less than the value calculated using Formula (1):

$$A = \frac{10\,000 \text{ N/mm}^2}{R_\text{d}} \quad (1)$$

NOTE For A, R_d and R_m1 only the numerical value with the unit according to 3.2 is given.

5.2.2.3.3 For sheet metal, when measuring the percentage elongation after fracture in accordance with EN ISO 6892-1, the axis of the tensile test piece shall be at right angles to the direction of rolling; where the material standard gives lower values in the direction of rolling, these values shall be used in the calculation.

5.2.2.3.4 When measuring the percentage elongation after fracture, a test piece of circular cross-section shall be used in which the initial gauge length is equal to five times the diameter. If test pieces of rectangular section are used, the gauge length shall be calculated using Formula (2):

$$L_0 = 5{,}65\sqrt{s_0} \quad (2)$$

NOTE Elongations based on fixed lengths can be converted to proportional elongations using EN ISO 2566-1 or EN ISO 2566-2 as applicable.

5.3 Compatibility of shell materials with substances carried

5.3.1 The manufacturer shall make available a list of the dangerous goods that may be carried without damage to the tank, or its lining. The substances or group of substances approved in the certificate shall be compatible with the characteristics of the tank and its service equipment.

NOTE RID/ADR (4.3.4.1.2) states that the listing of approved substances may be replaced by groups of substances according to the tank code taking into account any relevant special provision.

5.3.2 If contact between the substance carried and the material used for the construction of the shell is deemed likely to entail a progressive decrease in the thickness of the walls, this thickness shall be increased at manufacture by an appropriate amount.

NOTE This additional thickness, to allow for corrosion, is not taken into consideration in determining the minimum shell thickness (see 6.9.1).

5.3.3 If the shell is fitted with a non-metallic protective lining, only materials and their means of bonding to the shell that are known to remain leakproof, whatever the deformation liable to occur in normal conditions of carriage, shall be used.

5.3.4 If shells intended for the carriage of liquids having a flash-point of not more than 60 °C are fitted with non-conductive protective linings, precautions shall be taken to prevent the accumulation of electrostatic charges that could present a danger of ignition.

NOTE This requirement is also applicable to UN No. 1361 carbon and UN No. 1361 carbon black, packing group II.

6 Design

6.1 General

A shell may have a circular, elliptical or box-shaped cross-section or combinations thereof.

Shell projections outside the basic cross-section of a shell shall be kept to a minimum and protection shall be provided from all directions on the shell.

6.2 Design verification

The design of a tank shall be verified in accordance with one or a combination of the following methods:

a) for shells with a circular cross-section, EN 14025 or any one of the methods specified in Annex A;

b) for shells with non-circular cross-sections:

   1) dynamic testing (A.2);

   2) finite element stress analysis (A.3);

   3) reference design based on experience of the Competent Authority with existing tank designs (A.4);

   4) calculation method (A.5).

Documentation shall be produced that gives evidence of the design verification.

The design shall in any case conform to the minimum requirements of this European Standard.

6.3 Requirements for shells of non-circular cross-section

For shells of non-circular cross-section:

a) the radius of convexity of the shell wall shall not exceed 2 m at the sides and 3 m radius at the top and the bottom;

b) there shall be a minimum radius of 200 mm linking the top/bottom and side convexities; and

c) an equivalent diameter shall be calculated on the basis of the cross-sectional area.

6.4 Dynamic conditions

6.4.1 The dynamic conditions appropriate to the design temperature specified in 6.7, and requirements of the pressure test in EN 12972, shall be met without exceeding the stress levels specified in 6.8.

6.4.2 Shells, their attachments and their structural equipment shall be designed to withstand the forces and dynamic pressures resulting from the combination of the highest value of P_v or P_{ts} with, separately, each of the following, without exceeding the design stress in 6.8:

— in the direction of travel, an acceleration of 2 g on the maximum design mass (in the case of self-supporting trailers the maximum design mass shall include the mass of axles, wheels and tyres and shall be deemed to act at the coupling point); if any account is taken of surge plates in calculations, their effect shall be proven;

— at right angles to the direction of travel, an acceleration of 1 *g* acting on the maximum design mass;

— vertically upwards, an acceleration of 1 *g* acting on the maximum design mass;

— vertically downwards, an acceleration of 2 *g* acting on the maximum design mass;

— where the shell constitutes a stressed self-supporting member of a vehicle, the stresses thus imposed in addition to stresses from other sources.

6.4.3 With the following exceptions, a tank which has a maximum length of less than 2,9 m shall be designed to withstand the forces specified in 6.4.2, except that in all horizontal directions the forces shall be twice the maximum design mass:

— a tank permanently mounted on a vehicle chassis;

— a demountable tank on a road vehicle which can be fitted to the chassis only in one orientation.

6.5 Pressure conditions

6.5.1 The tank shell shall be designed to withstand a maximum test pressure which shall be the greater of:

a) the pressure created by a column of water equal to twice the depth of the tank multiplied by the relative density of the most dense substance to be carried;

b) the pressure created by a column of water equal to twice the depth of the tank;

c) 1,3 times the maximum working pressure.

6.5.2 Except for tanks for inter-modal tanks, compartments of compartmented tanks shall be designed to withstand a test pressure which subjects all parts of a compartment to a pressure at least equal to 1,3 × (P_{ta} + P_{ts}).

The test pressure shall be applied to the highest point of the compartment, and no account shall be taken of the pressure arising from the static head of the test liquid.

6.6 Partial vacuum conditions

The shell and partitions shall be capable of withstanding a vacuum condition of 3 kPa below atmospheric pressure.

6.7 Design temperature

The minimum design temperature range shall be –20 °C to +50 °C. Where the tank is likely to be subjected to more severe conditions, the design temperature range shall be extended within the range –40 °C to +50 °C, as applicable. The design temperature range of tanks intended for substances to be carried at elevated temperatures shall be extended at least to the maximum working temperature.

6.8 Design stress

The maximum stress in the material of the tank and its supporting structure shall not exceed the lower of 0,75 R_e or 0,5 R_m; for tank containers and tank swap bodies, the stress in the material of the supporting structure shall not exceed 0,66 R_e.

6.9 Shell thickness

6.9.1 Minimum shell thickness

The thickness of shells made of mild steel (with a guaranteed minimum tensile strength of 360 N/mm^2 to 490 N/mm^2) shall be not less than the following values, unless the conditions specified in 6.9.2 are met:

— 5 mm if the tank diameter is not more than 1,8 m;

— 6 mm if the tank diameter is greater than 1,8 m (except in the case of shells intended for the carriage of powdery or granulated substances).

If the shell is made of another material, the equivalent minimum thickness shall be determined in accordance with Formula (3):

$$e_1 = \frac{464 e_0}{\sqrt[3]{\left(R_{m1} A_1\right)^2}} \quad (3)$$

If the shell thickness is increased to allow for corrosive substances, this additional thickness shall not be taken into consideration in calculating the minimum shell thickness.

The actual minimum thickness shall not be below the absolute minimum shown in Table 1.

6.9.2 Reduction of shell thickness

6.9.2.1 Where protection against damage of the shell is provided in accordance with 6.9.2.2 to 6.9.2.3, the minimum thickness may be reduced by a maximum of 2 mm of reference steel (or equivalent thickness in another material, calculated using Formula (3)) from that specified in 6.9.1, but shall not be below the absolute minimum shown in Table 1.

Table 1 — Absolute minimum shell thickness

Diameter [a]	Minimum shell thickness				
	Austenitic steels	Austenitic ferritic steels	Other steels	Pure aluminium of 99,8 %	Aluminium alloys
m	mm	mm	mm	mm	mm
≤ 1,80	2,5[b]	**3**	3	6	4
> 1,80	3	**3,5**	4	8	5

[a] For non-circular cross-sections, see 6.3.

[b] For tank-containers and tank swap bodies not protected against damage, the shell thickness shall in no case be less than 3 mm whatever the material used.

6.9.2.2 Tank vehicles and demountable tanks shall be deemed to be protected against damage when one of the following measures given in a) to j) is adopted; dimensions that refer to distances between strengthening elements shall be taken between their attachment points on the tank shell:

a) For shells with a circular and/or elliptical cross-section including combinations of those cross sections having a maximum radius of curvature of 2 m, the shell is equipped with strengthening elements comprising partitions or surge plates, or external or internal rings, so placed that at least one of the following conditions is met:

1) the distance between two adjacent strengthening elements is less than or equal to 1,75 m;

2) the volume contained between two partitions or surge plates is less than or equal to 7 500 l.

A ring, and associated shell shall have a section modulus of at least 10 cm^3 in reference steel, or an equivalent section modulus in another metal (see 6.14.2.5), when calculated around the neutral axis parallel to the shell.

External strengthening elements shall not have projecting edges with a radius of less than 2,5 mm.

b) For shells with double walls having an intermediate layer of rigid solid material (e.g. foam, at least 50 mm thick), the outer wall has a thickness of at least 0,5 mm of mild steel, 0,8 mm of aluminium or 2 mm of fibre reinforced plastic material. For other insulating materials (e.g. mineral-wool, at least 100 mm thick), the outer wall has a thickness of at least 0,8 mm of austenitic steel, the outer wall of the ends may be of a fibre reinforced plastic material with a thickness of at least 3 mm.

Other combinations of materials used to provide protection against damage shall have specific resilience, as determined in accordance with Annex B, equivalent to that of the minimum thickness required by 6.9.1, and the thickness of the inner wall of the combination shall be not less than the minimum value specified in 6.9.2.1.

c) For shells of forms other than in a), the shell is provided all around the mid-point of its vertical height and over at least 30 % of its height with additional protection designed in such a way as to offer specific resilience, as determined in accordance with Annex B, at least equal to that of a shell constructed in reference steel of a thickness of 5 mm for a shell diameter not exceeding 1,80 m or 6 mm for a shell diameter exceeding 1,80 m.

The additional protection shall be applied in a durable manner to the shell.

This requirement shall be deemed to have been met without further proof of the specific resilience when:

1) the additional protection involves welding a plate of the same material as the shell, to the outside of the shell over the area to be strengthened, such that the shell thickness is not less than the minimum specified in 6.9.1 or this area consists of the same material as the shell with a thickness not less than the minimum shell thickness specified in 6.9.1; and

2) flanged ends to the full thickness are used with the additional side protection extending to cover at least one third of the flange length.

d) For shells made with single ends having the full thickness specified in 6.9.1, the shell has strengthening elements meeting both of the following requirements:

1) the capacity contained between two partitions is less than or equal to 7 500 l;

2) the volume between a partition and a surge plate is less than or equal to 4 000 l.

e) For shells made with double ends, the shell has strengthening elements meeting both of the following requirements:

1) the capacity contained between two partitions is less than or equal to 7 500 l;

2) the volume between a partition and a surge plate is less than or equal to 4 000 l.

The inner end shall have a thickness at least equal to the minimum specified in 6.9.2.1 and the outer end a thickness of at least 2 mm in reference steel or an equivalent thickness in another metal, calculated using Formula (3).

f) For shells made with double ends with a separation exceeding 100 mm, the ends of which conform to the requirements specified in e), the shell has partitions arranged such that the capacity contained between partitions is less than or equal to 7 500 l.

g) For shells of forms other than in a), the following conditions are all met:

1) the volume contained between adjacent strengthening elements does not exceed 7 500 l;

2) the volume of any compartment does not exceed 15 000 l except in the case of tanks dedicated to the carriage of liquids at or above 100 °C and below their flashpoint;

3) the distance between adjacent strengthening elements does not exceed 1,4 m;

4) the corner radii connecting the top, side and bottom radii are not less than 300 mm;

5) the thicknesses of ends conform to d) or e) as appropriate.

h) For demountable tanks, protection is provided on all sides by the drop sides or the cab of the carrying vehicle. The drop sides shall offer protection to at least half the height of the shell.

i) For shells of forms other than in a), when applying requirements of global resilience, the following conditions are all met:

1) the volume contained between adjacent strengthening elements does not exceed 7 500 l;

2) the volume of any compartment does not exceed 15 000 l except in the case of tanks dedicated to the carriage of liquids at or above 100 °C and below their flashpoint;

3) the distance between adjacent strengthening elements does not exceed 1,75 m;

4) the average distance between adjacent strengthening elements does not exceed 1,4 m;

5) the corner radii connecting the side, top and bottom radii are not less than 250 mm;

6) the thickness of the ends conform to d) or e) as appropriate;

7) for shells made with double ends with a separation exceeding 100 mm, the ends shall conform to the requirements specified in e);

8) the weakest 4 m-shell segment has a global resilience of at least 100 kNm.

The following values for global resiliencies shall be used:

i) for partitions or surge plates with a maximum thickness specified in 6.9.1: 40 kNm;

ii) for partitions or surge plates with a minimum thickness specified in 6.9.2.1: 20 kNm;

iii) for ends: 20 kNm.

Higher values of global resiliencies and global resiliencies for other types of reinforcement members shall only be used if confirmed by tests carried out in accordance with B.5 or an equivalent approved by the Competent Authority.

If the finite element analysis is used for the verification, A.3 shall be taken into account. In addition, the computer software and the procedure for its use shall be validated by the Competent Authority for elasto-plastic analysis.

j) The manufacturer shall provide to the Competent Authority the relevant validation examples (comparisons between calculation results and real test results).For shells of forms other than in a), the following conditions are all met:

1) the radius of convexity of the shell wall does not exceed 2 m at the sides, top and bottom;

2) the corner radii connecting the top, side and bottom are not less than 300 mm;

3) the volume contained between partitions and/or surge plates does not exceed 7 500 l, or the distance between partitions and/or surge plates is less than or equal to 1,75 m;

4) the energy absorbed during an impact and overturning is at least equal to that of a shell with a circular or elliptical cross-section with the same parameters as follows:

i) material of the shell, ends, partitions, surge plates and supporting structures;

ii) cross-sectional area (in case of an elliptical section, the same width);

iii) thickness of the shell, ends, partitions and surge plates (minimum as per 6.9.2.1);

iv) volume contained between partitions and/or surge plates, or the distance between adjacent partitions and/or surge plates;

v) maximum crown inside radius of the ends;

vi) distance, type and dimension of shell supporting structures;

vii) number and type of ends, partitions and/or surge plates;

viii) number, dimension and position of openings.

The comparative methods to calculate the energy absorbed shall be carried out in accordance with B.7.

6.9.2.3 Shells of fixed tanks and demountable tanks that either are of not more than 5 000 l capacity or are divided into tank compartments of not more than 5 000 l capacity shall be deemed to be protected against damage if their thickness in mild steel or their equivalent thickness calculated according to Formula (3) for other materials is not less than the values given in Table 2.

Table 2 — Minimum shell thickness for small and compartmented tanks

Capacity of shell or shell compartment	**Maximum radius of convexity top and bottom**	**Maximum radius of convexity of sides**	**Minimum thickness of reference steel**	**Other steels**	**Austenitic stainless steel**	**Austenitic-ferritic stainless steel**	**Aluminium alloys**	**Pure aluminium of 99,8 %**
m^3	m	m	mm	mm	mm	mm	mm	mm
≤ 3,5	3	2	3	3	2,5	3	4	6
> 3,5 but ≤ 5	3	2	4	4	3	3,5	5	8
≤ 5	2	2	3	3	2,5	3	4	6

Tank containers and swap bodies shall be deemed to be protected against damage when one of the following measures is adopted:

a) the shell is made with double walls in accordance with 6.9.2.2 b); or

b) there is a structure, conforming to the requirements of ISO 1496-3, in which the shell is supported by a complete skeleton including longitudinal and transverse structural members.

6.10 Shell openings, neckrings and closures

6.10.1 Inspection openings and manholes

Each tank and compartment with a capacity of 3 000 l or greater shall be provided with a manhole to allow inspection of the interior. Tanks and compartments with a capacity of less than 3 000 l shall be provided with either an inspection opening or a manhole.

The diameters of openings shall be:

— not less than 100 mm and not more than 300 mm for inspection openings;

— not less than 500 mm for circular manholes.

For non-circular manholes, no dimension shall be less than 500 mm.

NOTE It is advisable to allow access with full rescue facilities including self-contained breathing apparatus.

The minimum dimensions of manhole and inspection openings in lined vessels shall be maintained after the lining is applied.

6.10.2 Neckrings and closures

The neckring and flange of an opening shall conform to Annex C.

Cover plates, fixings and their sealing faces shall be designed to withstand an internal pressure of not less than 265 kPa.

The materials used in the formation of openings, sealing faces and cover plates shall be in accordance with Clause 5.

6.10.3 Cover plates

Closures that cover openings with an interior diameter of 200 mm or more shall be made of metallic materials in accordance with Clause 5.

6.10.4 Mountings for service equipment

The mountings of service equipment shall be arranged so as to permit protection against the risk of the equipment being wrenched off or damaged, and shall meet any strength requirements specified by the equipment manufacturer.

6.11 Shell partitions, surge plates and baffles

6.11.1 Surge plates and partitions shall be either:

a) dished, with a depth of dish of not less than 100 mm; or

b) corrugated, profiled or otherwise reinforced.

When the design verification techniques in A.3 or A.5 are used, the depth of dish (resulting from the crown radius) shall be verified.

6.11.2 Partitions and surge plates, including any backing plates, shall be continuously welded to the shell except as required by 6.11.4.

6.11.3 The thickness of partitions and surge plates shall not be less than the minimum thickness of the shell; for partitions, the material properties shall be at least the same as those of the shell itself, when having the minimum thickness.

6.11.4 Surge plates, baffles and strengthening elements extending more than 70 mm from the inner surface of the shell shall have openings at the top, bottom and sides to assist in emptying the tank in the partly or fully overturned position and to prevent vapour locks rendering level detection systems ineffective during filling. Openings at the top shall have a total cross-sectional area of at least 2 000 mm^2 entirely above a horizontal line 100 mm below the top of the shell cross-section. Openings in the bottom, together with any sumps, shall allow complete drainage to the discharge point.

6.11.5 Compartments adjacent to ends shall not be fitted with longitudinal partitions. Where longitudinal baffles or surge plates are fitted in compartments adjacent to ends, there shall be a clearance of at least 200 mm between them and the end of the tank at any point.

6.12 Attachments to the shell

6.12.1 Reinforcements for attachments to the shell shall be designed such that the stress specified in 6.8 is not exceeded.

6.12.2 The means by which attachments are fixed to the shell shall be designed to take into account the purpose of the attachment and the risk of damage to the shell when the attachment is subjected to additional forces.

6.12.3 Drainage facilities shall be provided where otherwise sealed spaces are created between the product containing skin of the shell and internal or external attachments, and reinforcements. The drainage facilities shall not be sealed.

6.12.4 Pipes passing through the shell shall be placed and designed in such a way as to minimize the risk of damage to the shell when external forces are applied to the pipe or shell. Pipes with an internal diameter exceeding 55 mm, with a length outside the shell of more than 50 mm at any place, shall be designed such that, in the event of accidental damage to the pipe outside the tank, the external section of the pipe breaks away without damaging the shell.

Open pipes passing through the shell that are not used for drainage shall extend outside the shell for a minimum length of 20 mm.

The wall thickness of pipes shall be not less than the thickness shown in Table 3, or the thickness of the shell, whichever is the lower.

Table 3 — Minimum thickness of pipes passing through the shell

Dimensions in millimetres

Internal diameter	Austenitic steel	Mild steel	Aluminium alloy
≤ 55	2,5	3,0	4,0
> 55	3,0	4,0	5,0

6.13 Shell supporting structure

6.13.1 Shell supporting structures shall be designed such that the stresses specified in 6.8 are not exceeded when they are subjected to the static and dynamic loading forces specified in 6.4.1, 6.4.2 and 6.4.3.

6.13.2 Shell supporting structures to be welded at the shell shall be provided with a backing plate or locating reinforcement as a means of conforming to 6.13.1. Materials used for backing plates or other reinforcements, welded directly to the shell, shall be known to be compatible with the material of the shell, and capable of being welded without producing defects.

6.14 Protection of service equipment mounted on the tank top

6.14.1 General requirements

6.14.1.1 Protection against damage caused by overturning shall be provided on the tank shell so that it contains entirely service equipment mounted on the top of the shell that connects with the inside of the shell.

6.14.1.2 The protecting device(s) and the mounting position(s) for the service equipment shall be designed in such a way that the service equipment mounted on the upper part of the shell is at least 25 mm within the contour of the protecting device.

6.14.1.3 Where the area surrounded by the protecting device(s) is not self-draining, a drainage system shall be provided.

6.14.1.4 The complete tank top protection shall be designed to withstand, without permanent deformation, a static load, applied vertically, equal to twice the laden mass of the tank vehicle. This requirement shall be deemed to be met when the protecting device conforms to the requirements specified in 6.14.2.

6.14.2 Minimum requirements

6.14.2.1 General

Specific forms of protection shall meet the requirements specified in the following subclauses:

a) 6.14.2.2 for longitudinal and transverse members;

b) 6.14.2.3 for shell contours;

c) 6.14.2.4 for spill-trays;

d) 6.14.2.5 for roll-over bars;

e) 6.14.2.6 for transverse box sections.

6.14.2.2 Longitudinal and transverse members

NOTE 1 A typical arrangement of service equipment protected by longitudinal and transverse members is shown in Figure 1.

Where longitudinal and transverse members are used to protect the service equipment:

a) they shall be designed to form an enclosed box-section when mounted on the tank top;

b) the width of longitudinal members, measured at the level of the tank top, shall be not less than one third of the height;

c) the height of the longitudinal members shall be not less than the highest item of service equipment plus 30 mm;

d) transverse members shall support both longitudinal members and the spacing between them shall not exceed 3 000 mm;

e) transverse members shall extend at least 50 mm in front of the first item of service equipment and at least 50 mm behind the last item of service equipment;

f) the height of the transverse members shall not be less than the highest item of service equipment plus 15 mm;

g) the vertical distance between transverse members and the shell at the tank centre line shall be not less than 10 mm;

h) the cross-section of the transverse members shall have a minimum section modulus about the horizontal axis of at least 10 cm^3 in reference steel or equivalent in another metal. The section modulus shall be maintained where cutaways are provided for separate vapour collection or other pipes;

i) transverse members shall have at least one drain opening at the lowest point;

j) the wall thickness of the longitudinal members and the transverse members shall be not less than:

   1) 2 mm for austenitic steel;

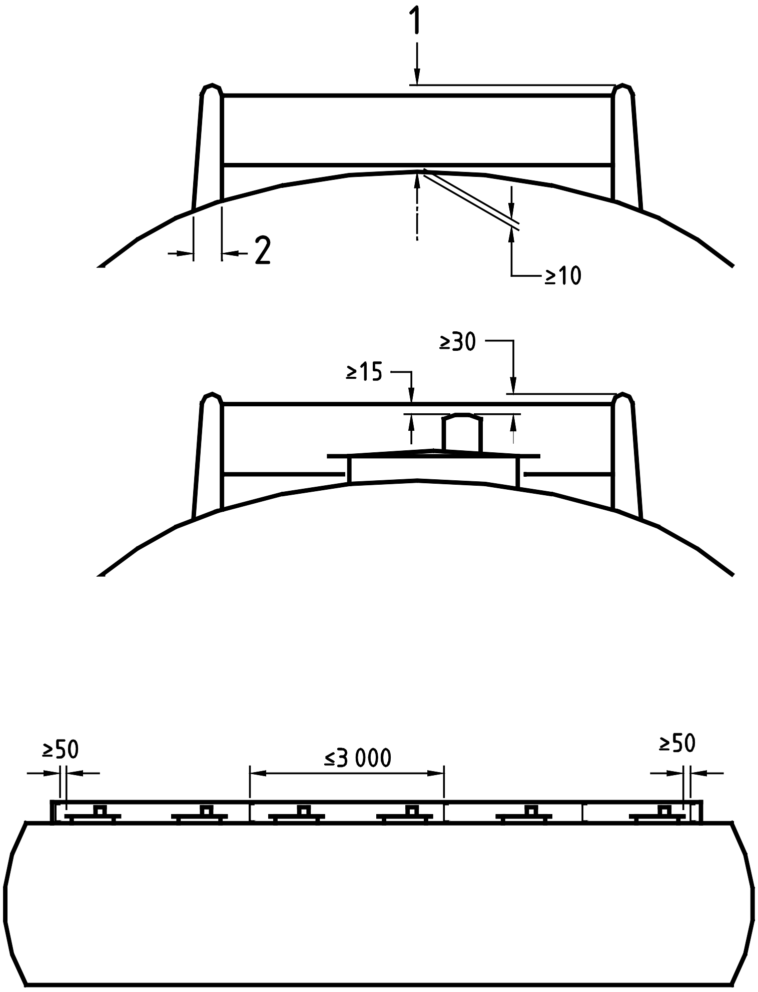
   2) 2,5 mm for other steel;

   3) 4 mm for aluminium alloy.

k) a minimum of two drainage tubes shall be provided, one on each side of the tank vertical centre line, and shall take into account the slope(s) of the tank in service; they shall be unobstructed and shall not be used for services including cables and pneumatic pipework.

NOTE 2 Longitudinal members can be used for vapour collection.

Dimensions in millimetres



Key

1 height of longitudinal protection member above top of shell (measured at top centre line of shell)

2 width of longitudinal protection member (measured at its base) – not less than one third of the height

Figure 1 — Typical arrangement of service equipment protected by longitudinal and transverse members

6.14.2.3 Shell contours

NOTE A typical arrangement of service equipment protected by the contour of a shell is shown in Figure 2.

When it is impossible to fill completely the shell or shell compartment because of its shape or construction, this reduced capacity shall be used for the determination of the degree of filling and for the marking of the tank.

Where items of service equipment are positioned entirely within the contour of the shell for protection:

a) they shall be mounted in a protective ring recessed into the shell in such a way that they are at least 25 mm within the contour of the upper edge of this ring;

b) the ring shall not extend outside the contour of the shell by more than 20 mm;

c) the exterior diameter of the protecting ring shall be not more than 700 mm;

d) the wall thickness of the ring shall be not less than:

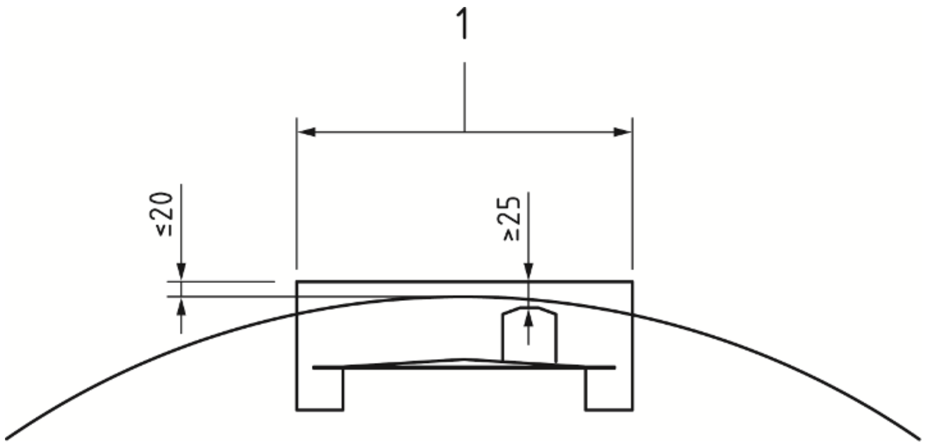
   1) 6 mm for mild steel;

   2) 4 mm for austenitic steel;

   3) 5 mm for austenitic ferritic steel;

   4) 8 mm for aluminium alloy.

Dimensions in millimetres



Key

1 ≤ 700 outside

Figure 2 — Typical arrangement of service equipment protected by the contour of a shell

6.14.2.4 Spill-trays

NOTE A typical arrangement of service equipment protected by spill-trays is shown in Figure 3.

Where spill-trays are used to protect the service equipment:

a) they shall be the height of the highest item of service equipment plus 30 mm;

b) they shall enclose all components of the service equipment completely with a minimum lateral clearance of 30 mm between the spill-tray and the equipment being protected;

c) where spill-trays without covers are used, the upper edge of the spill-tray shall be angled twice, not less than 30 mm (horizontally) and 20 mm (vertically down);

d) where spill-trays with covers are used, the upper edge of the spill-tray shall be angled twice, not less than 20 mm (horizontally) and 20 mm (vertically down);

e) the exterior diameter shall not exceed 900 mm or, if rectangular, the width shall not exceed 900 mm and the length shall not exceed 1 500 mm;

f) the wall thickness shall be not less than:

   1) for spill trays:

      i) 4 mm for mild steel;

      ii) 2,5 mm for austenitic steel;

      iii) 3 mm for austenitic-ferritic steel;

      iv) 6 mm for aluminium alloy.

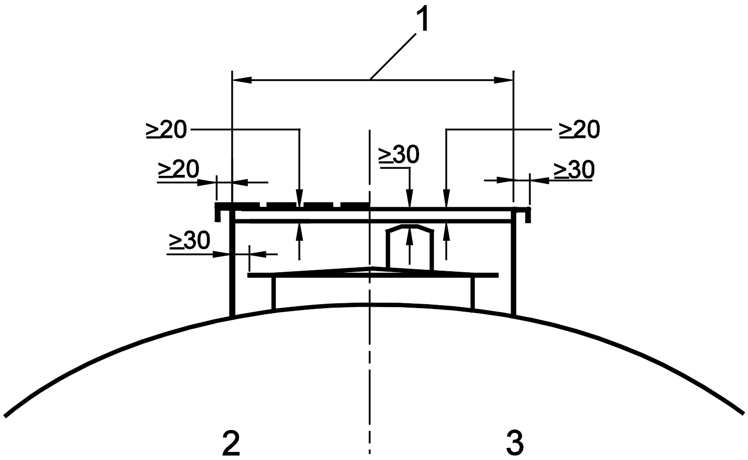
   2) for protective covers:

      i) 1,5 mm for austenitic steel;

      ii) 2 mm for other steel;

      iii) 3 mm for aluminium alloy.

Dimensions in millimetres



Key

1 ≤ 900 width, diameter, ≤ 1 500 length (if rectangular)

2 Spill tray with cover

3 Spill tray without cover

Figure 3 — Typical arrangement of service equipment protected by spill-trays

6.14.2.5 Roll-over bars

NOTE A typical arrangement of service equipment protected by roll-over bars is shown in Figure 4.

Roll-over bars shall be positioned on strengthening elements of the shell, such as partitions or surge plates.

The values of the section modulus are applicable to reference steel (Z_0); if another material is used for the roll-over bars, the equivalent section modulus in that material (Z_1) shall be determined in accordance with Formula (4). If mild steel is used no calculation is required.

$$Z_1 = \frac{10\ 000\ \text{N/mm}^2}{R_{\text{m1}} A_1} \times Z_0 \qquad (4)$$

Where service equipment is protected by roll-over bars:

a) the roll-over bars shall be at right angles to the direction of travel;

b) the roll-over bars shall be as low as possible;

c) the service equipment shall be not less than 50 mm within the contour of the roll-over bar;

d) the roll-over bars shall be placed in front of the first and behind the last item of service equipment;

e) the distance between the individual roll-over bars shall be not more than 3 000 mm;

f) the section modulus of each roll-over bar shall be not less than 5 cm^3 plus an additional 1 cm^3 for each 1 000 l of shell capacity with a maximum of 30 cm^3;

g) the roll-over bars and bracings shall be connected to the shell on locally reinforced places to reduce the risks of damage to the shell;

h) the roll-over bars shall be braced for stability on the longitudinal axis of the shell;

i) the angle to the shell of the bracings shall be not more than 45°;

j) the bracings shall be attached as high as possible to the roll-over bar;

k) the section modulus of the bracings together shall be not less than the value of the roll-over bar;

l) where strengthening plates are used as bracings, their resistance to buckling shall not be less than that of tubing complying with h), i), j), and k).

Dimensions in millimetres

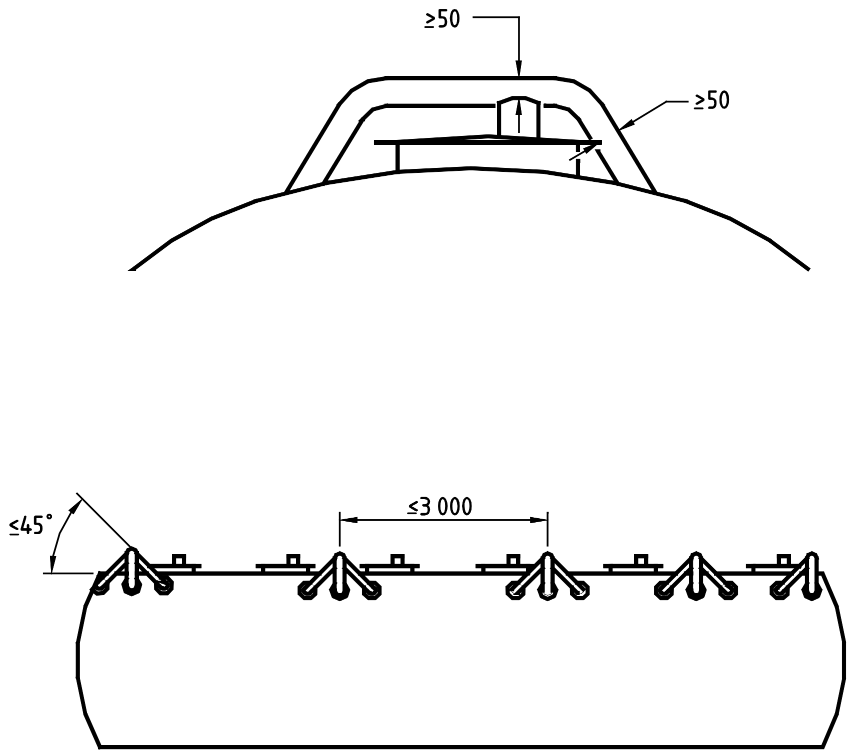


Figure 4 — Typical arrangement of service equipment protected by roll-over bars

6.14.2.6 Transverse box sections

NOTE A typical arrangement of service equipment protected by transverse box sections is shown in Figure 5.

Where service equipment is protected by transverse box sections:

a) they shall be made from materials in accordance with Clause 5 as sheet metal fabrications, continuously welded to the shell and forming closed sections with it;

b) the height of the transverse box sections shall be as low as possible but in any case:

  1) for tanks for granular substances, not less than the highest item of service equipment plus 25 mm;

  2) for tanks for all other substances, not less than the highest item of service equipment plus 50 mm.

c) they shall be placed in front of the first and behind the last item of service equipment;

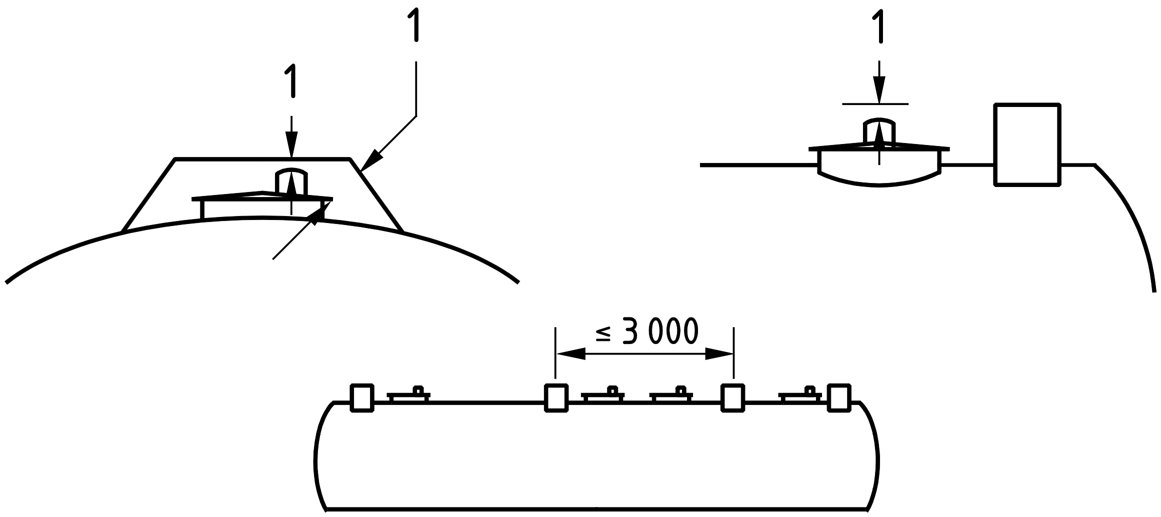
d) the distance between transverse box sections shall be not more than 3 000 mm;

e) the section modulus of each transverse box section shall be not less than 5 cm^3 plus an additional 1 cm^3 for each 1 000 l of shell capacity with a maximum of 30 cm^3;

f) where material other than mild steel is used for the transverse box section, an equivalent section modulus shall be calculated using the formula given in 6.14.2.5;

g) if the width of the transverse box section in the longitudinal plane of the tank is greater than its height, measured at the highest point over the shell, no additional bracing is necessary; otherwise the provisions of 6.14.2.5 shall apply.

Dimensions in millimetres



Key

1 ≥ 25 for granular substances

≥ 50 for all other substances

Figure 5 — Typical arrangement of service equipment protected by transverse box sections

7 Manufacture

7.1 General

7.1.1 Manufacturing processes shall be such that the degree of shaping required by a particular shell design does not generate cracking or other signs of distress in the shell material.

7.1.2 The manufacturer of the shell shall maintain a system of identification for the material used in the fabrication in order that all material in the shell can be traced to its origin. The system shall:

a) incorporate appropriate procedures that aim at verifying the identity of materials of the shell and its supporting structure received from suppliers, and that shall be based on the provision of material certificates 3.1 in accordance with EN 10204, and/or acceptance tests;

b) specify that before cutting and forming parts of the shell, the original identification mark of the material is transferred to any part that would be without the marking after the process has been completed.

7.2 Cutting and edge preparation

7.2.1 Material shall be cut to size and shape by thermal cutting, machining, cold shearing or other suitable process. Surfaces that have been thermally cut shall be dressed back by machining or grinding to remove severe notches, slag and scale. Plates over 10 mm thick that have been cold sheared shall be dressed back prior to welding. The cut edges of ferritic alloy steels, which have been cut by a thermal process, shall be dressed back by grinding or machining for a distance of at least 1,5 mm unless the fabricator can demonstrate that the material has not been adversely affected by the cutting process.

7.2.2 Edges which are to be welded shall be inspected after cutting and preparation, and the welding shall be carried out only if none of the following defects are present:

— tearing of the material (laminations);

— patches of mill scale;

— stress cracks due to oxygen cutting;

— copper or carbon deposits;

— split ends open to the surface;

— traces of paint, except when the paint is not expected to adversely affect the welding quality;

— traces of grease or other surface contamination that might adversely affect the welding quality;

— slag inclusions.

7.3 Forming

7.3.1 General

7.3.1.1 Materials shall be formed to the required shape by any suitable process providing that the extent of the bends and the radii do not exceed that specified in the material standard. After forming, the thickness shall not be less than the minimum specified in 6.9.1. Plates shall be formed to the correct contour up to their edges unless they are to be dressed after forming.

7.3.1.2 If plates are to be butt welded together prior to forming, the joint shall be non-destructively tested as specified in 7.4.4, after forming when the radius of the formed section is less than 20 times the thickness of the material for steels and 40 times the thickness of the material for aluminium.

When sheets of different thicknesses are butt welded together prior to forming, this value should be taken as the thickness of the thicker sheet.

7.3.1.3 When applicable, the weld itself shall be ground back prior to forming to avoid severe stresses in the weld.

7.3.2 Hot forming

7.3.2.1 Where a hot forming process is used, the material strength after forming shall be not less than the minimum specified in the material specification for those properties given in 5.2.

7.3.2.2 Heavy scale remaining after any hot forming process shall be removed by a descaling process that has been proven not to reduce the mechanical and corrosion-resisting properties below those required by the original design.

7.3.2.3 Austenitic steel plates that are to be heated or hot worked shall be heated uniformly in a neutral or oxidizing atmosphere, without flame impingement, to a temperature not exceeding the hot working temperature recommended by the manufacturer of the material. Forming shall not be carried out if the temperature of the material has fallen below 900 °C; slow cooling between 750 °C and 600 °C shall be avoided.

7.4 Welding

7.4.1 Qualification

7.4.1.1 A welding quality assurance system shall be operated and maintained that is in accordance with EN ISO 3834-1 and EN ISO 3834-2.

7.4.1.2 Welding procedures shall be approved in accordance with the relevant clauses of EN ISO 15607, EN ISO 15609-1, EN ISO 15609-2, EN ISO 15613, or with the relevant parts and clauses of the EN ISO 15614 series, as appropriate.

7.4.1.3 The manufacture of welded shells shall be carried out by persons who are qualified to EN ISO 9606-1, EN ISO 9606-2 or EN ISO 14732 as applicable.

7.4.2 Welded joints

7.4.2.1 Weld details shall be selected to take into account:

— the method of manufacture;

— the service conditions;

— the ability to carry out necessary non-destructive testing.

7.4.2.2 Examples of suitable weld details are given in Annex D, but other weld details may be used provided that they are found to be suitable when tested in accordance with EN ISO 15614-1, EN ISO 15614-2 or EN ISO 15613 as applicable.

7.4.2.3 Where any part of a shell is made in two or more circumferential sections, either:

— the longitudinal welds of adjacent sections shall be separated by not less than 50 mm; or

— a weld crossing shall be replaced by a circular plate of the same material with a diameter of not less than 150 mm, unless the applied procedure for cross-welding is included in the approved welding procedures for the shell.

7.4.3 Temporary attachments

7.4.3.1 Temporary attachments welded directly to the shell shall be kept to a practicable minimum. Materials used for temporary attachments shall be known to be compatible with the material of the shell, i.e. capable of being welded without producing defects.

7.4.3.2 Temporary attachments shall be removed from the shell prior to the hydraulic test. The removal technique shall be such as to avoid impairing the integrity of the shell. Any rectification necessary by welding of damaged regions shall be undertaken in accordance with the appropriate part of EN ISO 15607.

7.4.3.3 Dissimilar metal attachments may be welded to intermediate components, such as pads, which are connected permanently to the shell. Compatible welding materials shall be used for dissimilar metal joints.

7.4.4 Examination and testing of welds

7.4.4.1 All welds shall be visually examined over their entire length in accordance with EN ISO 17637, and shall meet the following criteria:

— EN ISO 5817, Level C for steel;

— EN ISO 10042, Level C for aluminium.

7.4.4.2 A proportion of welds shall be subjected to non-destructive testing as specified in EN 12972 for a weld efficiency factor of 0,8. Examination shall be in accordance with EN ISO 17635 and shall be by either radiographic testing in accordance with EN ISO 17636-1 or ultrasonic testing in accordance with EN ISO 17640.

Ultrasonic testing shall not be used for stainless steel tanks or as the sole means of inspection for tanks having a shell thickness of less than 6 mm.

All welds examined shall meet the following criteria:

— EN ISO 5817, Level C for steel;

— EN ISO 10042, Level C for aluminium.

The correlation between the quality levels defined above and the acceptance criteria of the various techniques of non-destructive testing shall be performed according to EN ISO 17635.

7.4.4.3 Non-destructive testing shall be carried out by competent persons qualified to EN ISO 9712. Procedures shall be approved by a person qualified to at least level 3; examinations shall be carried out and reports shall be signed by a person qualified to at least level 2.

7.5 Manufacturing tolerances

7.5.1 Plate alignment

7.5.1.1 Except where a tapered transition is provided, misalignment of the surfaces of adjacent plates at welded longitudinal and circumferential seams shall be not more than 25 % of the thickness of the thinner plate and shall not exceed 1 mm.

7.5.1.2 Where a taper is provided between the surfaces, this shall have a slope of not more than 1 in 3. Where material is removed from a plate to provide a taper, the thickness of either plate shall not be reduced below that required for the design.

NOTE The taper can include the width of the weld, the lower surface being built up with added weld metal if necessary.

7.5.1.3 The distance between either surface of the thicker plate and the centre line of the thinner plate of tapered seams shall be:

— for longitudinal seams, not less than 35 % of the thickness of the thinner plate;

— for circumferential seams, not less than 25 % of the thickness of the thinner plate.

7.5.2 Defects of form

Bulges and dents shall be smooth and their depth, measured as a deviation from the normal curvature or from the line of the cylindrical shell, shall be not greater than 2 % of their length or width.

7.5.3 Thickness

The thickness of the shell walls after manufacture shall be not less than the minimum thickness specified in 6.9; any variations in thickness shall be gradual.

7.5.4 Tank ends

Tank ends shall conform to the following requirements:

— the overall depth of the end, excluding any flange, shall not be less than the depth specified by the design;

— any knuckle radius shall not be less than that specified by the design;

— any crown radius shall not be greater than that specified by the design.

7.6 Rectification of defects

7.6.1 General requirements

7.6.1.1 Defects shall be rectified by a mechanical or a thermal process or a combination of both.

7.6.1.2 Surface defects in the parent material, such as arc strikes, tool marks, cutting marks, etc. shall be removed by grinding. The ground area shall have a smooth transition with the surrounding areas.

7.6.1.3 Any rectification shall be made in accordance with 7.1 to 7.5.

7.6.1.4 The thickness of the material after a rectification has been completed shall be within the tolerances of the design and never in any circumstances less than the minimum thickness determined in accordance with 6.9.1.

7.6.1.5 Following completion of a rectification, the area affected by the rectification shall be examined by an appropriate procedure, depending on the method of rectification (mechanical or thermal) and, in the case of welding, to an extent not less than that specified in 7.4.

7.6.2 Rectification of weld defects

7.6.2.1 The extent of a rectification shall be determined by the position, size and type of defect. It shall consist of either a rectification of the defect and the surrounding area only, or the complete removal of the weld containing the defect.

7.6.2.2 Rectification by grinding or another process involving removal of the material and which does not include welding shall be finished to give a smooth transition with the surrounding areas.

7.6.2.3 Thermal gouging shall be carried out using electrodes that are likely to minimize contamination of the remaining material surfaces. Where carbon or carbon steel electrodes are used on stainless steel shells, the surface of the material in the area subject to gouging shall be ground off for a depth of not less than 0,3 mm prior to further rectification work.

7.6.2.4 The area of a rectified defect shall be examined in accordance with 7.4.4.

Annex A
(normative)

Methods of design verification

A.1 General

One or a combination of the methods specified in A.2 to A.5 shall be used to verify the design of the tank and the structure for its attachment to the vehicle.

A.2 Dynamic testing

A.2.1 Methods for the verification of the loads specified in 6.4.2

A.2.1.1 General

Measurements of acceleration and associated strain shall be made by means of the following tests:

a) braking (A.2.1.2);

b) driving over a bumpy track (A.2.1.3);

c) driving slowly in a circle of minimum diameter 15 m (applicable to vehicle combinations not exceeding a total length of 18,65 m; for other vehicle combinations other turning diameters can apply) (A.2.1.4).

The testing specified in A.2.1.2 to A.2.1.4 shall be carried out with the tank filled with water to at least 97 % of its capacity. Where this causes overloading of the vehicle for testing, the test procedure shall take this into account and a procedure agreed with the Competent Authority; for example, for compartmented tanks, some compartments may be left unfilled and the test repeated with those compartments filled. However, in all cases each compartment shall be filled to its nominal capacity with the test fluid and not simply loaded by weight.

Linear extrapolation of measured strains shall be carried out to take account of:

— the difference between the measured accelerations and the design accelerations specified in A.2.1.2 to A.2.1.4;

— the difference between the mass of the test fluid (water) and the maximum substance mass shown on the tank plate.

A.2.1.2 Test a) — Braking

Braking shall be carried out on a flat and dry track with a deceleration of approximately 0,6 *g*. The measured values shall be linearly extrapolated up to the required 2 *g*.

A.2.1.3 Test b) — Driving over a bumpy track

It is not necessary to drive on a test track as used in automobile construction for ensuring durability. Flat tracks with obstacles (e.g. wooden bumps 45 mm high and sloped in direction of travel, at a distance corresponding to that between the first and last axle of the road tank vehicle), are sufficient.

The obstacles shall be positioned alternately on the right-hand and the left-hand sides. The velocity of the road tank vehicle and the height of the obstacles shall be such that the resulting values permit extrapolation up to 2 *g*.

A.2.1.4 Test c) — Driving slowly in a circle of minimum diameter 15 m

The velocity shall be such that the overturn limit of the road tank vehicle is not reached. If necessary, a supporting device shall be provided. When a transverse acceleration of 0,4 *g* has been reached a linear extrapolation shall be made.

A.2.2 Test programme

Content and details of the test programme shall be agreed for each individual case with the Competent Authority.

Strain gauges shall be attached to the areas of the tank and its attachments that are expected to be most severely stressed (in particular the areas at the bottom side of tank vehicles constructed to be self-supporting where according to experience stress peaks occur). The strain gauges shall be calibrated at zero load (empty tank).

The acceleration values of the *x*-, *y*- and z-coordinates shall be measured by means of accelerometers placed on the following support structures of the tank:

a) for rigid tank trucks, on the front and rear supports of the tank;

b) for semi-trailers, above the kingpin and the rear bogie;

c) for draw-bar trailers, above the front and rear bogie;

d) for self-supporting tanks (without a longitudinal framework at the bottom), at the front.

The maximum pressures resulting from surge of the tank contents in the direction of travel shall be determined by a sensor positioned at the front end of the tank compartment with the greatest volume and at one-third depth from the bottom of the tank.

A.3 Finite element stress analysis

A.3.1 Software selection

The computer software used for finite element stress analysis shall:

a) be capable of analysing thin shells;

b) be capable of calculating the bending stresses across the thickness of the material;

c) be capable of calculating shell deflections;

d) automatically generate warnings where elemental shape, aspect ratio or other parameters exceed limits set by the software supplier;

e) be capable of displaying the model in such a way that unintended disconnections between elements are clearly visible;

f) be capable of displaying duplicated elements;

g) have a modelling system capable of applying hydrostatic pressure;

h) have the ability to auto-locate maximum membrane stress and locate subsequent next maximum stress points.

A.3.2 Validation

The tank manufacturer shall present the Competent Authority with evidence that the manufacturer is authorized to use the software and that the software has been maintained up to the latest standards.

The manufacturer shall provide the Competent Authority with relevant thin shell validation examples if such examples are available.

NOTE If examples are not available, the Competent Authority is expected to validate the analysis by measuring one, or both, of the following:

— stress in the shell (by means of strain gauges) during pressure test;

— deflection during hydraulic pressure test.

The manufacturer shall provide the Competent Authority with access to both model and software in such a way that the Competent Authority can audit the model for all of the following:

a) elemental geometry;

b) elemental thickness;

c) elemental pressures;

d) external loads applied at nodes;

e) any nodal constraints at the edge of the model or elsewhere.

A.3.3 Approval

The manufacturer shall demonstrate to the Competent Authority that all the following criteria have been met:

a) the model is sufficiently detailed, particularly in the area of the supports;

b) the model is representative of the complete tank structure so far as it is likely to influence the stresses in the shell;

c) the limitations of the software have not been exceeded;

d) each of the following load cases has been correctly applied and the resultant stresses in the shell do not exceed the limit specified in 6.8:

   1) test pressure as 6.5.1;

   2) compartment test pressure as 6.5.2;

   3) operational requirements specified in 6.4.2;

e) none of the above cases produce stresses elsewhere in the structure, which are likely to result in plastic deformation which would invalidate the analysis.

A.3.4 Permanent record

The manufacturer shall provide the Competent Authority with recognized storage media containing complete details of:

a) the model and all the load cases;

b) the calculated stresses and deflections for all load cases.

A.4 Reference design

New designs may be approved if the manufacturer can prepare a satisfactory dossier on an existing reference design. As a minimum, this dossier shall include the following:

— five consecutive manufacturers' serial numbers of identical reference tanks;

— the dates of pressure test for first and last tanks in the reference batch;

— the Competent Authority's inspection certificates for all five tanks showing that all were free of shell, partition, surge plate, baffle and support damage at least 6 years (5 years in the case of tank containers) after the date of the initial pressure test for any of the nominated reference tanks;

— a written statement obtained from the tank owners to the Competent Authority declaring that the shell, partitions, surge plates, baffles and supports have not been repaired during the qualifying period. If any tanks in the reference batch have been subject to accident repair to the shell or supports then the size of the reference batch shall be increased to seven consecutive serial numbers. The enlarged reference batch shall not include more than one tank that has been subject to such damage and repair;

— a statement obtained from the Competent Authority that the subject design is covered by the reference design in the manner required by EN 12972:2007, 4.1.1;

— a statement obtained from the Competent Authority as to whether any features of the shell, partitions, surge plates baffles and supported in the subject design require further analysis or test;

— copies of the manufacturer's original drawings for the reference design and the subject design.

If the existing shell and its structural elements have proved to be capable of withstanding the forces during operation after the applicable period of time, it shall be deemed to have met the requirements of 6.4.2.

NOTE The Competent Authority can then allow the manufacturer to use this type of construction for the design of new tanks, provided that the variations in design are within the limits of EN 12972:2007, 4.1.1.

A.5 Calculation method – worksheet

A.5.1 Introduction

A.5.1.1 General

This method applies to the verification of the design of tanks with

— circular or elliptical cross-section; and

— other cross-sections with P_{ts} not exceeding 0,14 bar (14 kPa).

One of the methods given in A.1 to A.4 shall be used to calculate stresses in areas not covered by the method (such as tank supports or attachments).

A.5.1.2 Methodology of the calculation method

A.5.1.2.1 General

The verification of the design is made in accordance with A.5.1.2.1 to A.5.1.2.3.

The results determine the adopted minimum thickness for the different parts of the shell (see A.5.1.4).

A.5.1.2.2 Minimum thicknesses of the walls, ends and closures

Based upon the principal characteristics of the shell (see A.5.1.3), the minimum thickness of the shell components shall be determined in accordance with A.5.4. The results shall be entered in Table A.9 (see A.5.1.5).

The minimum thickness of the shell according to 6.9.1 and according to 6.9.2 for shells protected against damage shall be entered in Table A.10 (see A.5.1.5).

A.5.1.2.3 Verification of the stresses in test condition

Verification of the stresses in test condition in accordance with 6.5 (see A.5.1.6 and A.5.5) with respect to the values specified in 6.8, i.e.:

$$\sigma = \min.\{0,75R_\mathrm{e};0,5R_\mathrm{m}\}$$ (see Table A.7)

A.5.1.2.4 Verification of the stresses in service condition

Verification of the stresses in service condition (see A.5.1.7 and A.5.6) with respect to the values of the maximum mandatory stresses, i.e.:

$$\sigma = \min.\{0,75R_\mathrm{et};0,5R_\mathrm{mt}\}$$ (see Table A.5);

With the calculation pressures equal to those defined in a), b) and c) as follows:

a) longitudinal wall: P_ts increased by the static pressure equivalent to twice the height of the most dense substance to be carried for the shell section studied;

b) ends:

   1) for the front end of a fixed tank and the ends of tank containers/swap bodies: P_ts increased by the static pressure due to the height of the most dense substance to be carried for the end studied, and by the dynamic pressure due to the 2 *g* acceleration of the substance to be carried on the front end;

   2) for the rear end of a fixed tank: P_ts increased by the static pressure due to twice the height of the most dense substance to be carried for the rear end studied;

c) partitions: P_ts increased by the static pressure due to the height of the most dense substance to be carried for the shell section studied.

A.5.1.3 Principal characteristics of the shell

The principal characteristics of the shell shall be recorded as follows in Tables A.1 to A.7:

a) principal dimensions of the shell (Table A.1);

b) pressures induced by the product being transported (Table A.2);

c) calculation pressure in service conditions (Table A.3);

d) working temperature (Table A.4);

e) mechanical characteristics of the shell constituent materials and of the attachments (Table A.5);

f) $R_m \times A$ selected values for calculation of the equivalent thickness (Table A.6.);

g) maximum permissible stresses in test and service conditions (Table A.7).

A.5.1.4 Minimum thicknesses adopted

The minimum thicknesses adopted for the tank shell components shall be recorded in Table A.8.

A.5.1.5 Mandatory minimum thicknesses

The mandatory minimum thickness of the tank shell components shall be recorded in Tables A.9 and A.10 as follows:

a) calculated (Table A.9);

b) required (Table A.10).

A.5.1.6 Verification of the stresses at test pressure

The verification of the stresses at test pressure shall be recorded in Tables A.11 to A.16 as follows:

a) in the shell walls (Tables A.11 and A.12);

b) on the ends (Tables A.14 and A.16 for which the mechanical and geometrical characteristics figure in Tables A.13 and A.15).

A.5.1.7 Verification of the stresses in service condition

The verification of the stresses in service condition shall be recorded in Tables A.17 to A.22 as follows:

a) circumferential stresses on the shell walls (Tables A.17 and A.18);

b) transport dynamic stresses on the shell walls (A.5.6.2);

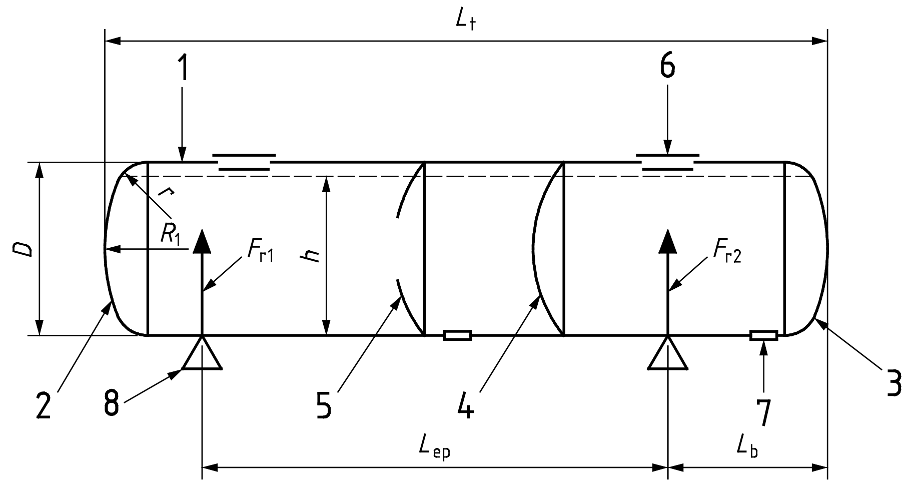
c) stresses on the ends (Tables A.20 and A.22 for which the mechanical and geometrical characteristics figure in Tables A.19 and A.21);

d) stresses on partitions (Tables A.24 and A.26 for which the mechanical and geometrical characteristics figure in Tables A.23 and A.25).

A.5.2 Symbols and units

A.5.2.1 Main tank characteristics

Figures A.1 and A.2 illustrate the following characteristics of a tank shell.	
— tank body: form__________________________________	(to be completed by the manufacturer);
— section____	(to be completed by the manufacturer).



Key

1 shell wall

2 front end

3 rear end

4 partition

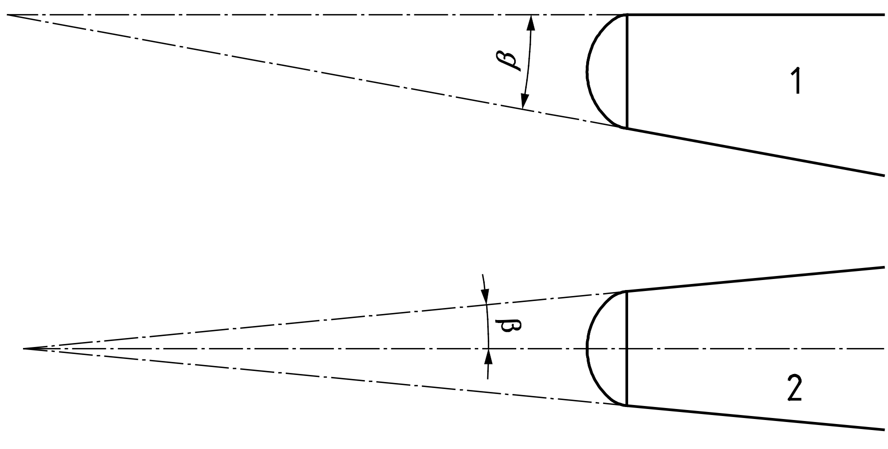
5 surge plate

6 top opening

7 bottom opening

8 supports

Figure A.1 — Main tank characteristics



Key

1 wedge-shaped section

2 cone-shaped section

Figure A.2 — Wedge and cone -shaped tank sections

Table A.1 — Dimensional parameters

N°	Element	Symbol	Unit	Value
1	Tank overall length	L_t	mm	
2	Maximum gross mass (tank filled)	M	N	
3	Payload (maximum gross weight – tare weight)	Q	N	
4	Rear supporting position	L_b	mm	
5	Distance between supports	L_{ep}	mm	
6	Front support reaction	F_{r1}	N	
7	Rear support reaction	F_{r2}	N	
8	Maximum density of the product carried	d	kg/m^3	
9	Maximum filling height	h	mm	[a]
10	Maximum inside diameter or equivalent diameter for non circular cross-sections	D	mm	[a]
11	Knuckle inside radius	r	mm	[a]
12	Crown inside radius	R_1	mm	[a]
13	Apparent yield strength at design temperature	R_{et}	N/mm^2	
14	Tensile strength at design temperature	R_{mt}	N/mm^2	
15	Weight of the product transported in the compartment	M_p	N	
16	Tensile elastic modulus (Young's modulus)	E	N/mm^2	
17	Distance from rear of tank to point of maximum bending moment	X	mm	
18	Half-angle of conical envelope	β	°	

[a] These values will be filled in subsequent tables.

A.5.2.2 Calculation parameters

A.5.2.2.1 Pressures

Table A.2 — Pressures

N°	Pressure	Symbol	Unit	Value
1	Vapour pressure at design temperature (gauge pressure)	P_{vd}	MPa	
2	Maximum working pressure [b]	P_{ms}	MPa	
3	Static pressure (gauge pressure)	P_{ta}	MPa	[a]
4	Dynamic pressure	P_{dyn}	MPa	[a]
5	Test pressure of tank (gauge pressure) (from 6.5.1)	P_e	MPa	
6	Test pressure in each compartment (from 6.5.2)	P_{ec}	MPa	
7	Calculation pressure according to 6.5	P_c	MPa	

[a] Value calculated in Table A.3.

[b] P_{ms} is the maximum of P_{vd}, P_{ts}, P_d and P_r.

A.5.2.2.2 Calculation Pressure (P_c) in service conditions

Table A.3 — Calculation pressure in service conditions

		Units	Shell wall				Front end	Rear end	Partitions			
			1	2	3	4			1	2	3	4
	Internal cross-sectional area S_t	mm[2]										
	Diameter D	mm [a]										
	Maximum weight of substance in compartment M_P	N					[e]					
	Maximum density d	kg/m[3]										
	Maximum height h	mm										
1	P_{ta} 1[b]	MPa										
2	2 × P_{ta} 1	MPa										
3	2 × $P_{ta\ water}$	MPa										
4	P_{ms}	MPa										
5	P_{ms} + P_{ta} 1	MPa										
6	P_{ms} + 2 P_{ta} 1	MPa										
7	P_{ms} + P_{ta} 1 + 2 P_{dyn}[c]	MPa					[e]					
8	P_c [d]	MPa										

NOTE 1 The number of columns in the table can be adapted to the overall design of the tank.

NOTE 2 The shaded areas are not applicable.

[a] For a non-circular section $D = 2\sqrt{\frac{S_t}{\pi}}$.

[b] $P_{ta\,1} = \frac{g \times d \times h}{10^9}$

[c] $P_{dyn} = \frac{M_P}{S_t}$

[d] For each element considered, P_c is the highest pressure value from 1 to 7.

[e] Not to be completed for tanks which have a defined direction of travel.

A.5.2.2.3 Temperature

Table A.4 — Temperature

Design (working) temperature (only if it is greater than + 50 °C, or lower than −20 °C)	°C
Temperature (t)	

A.5.2.2.4 Tank and attachment materials

Table A.5 — Materials

	Units	Shell wall	Front end	Rear end	Partitions
Material type					
Grade					
Standards or specifications					
R_m	N/mm^2				
R_{mt} at design temperature	N/mm^2				
R_e [a]	N/mm^2				
R_{et} at design temperature [a]	N/mm^2				
E	N/mm^2				
E_t at design temperature					
[a] At 0,2 % or for austenitic steels at 1 %.					

Table A.6 — Values selected for calculation of equivalent thickness

	Units	Shell wall	Front end	Rear end	Partitions
R_{m1} (see 3.2)	N/mm^2				
A_1 (see 3.2)	%				
$R_m \times A$					

A.5.2.2.5 Maximum stresses permissible

Table A.7 — Maximum stresses

	Units	Shell wall	Front end	Rear end	Partitions
0,5 R_m [a]	N/mm^2				
0,75 R_e [a]	N/mm^2				
0,5 R_{mt} [b]	N/mm^2				
0,75 R_{mt} [b]	N/mm^2				
$R_e/1,5$ [c]	N/mm^2				
$R_{et}/1,5$ [c]	N/mm^2				
Selected value σ in test condition [d]	N/mm^2				
Selected value σ in service condition only for fixed tank (tank vehicle) and demontable tank [e]	N/mm^2				
Selected value σ in service condition only for tank containers, tank swap bodies [f]	N/mm^2				
E at ambient temperature	N/mm^2				
E_t in service condition	N/mm^2				

NOTE σ is the lowest permissible stress.

[a] For all tanks.

[b] Only for fixed tank (tank vehicle) and demontable tank.

[c] Only for tank containers, tank swap bodies.

[d] Lowest value of [a].

[e] Lowest value of [a] and [b].

[f] Lowest value of [a, b] and [c].

A.5.3 Minimum thicknesses adopted

Table A.8 — Minimum thicknesses

Designation		Symbol	Units	Value
Shell wall	1	e_{v1}	mm	
Shell wall	2	e_{v2}	mm	
Shell wall	3	e_{v3}	mm	
Shell wall	4	e_{v4}	mm	
Front end		$e_{f\,av}$	mm	
Rear end		$e_{f\,ar}$	mm	
Partition	1	e_{f1}	mm	
Partition	2	e_{f2}	mm	
Partition	3	e_{f3}	mm	
Partition	4	e_{f4}	mm	
NOTE The number of rows in the table can be adapted to the shape of the tank.				

A.5.4 Mandatory thicknesses

A.5.4.1 Calculated thicknesses

The minimum mandatory calculated thickness is the greater of:

$$e = \frac{P_c \times D}{2\sigma} \text{ or } \frac{P_e \times D}{2\sigma \times \lambda} \quad \text{(A.1)}$$

Table A.9 — Calculated thicknesses

		D mm	σ[a] N/mm²	λ[b]	P_c[c] MPa	P_e MPa	e mm
Shell wall	1						
Front end	2						
Rear end	3						
NOTE The number of rows in the table can be adapted to the shape of the tank.							

[a] σ in test condition – see Table A.7.

[b] λ = 1 if the design pressure is higher than the test pressure (welding coefficient).

[c] See Table A.2.

A.5.4.2 Required or equivalent thicknesses

Table A.10 — Required or equivalent thicknesses

			e_0 [a] and/or [e]	e_1 [b] and/or [e]
	Shell wall	1		
		2		
		3		
		4		
	Front end			
	Rear end			
	Partitions			
Total thickness including supplementary protection [c, d]	Shell wall	1 2 3 4		
	Front end			
	Rear end			

NOTE The number of rows in the table can be adapted to the shape of the tank.

[a] e_0 = minimum thickness of reference steel in millimetres.

[b] e_1 = equivalent thickness = $\frac{464 e_0}{\sqrt[3]{(R_{m1} \times A_1)^2}}$ (see Table A.6).

[c] If applicable.

[d] Tank with a section other than circular or elliptical.

[e] Thickness imposed by requirements relative to substance being transported.

A.5.5 Verification of stresses at test pressure

A.5.5.1 Shell walls

A.5.5.1.1 Circular or non-circular cylindrical section wall (shell wall n°__________________)

$$\sigma = \frac{P_e \times D}{2 e_v \times \lambda} \qquad \text{(A.2)}$$

with

P_e = _______ MPa (see Table A.2)

D = ________mm (see Table A.1)

e_v = ________mm (see Table A.8)

λ = ________

Table A.11 — Stress at test pressure

Designation		σ calculated [a] N/mm²	σ max permissible in test condition [b] N/mm²
Shell wall	1		
	2		
	3		
	4		
NOTE The number of rows in the table can be adapted to the shape of the tank.			

[a] σ calculated ≤ σ max permissible.

[b] See Table A.7.

A.5.5.1.2 Circular or non-circular conical section wall (shell wall n°________)

$$\sigma = \frac{P_e \times D}{2\cos\beta \times e_v \times \lambda} \tag{A.3}$$

with

P_e = ________ MPa (see Table A.2)

D = ________ mm

β = ________ half-angle at top of conical envelope (β max = 30°)

$\cos\beta$ = ________

e_v = ________ mm (see Table A.8)

λ = ________

Table A.12 — Stress at test pressure

Designation		**σ calculated** [a] N/mm²	**σ max permissible in test condition** [b] N/mm²
Shell wall	1		
	2		
	3		
	4		
NOTE The number of rows in the table can be adapted to the shape of the tank.			
[a] σ calculated ≤ σ max permissible. [b] See A.5.2.2.5.			

A.5.5.2 Formed ends having circular or non-circular cross-section

A.5.5.2.1 Pressure on the concave face

$$\sigma = \frac{P_e \times R_1 \times C}{2\lambda \times e_f} \qquad \text{(A.4)}$$

with values as defined in Table A.13:

Table A.13 — Data to be used for calculation

	Units	**Front end**	**Rear end**
P_e (see Table A.2)	MPa		
R_1 [a]	mm		
r	mm		
C [b] = $\frac{1}{4}\left[3+\sqrt{\frac{R_1}{r}}\right]$			
λ [c]			
$e_{f\ av}$ and $e_{f\ ar}$ adopted (see Table A.8)	mm		

[a] The biggest radius of curvature of either the horizontal or the vertical plane.

[b] C = 1, in the case of hemispherical ends.

C = 0,93, in the case of elliptical ends with axial ratio = 1,9:1.

[c] Made up of welded elements: in the case where ends made of welded elements are assembled according to provisions of A.5.8, there is no need to take into account the welding coefficient.

Table A.14 — Stress at test pressure

	σ calculated [a] N/mm^2	**σ max permissible in test condition(see Table A.7)** N/mm^2
Front end Rear end		
[a] σ calculated ≤ σ max permissible.		

A.5.5.2.2 Pressure on their convex face

$$E_c = \frac{100 R_1^2 \times 2,2 P_e}{36,6 e_f^2} \quad (A.5)$$

with values as defined in Tables A.15 and A.16:

Table A.15 — Data to be used for calculation

	Units	**Front end** **($e_{f\ av}$)**	**Rear end** **($e_{f\ ar}$)**
P_e (see Table A.2)	MPa		
R_1 (see Table A.1)	mm		
e_f adopted (see Table A.8)	mm		

Table A.16 — Elastic modulus in test conditions

	E calculated [a]**: E_c** N/mm^2	**E max at ambient temperature (see Table A.7)** N/mm^2
Front end		
Rear end		
[a] E calculated ≤ E max.		

A.5.6 Verification of stresses in service condition

A.5.6.1 Circumference stresses on shell walls

A.5.6.1.1 Circular or non circular section cylindrical shell (shell wall n°________)

$$\sigma = \frac{P_c \times D}{2e_v \times \lambda} \tag{A.6}$$

with

P_c = ________ MPa (see Table A. 3)

λ = ________

D = ________ mm

e_v = ________ mm (see Table A.8)

Table A.17 — Stresses in service conditions

Designation		σ calculated [a] N/mm²	σ max permissible in service condition (see Table A.7) N/mm²
Shell wall	1		
	2		
	3		
	4		
NOTE The number of rows in the table can be adapted to the shape of the tank.			
[a] σ calculated ≤ σ max in service condition.			

A.5.6.1.2 Circular or non-circular section conical shell wall (shell wall n° ________)

$$\sigma = \frac{P_c \times D}{2e_v \times \cos\beta \times \lambda} \tag{A.7}$$

with

P_c = ________ MPa (see Table A.3)

D = ________ mm

β = ________ half-angle at top of conical envelope (β max = 30°) (see A.5.2.1)

cos β = ________

λ = ________

e_v = ________ mm (see Table A.8)

Table A.18 — Stresses in service conditions

Designation		**σ calculated** [a] N/mm²	**σ max permissible in service condition (see Table A.7)** N/mm²
Shell wall	1		
	2		
	3		
	4		
NOTE The number of rows in the table can be adapted to the shape of the tank.			
[a] σ calculated $\leq$ σ max in service condition.			

A.5.6.2 Dynamic stresses

A.5.6.2.1 Under normal transport conditions

A.5.6.2.1.1 Stress due to bending

For cylinder-conical tanks the maximum stress may be located elsewhere than at the point of maximum bending moment.

For cylindrical tanks with circular or non-circular section, the following calculations apply:

a) position of the maximum bending moment:

$$X = \frac{F_{r2} \times L_t}{M} = \_\_\_\_\_\_\_\_ \text{ mm (see A.5.2.1 and Table A.1)} \quad \text{(A.8)}$$

b) value of the maximum bending moment (B_m):

$$B_m \max = F_{r2}\,(X\text{-}L_b) - \frac{M \times X^2}{2L_t} \text{ (see A.5.2.1 and Table A.1)} \quad \text{(A.9)}$$

B_m max = ________ N.mm

c) Internal cross-sectional area of the shell wall at the point of maximum bending moment:

S_t = ________ mm² (see Table A.3)

d) Thickness of the shell wall:

e_v = ________ mm (see Table A.8)

e) minimum section modulus of the shell wall cross-section about the horizontal neutral axis at the point of maximum bending moment:

Z_t = ________ mm³

f) bending stress:

$$\sigma_x = \frac{B_m \max}{Z_t} \_\_\_\_\_\_\_\_ \text{ N/mm}^2 \quad \text{(A.10)}$$

σ_x = ________ N/mm²

A.5.6.2.1.2 Tensile stress due to pressure during transport

a) Force

$T_1 = P_{ms} \times S_t$ = ________ N (see Tables A.2 and A.3) (A.11)

b) Length of shell wall perimeter at the cross-section corresponding to the point of maximum bending moment:

l = ________ mm

c) Stress under this force:

$$\sigma_{tr} = \frac{T_1}{l \times e_v} = \_\_\_\_\_\_\_\_ \text{ N/mm}^2 \quad \text{(A.12)}$$

σ_{tr} = ________ N/mm²

A.5.6.2.1.3 Tensile stress due to static pressure

a) Force:

$T_2 = P_{ta1} \times S_t$ = ________ N (see Table A.3) (A.13)

b) Stress under this force:

$$\sigma_{ta} = \frac{T}{l \times e_v} = \_\_\_\_\_\_\_\_ \text{ N/mm}^2 \quad \text{(A.14)}$$

σ_{ta} = ________ N/mm²

A.5.6.2.1.4 Combined stress under normal transport conditions

$$\sigma_1 = \frac{\sigma_x + \sigma_{tr} + \sigma_{ta}}{\lambda} = \_\_\_\_\_\_\_\_ \text{N/mm}^2 \quad \text{(A.15)}$$

σ_1 = ________ N/mm² ≤ σ max in service condition (see Table A.7)

A.5.6.2.2 Stress under dynamic transport conditions

A.5.6.2.2.1 Combined stress under pressure during transport, with static pressure and 2 *g* vertical

$$\sigma_2 = \frac{2\sigma_x + \sigma_{tr} + \sigma_{ta}}{\lambda} = \_\_\_\_\_\_\_\_ \text{ N/mm}^2 \quad \text{(A.16)}$$

σ_2 = ________ N/mm² ≤ σ max in service condition (see Table A.7)

A.5.6.2.2.2 Tensile stress due to longitudinal force of product in the tank with 2 *g*

— Payload

Q = ________ N (see Table A.1)

$$\sigma_t = \frac{2Q}{l \times e_v} = \_\_\_\_\_\_\_\_ \text{ N/mm}^2 \tag{A.17}$$

σ_t = ________ N/mm^2 ≤ σ max in service condition (see Table A.7)

A.5.6.2.2.3 Combined stress under pressure during transport, with 1 *g* vertical and 2 *g* longitudinal

$$\sigma_3 = \frac{\sigma_{tr} + \sigma_x + \sigma_t}{\lambda} = \_\_\_\_\_\_\_\_ \text{ N/mm}^2 \tag{A.18}$$

σ_3 = ________ N/mm^2 ≤ σ max in service condition (see Table A.7)

A.5.6.3 Stresses in formed ends with circular or non-circular section

A.5.6.3.1 Pressurized on their concave face

$$\sigma = \frac{P_C \times R_1 \times C}{2e_f \times \lambda} \tag{A.19}$$

with values as defined in Tables A.19 and A.20.

Table A.19 — Data to be used for calculation

	Units	Front end	Rear end
P_C (see Table A.3)	MPa		
R_1 (the biggest radius of curvature)	mm		
r	mm		
C [a] = $\frac{1}{4}\left[3 + \sqrt{\frac{R_1}{r}}\right]$			
λ [b]			
e_f adopted (see A.5.3)			

[a] C = 1, in the case of a hemispherical end.
C = 0,93, in the case of elliptical ends with axial ratio = 1,9:1.

[b] In case where the welded element ends are assembled according to the provisions of A.5.8, there is no need to take into account the welding coefficient.

Table A.20 — Stress in service conditions

	σ calculated [a] N/mm^2	σ max in service condition (see Table A.7) N/mm^2
Front end Rear end		

[a] σ calculated ≤ σ max in service condition.

A.5.6.3.2 Pressurized on their convex face

$$E_C = \frac{100 R_1^2 \times 2{,}2 P_C}{36{,}6 e_f^2} \quad \text{(A.20)}$$

Table A.21 — Data to be used for calculation

	Units	Front end ($e_{f\,av}$)	Rear end ($e_{f\,ar}$)
P_c (see Table A.3)	MPa		
R_1	mm		
e_f adopted (see Table A.8)	mm		

Table A.22 — Elastic modulus comparison in service conditions

	E **calculated**[a]**:** E_c N/mm²	E (see Table A.7) N/mm²
Front end		
Rear end		
[a] E calculated ≤ E in service condition.		

A.5.6.4 Formed partitions having circular or non-circular cross-section

A.5.6.4.1 Pressurized on their concave face

$$\sigma = \frac{P_C \times R_1 \times C}{2 e_f \times \lambda} \quad \text{(A.21)}$$

with values as defined in Tables A.23 and A.24.

Table A.23 — Data to be used for calculation

	Units	Tight formed partition
P_c (see Table A.3)	MPa	
R_1(the biggest radius of curvature)	mm	
r	mm	
C [a] = $\frac{1}{4}\left[3 + \sqrt{\frac{R_1}{r}}\right]$		
λ[b]		
e_f adopted (see Table A.8)		
NOTE The number of columns in the table can be adapted to the shape of the tank.		
[a] C = 1, in the case of a hemispherical end. C = 0,93, in the case of elliptical ends with axial ratio = 1,9:1. [b] In case where the welded element ends are assembled according to the provisions of A.5.8, there is no need to take into account the welding coefficient.		

Table A.24 — Stress in service conditions

	σ calculated [a] N/mm^2	σ max in service condition N/mm^2
Tight formed partition		
NOTE The number of columns in the table can be adapted to the shape of the tank.		
[a] σ calculated ≤ σ max in service condition.		

A.5.6.4.2 Pressurized on their convex face

$$E_C = \frac{100 R_1{}^2 \times 2{,}2 P_C}{36{,}6 e_f{}^2} \qquad \text{(A.22)}$$

with values as defined in Tables A.25 and A.26.

Table A.25 — Data to be used for calculation

	Units	Tight formed partition
P_c (see Table A.3)	MPa	
R_1 (the biggest radius of curvature)	mm	
e_c adopted (see Table A.8)	mm	
NOTE The number of columns in the table can be adapted to the shape of the tank.		

Table A.26 — Elastic modulus comparison in service conditions

	E calculated[a]: E_c N/mm^2	E_t (see Table A.7) N/mm^2
Tight formed partition		
NOTE 1 The number of columns in the table can be adapted to the shape of the tank. NOTE 2 E_c is the calculated elastic modulus.		
[a] E calculated ≤ E_t in service condition.		

A.5.7 Calculation of stress in tank attachments

The calculation of stresses of the tank attachments shall be in accordance with the methods described in A.2 and A.3 or in accordance with an analytical method which accurately calculates the stresses due to the loading specified in 6.4.2.

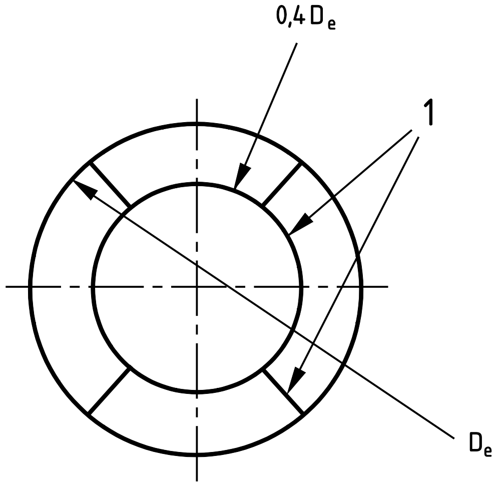
A.5.8 End made up of several welded elements

The dimensioning rules apply to the following ends:

a) hemispherical ends, whatever the weld location;

b) ends where welds are within 0,4 D_e of the central axis or, if outside 0,4 D_e, are on a plane including the central axis.

Figure A.3 shows an example of an end that meets condition b).



Key

1 welds

D_e end diameter

Figure A.3 — Example of end made up of several welded elements

Annex B
(normative)

Method of measurement of specific resilience

B.1 Principle

The comparison method consists of a determination of the specific resilience of:

— the material used for the shell having a minimum thickness calculated in accordance with 6.9.1 (equivalent minimum thickness); and

— the proposed combination of materials for double wall construction.

EXAMPLE An example is where the shell material is mild steel, and the proposed combination of materials for double wall construction is the same mild steel plus polyurethane foam plus a cladding.

B.2 Apparatus

B.2.1 Test machine, capable of applying force of at least 1 000 kN with sufficient travel to allow the test to be completed in one application at the penetration speed given in B.2.1.1. The test machine shall incorporate:

— a control system (B.2.1.1);

— a force measuring device (B.2.1.2);

— a displacement measuring device (B.2.1.3);

— monitoring and recording equipment (B.2.1.4); and

— a supporting fixture (B.2.1.5).

B.2.1.1 Control system, that allows pre-selection of the penetration speed (2 mm/s to 4 mm/s) and ensures that it is constant.

B.2.1.2 Force measuring device, meeting the requirements of a Class 1 testing machine in accordance with EN ISO 7500-1.

B.2.1.3 Displacement measuring device, having an accuracy and a resolution of 0,5 %.

B.2.1.4 Monitoring and recording equipment, that has an X–Y plotter used for monitoring with a response time of less than 20 % of the rise time interval of the input signal, and a recording system capable of recording force and displacement signals simultaneously. Digital recorders and plotters shall sample at a sufficiently high rate to ensure that a true representation of the load/displacement curve is obtained.

B.2.1.5 Supporting fixture, that supports the base of the test piece mounting assembly so that there is a minimum of movement of the assembly during the test that might contribute to the overall recorded displacement. If the test piece mounting assembly is not supported around the full circumference of the base flange on the bed of the machine, a base plate may be used with fittings to attach the test piece mounting assembly to the machine.

The base plate shall be not less than 38 mm in thickness.

B.2.2 Test piece mounting assembly, comprising a body (B.2.2.1), clamping ring (B.2.2.2) and test bar (B.2.2.3).

B.2.2.1 Test piece mounting assembly body, constructed from carbon steel and conforming to the dimensions given in Figure B.1. The lower flange shall conform to the overall dimensions given in Figure B.1. The method of attachment to the base of the test machine will determine the need for any holes in this flange for bolts, etc.

Dimensions in millimetres

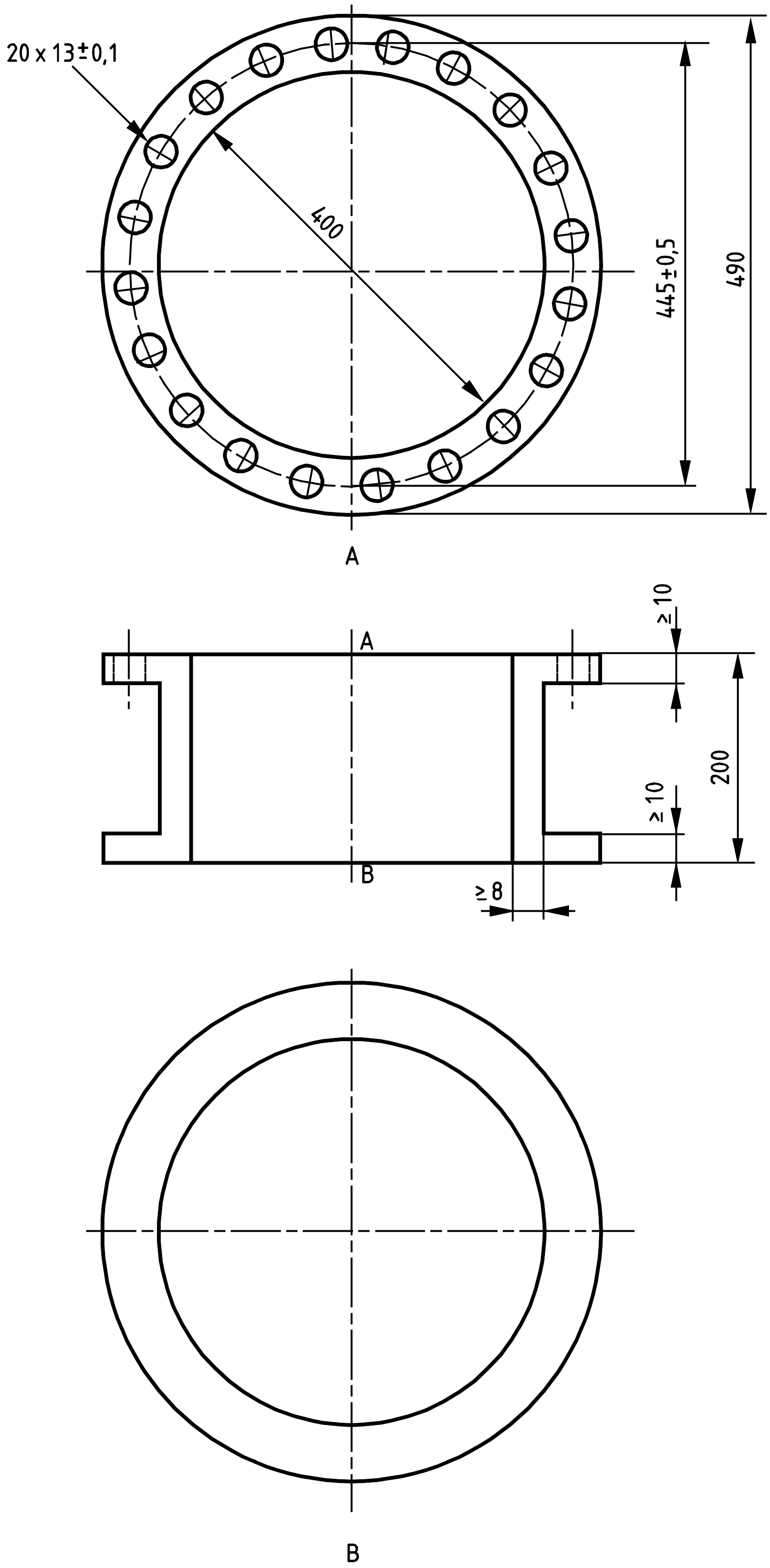


Figure B.1 — Test piece mounting assembly body

B.2.2.2 **Clamping ring**, made from steel and conforming to the dimensions given in Figure B.2.

Dimensions in millimetres

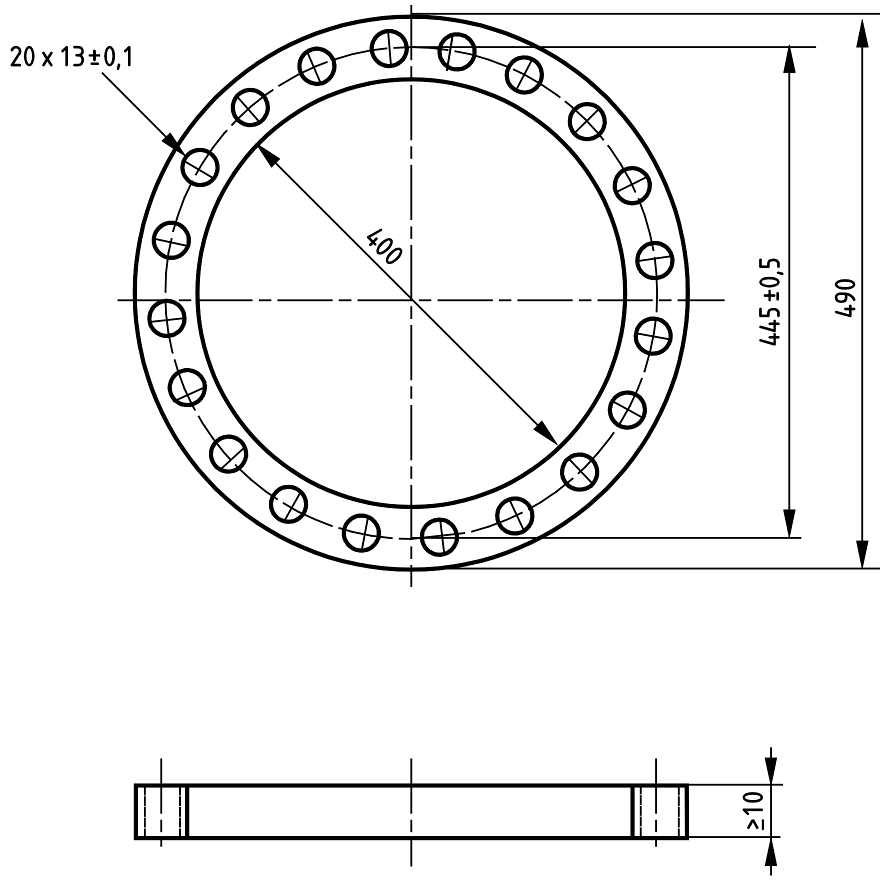
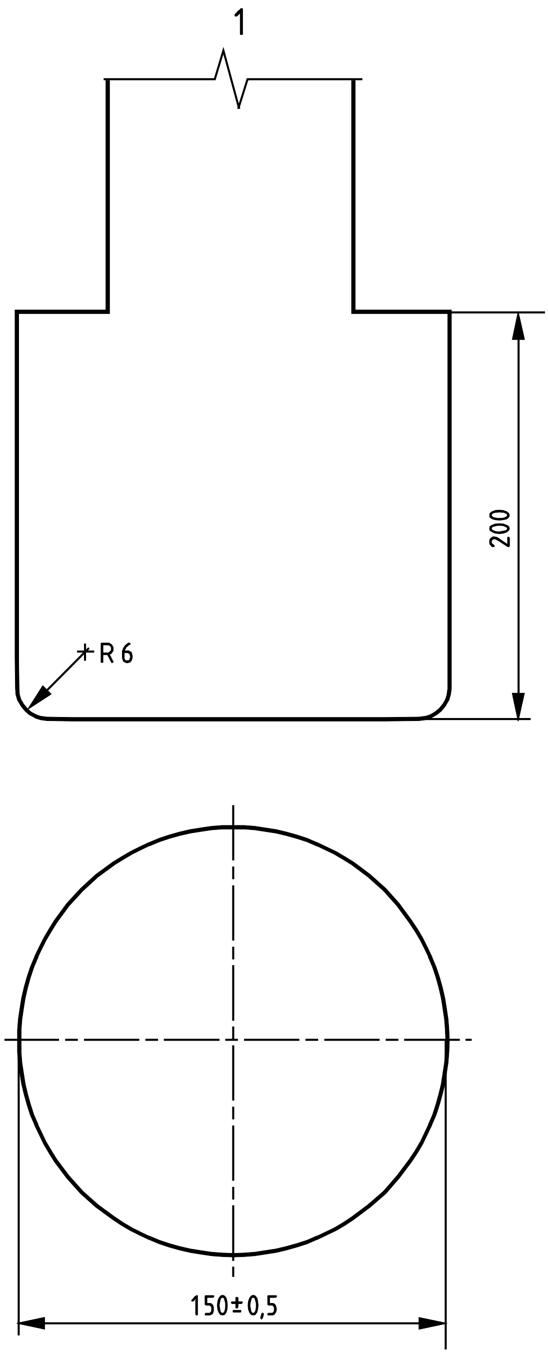


Figure B.2 — Clamping ring

B.2.2.3 **Test bar**, constructed from mild steel, or equivalent steel. It shall conform to the dimensions given in Figure B.3. It shall be designed and manufactured to ensure correct fitting with the test machine, and shall have a surface finish finer than N5 (0,8 µm).

Dimensions in millimetres



Key

1 shape and dimensions to suit test machine

Figure B.3 — Test bar

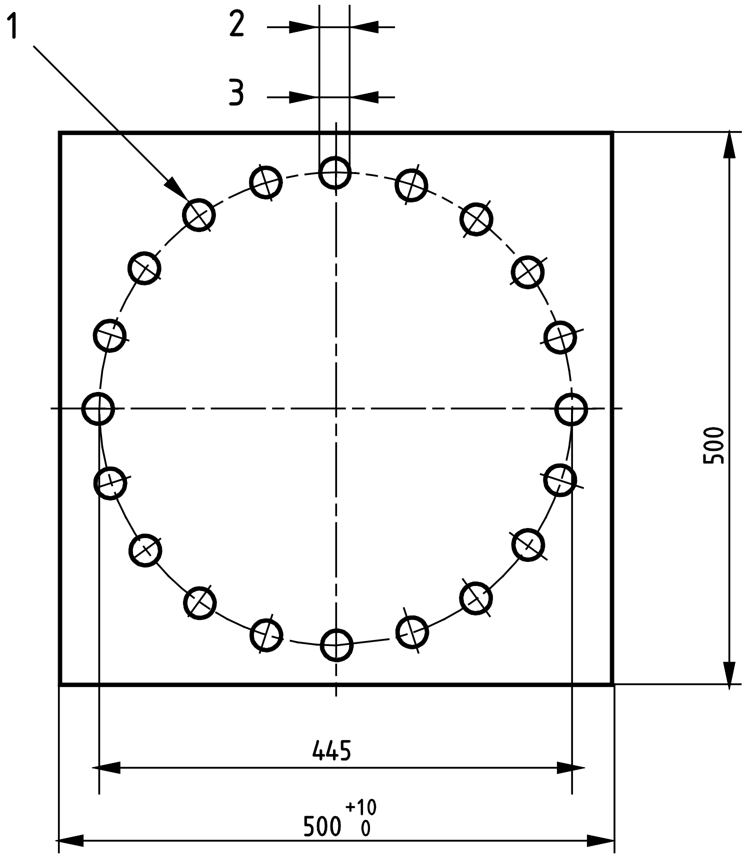
B.3 Samples of materials to be tested

The test pieces shall be:

— a sheet of the test material for comparison, conforming to Figure B.4;

— a section of the proposed combination of materials for double wall construction, conforming to Figure B.4 and with each hole fitted with an insert made from carbon steel (or other material of equivalent strength) and conforming to Figure B.5.

Dimensions in millimetres



Key

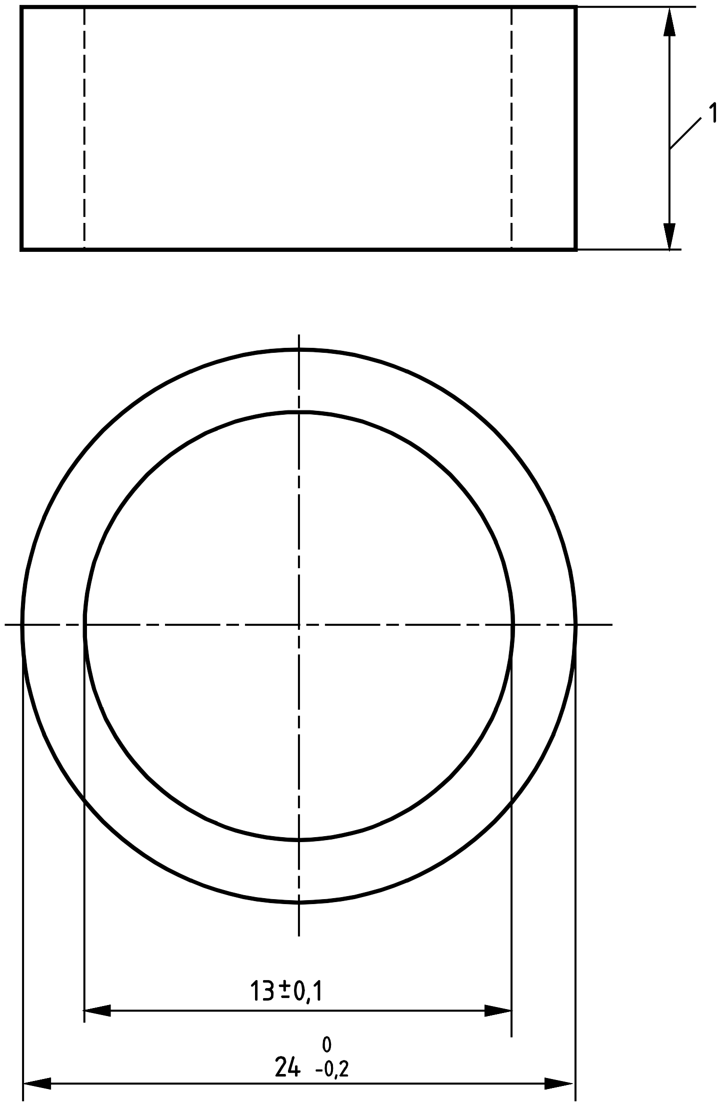
1 20 holes

2 holes diameter 13,0 ± 0,1 – for metallic test plates

3 holes diameter $24,0^{+0,2}_{-0}$ – for non-metallic test plates

Figure B.4 — Test plate

Dimensions in millimetres



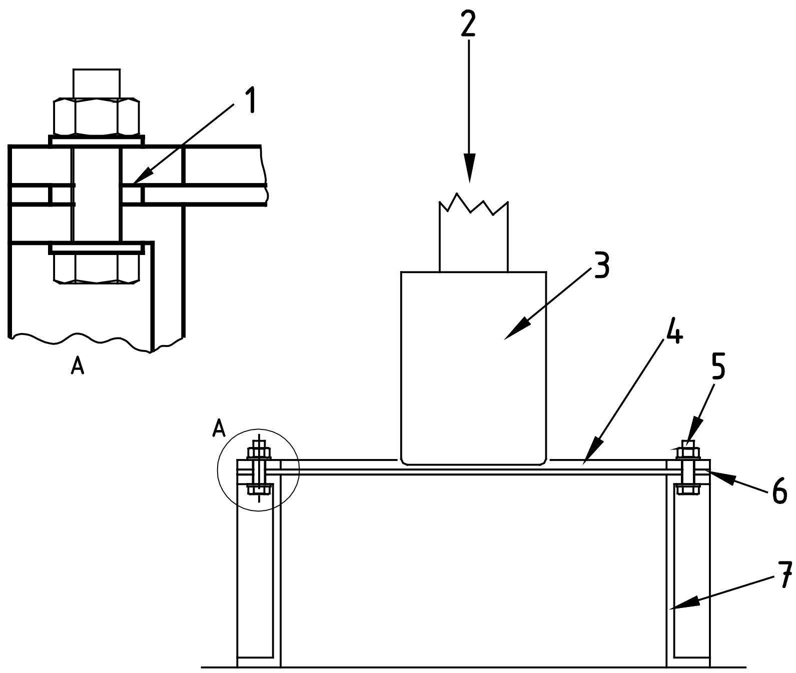
Key

1 thickness by agreement with Competent Authority to suit test plate thickness

Figure B.5 — Clamp bolt sleeve (for non-metallic test plates only)

B.4 Procedure

Each test piece shall be clamped in the mounting assembly using M12 bolts, tightened to a torque of at least 70 N.m, to secure the clamping ring into position (see Figure B.6).



Key

1 for non-metallic test plates only – use clamp bolt sleeve (see Figure B.5)

2 test force F

3 test bar (Figure B.3)

4 clamping ring (Figure B.2)

5 20 Bolts and nuts M 12 × 1,75 grade 8.8

6 test plate (Figure B.4)

7 body (Figure B.1)

Figure B.6 — Test rig assembly

The test bar shall be cleaned such that it meets the requirement for surface finish specified in B.2.2.3.

The test piece mounting assembly and the test bar shall be mounted on the test machine so that the centre of the test bar is in line with the centre of the test piece and within 5 mm of it. With the measuring instruments switched on, the test bar shall be moved at a speed of between 2 mm/s and 4 mm/s towards and into the test piece until it causes the test piece to rupture.

Three tests shall be carried out on samples of the material of the shell with a minimum thickness in accordance with 6.9.1 or 6.9.2.3 as appropriate, and three tests on samples of the actual material or combination of material(s) and the thickness(es) that are proposed for use.

B.5 Results

B.5.1 Test values

The mean of three individual test values shall be used to determine the result for specific resilience of each material tested.

Where one of the three individual test values is more than 5 % and less than 10 % from their mean, the following procedure may be adopted:

— a fourth test shall be carried out;

— the individual test that is more than 5 % and less than 10 % from the mean shall be discarded and replaced by the value obtained from the fourth test;

— the new determined result for specific resilience shall be the mean of the two remaining original individual test values plus the fourth individual test value; and

— if one of the test values now deviates by more than 5 % from the new result, the result of the test shall be rejected and the complete test procedure repeated.

B.5.2 Calculation of results

The specific resilience shall either be measured directly by the measuring system or calculated from the force/deflection graph by determination of the area under the line.

In the latter case it is permissible to use planimetry or triangulation, provided that the required accuracy can be achieved.

B.5.3 Acceptability of material

The proposed combination of materials for double wall construction shall be deemed to be acceptable provided that the result of the test of its specific resilience is not more than 5 % below the test result for the shell material at the equivalent minimum thickness.

B.6 Global resilience (see 6.9.2.2 i))

Higher values of global resiliencies and global resiliencies for other types of reinforcement members shall be confirmed by the following tests and restrictions:

— the load on the shell section (4 m length) shall be applied on one side near the centre line of the section and in radial direction (perpendicular to the direction of motion);

— the stress shall be applied constantly on the entire length of the tank section with a test beam of 430 mm width;

— the penetration test distance shall be 250 mm.

The global resilience determined for a tank section length of 4 m is a sufficient protection against damages only if the outer shell is not ruptured. If partitions, surge plates and ends are equipped with additional stiffening members, the value of the global resilience shall not exceed more than 50 % of the values given in 1, 2 or 3 of 6.9.2.2.i).

A test report shall be made of the test carried out which shall include a description of the test conditions, an evaluation of the test results and an assessment regarding the integrity of the tank construction.

A certificate shall be issued confirming that higher values of global resilience may be used.

B.7 Comparative methods to calculate the energy absorbed during an overturning or an impact. (see 6.9.2.2 j))

B.7.1 Calculation of absorbed energy

The energy absorbed by the two shells (circular or elliptical and other forms) shall be calculated from the force/deflection graph by determination of the area under the plotted line.

The comparative calculation methods shall be carried out by test or using finite element analysis (FEA); if FEA is used for the verification, A.3 shall be taken into account; in addition the computer software and the procedure for its use shall be validated by the Competent Authority for elasto-plastic analysis.

The manufacturer shall provide to the Competent Authority the relevant validation examples (comparisons between predicted calculation results and actual test results).

B.7.2 Procedure to be adopted:

B.7.2.1 Overturning

The energy absorbed shall be evaluated according to the global resilience method as per B.5 and in particular:

a) the load on the shell shall be applied on one side near the centre line of the section, in radial direction (perpendicular to the direction of travel);

b) the stress shall be applied constantly on the entire length of the tank section with a test beam of 430 mm width and 4 m length;

c) the penetration test distance shall be 250 mm (or less in the event of shell rupture).

B.7.2.2 Impact on lateral side and end

The energy absorbed shall be evaluated as follows:

The test force shall be applied with a bar as described in B.2.2.3 in the following positions for the shell and for the end:

— In the centre line of the section, in radial direction, perpendicular to the direction of travel and in the middle between two adjacent partitions and/or surge plates;

— In the centre of the end in the direction of travel;

— An increased load is applied to the test bar to reach a penetration distance of 250 mm or to shell rupture (whichever comes first).

Annex C
(normative)

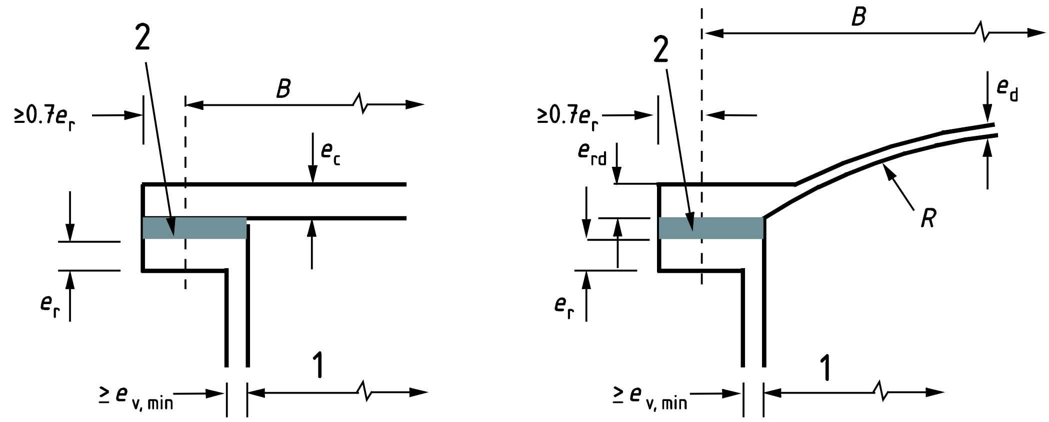
Design of neckrings, flanges and closures

Neckrings, flanges and closures shall conform to:

— the criteria shown in Figure C.1 and the requirements specified in Table C.1, or

— EN 13317, or

— the relevant section of EN 14025.



Key

1 average of major and minor diameters

2 full face gasket only

B pitch circle diameter

Figure C.1 — Design of neckrings, flanges and closures

Table C.1 — Requirements for neckrings, flanges and closures

Parameter	Requirement
e_c	The thickness of a flat closure, e_c' in millimetres (mm), shall be not less than $(0{,}03 \times B^2 \times P_x / \sigma_c)^{0,5}$ or $e_{v, min}$, whichever is the greater.
e_d	The thickness of a domed closure, e_d' in millimetres (mm), shall be not less than $((P_x \times R) / (20 \times \sigma_c))$ or $e_{v, min}$, whichever is the greater.
e_r	The thickness of a flange, e_r, in millimetres (mm), shall be not less than $(0{,}0445 \times B^2 \times P_x/\sigma_r)^{0,5}$ or $e_{v, min}$ whichever is the greater.
e_{rd}	The thickness of a domed closure flange, e_{rd}' in millimetres (mm), shall be not less than $(0{,}083 \times P_x \times R/\sigma_c)$ or the calculated value of e_c, whichever is the greater.
S_B	The total tensile area, S_B' in square millimetres (mm^2), of all bolts on pitch circle diameter B shall be not less than $(N \times B^2 \times P_x \times 10^{-4})$, where $N = 8$.

Annex D
(informative)

Examples of welding details

D.1 General

This annex shows examples of sound and currently accepted practice; these are not the only methods available and it is not intended that they should restrict the development of welding technology in any way.

The figures of this annex generally illustrate the penetration of the weld material, but not the required preparation of the parts to be joined which should be provided where necessary to achieve the effective penetration depth.

D.2 Tank construction

D.2.1 Fillet welds

Typical examples of effective depth of fillet welds are shown in Figure D.1.

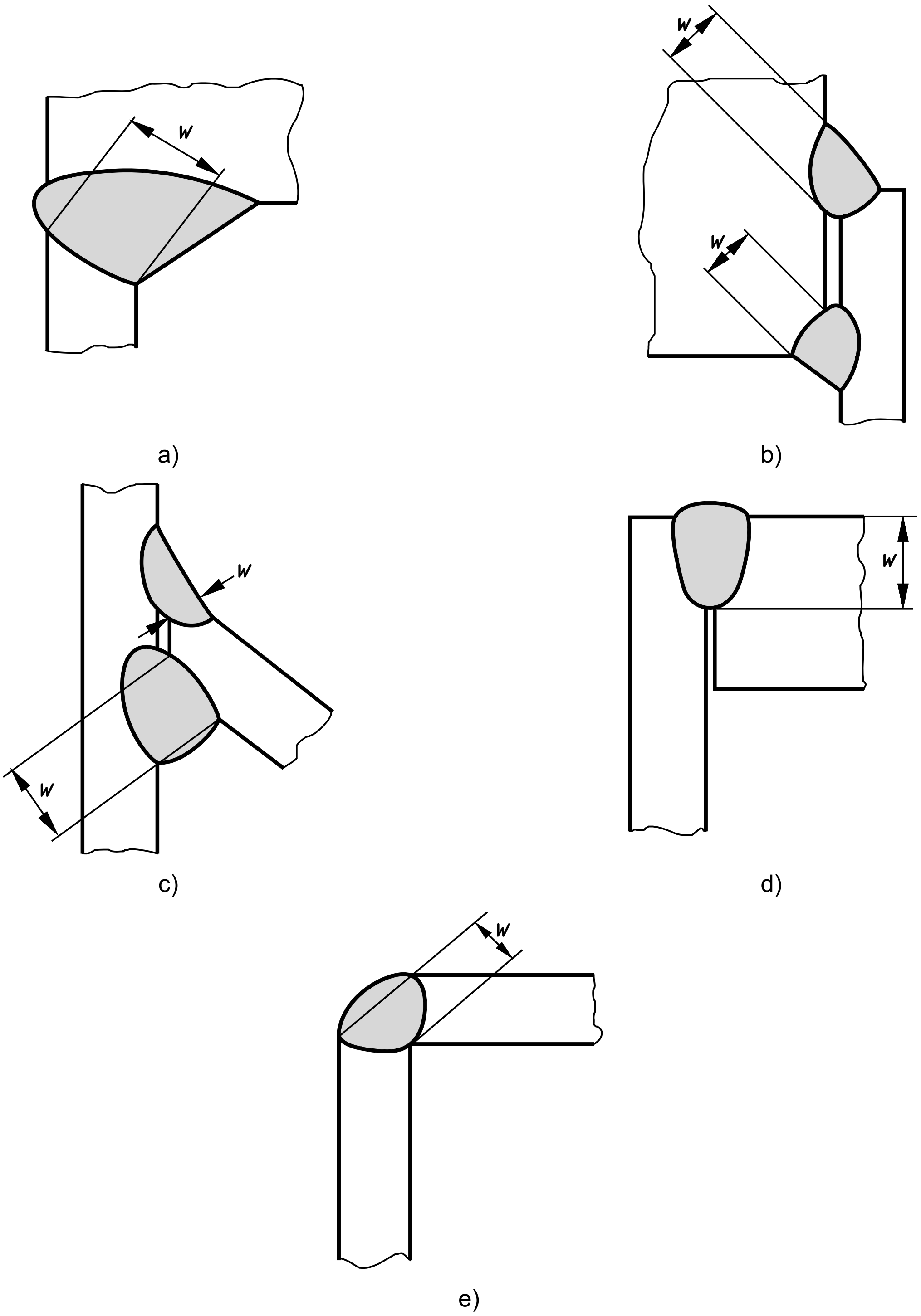


Figure D.1 — Typical examples of effective depth of fillet welds

D.2.2 Joint types

D.2.2.1 General

A joint can be one of the following four types:

a) butt joint (D.2.2.2);

b) lap joint (D.2.2.3);

c) corner joint (D.2.2.4);

d) joint, other than a corner type, for partitions, surge plates and baffles (D.2.2.5).

D.2.2.2 Butt joints

D.2.2.2.1 Material of equal thickness

When welding materials of equal thickness (see Figure D.2):

a) the axes of the two parts to be joined should be within the manufacturing tolerances specified in 7.5.1;

b) all welds should be full-penetration welds and the thickness of the joint should be greater than or equal to the smallest thickness of the parts to be joined.

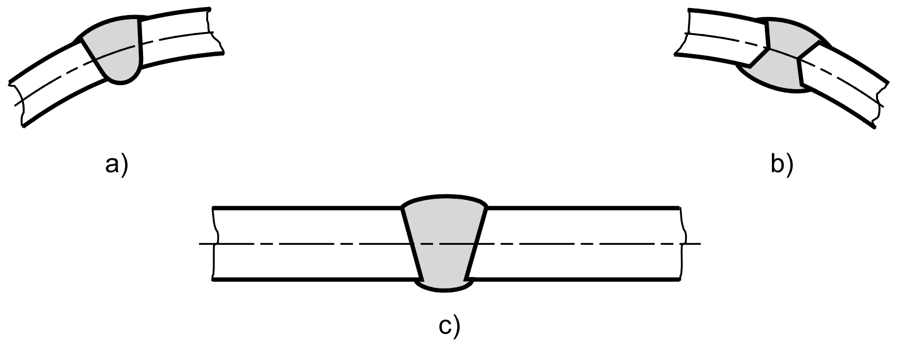


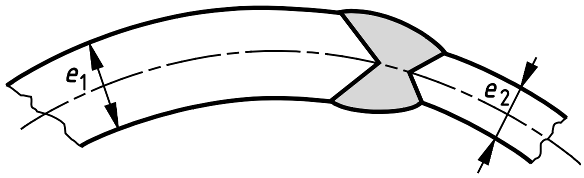
Figure D.2 — Typical examples of butt joints with plates of equal thickness

D.2.2.2.2 Material of different thickness

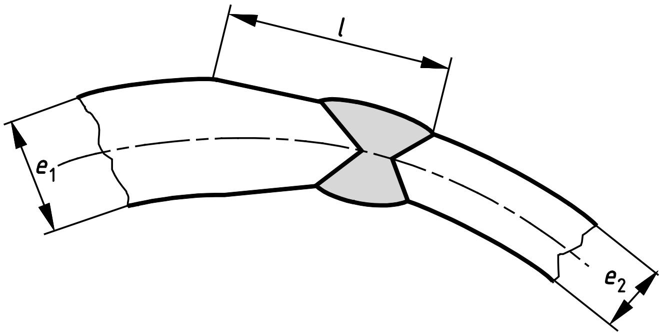
When welding material of different thickness:

a) the axes of the two parts to be joined should be within the manufacturing tolerances specified in 7.5.1;

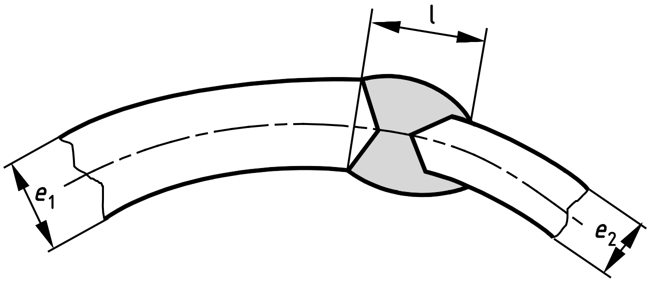
b) the maximum slope of the joint should not exceed one in three [see Figure D.3 b) and c)]. However, this slope is not necessary when the misalignment of the face is less than or equal to 2 mm [see Figure D.3 a) and Figure D.4 a)].



a)



b)



c)

Figure D.3 — Typical examples of butt joints with plates of different thickness

When joining a shell to an end:

a) the maximum slope that the joint may attain is one in three; and

b) the centrelines of the parts to be joined can be offset in relation to each other but this offset should not exceed the alignment of the outer or inner faces (see Figure D.4).

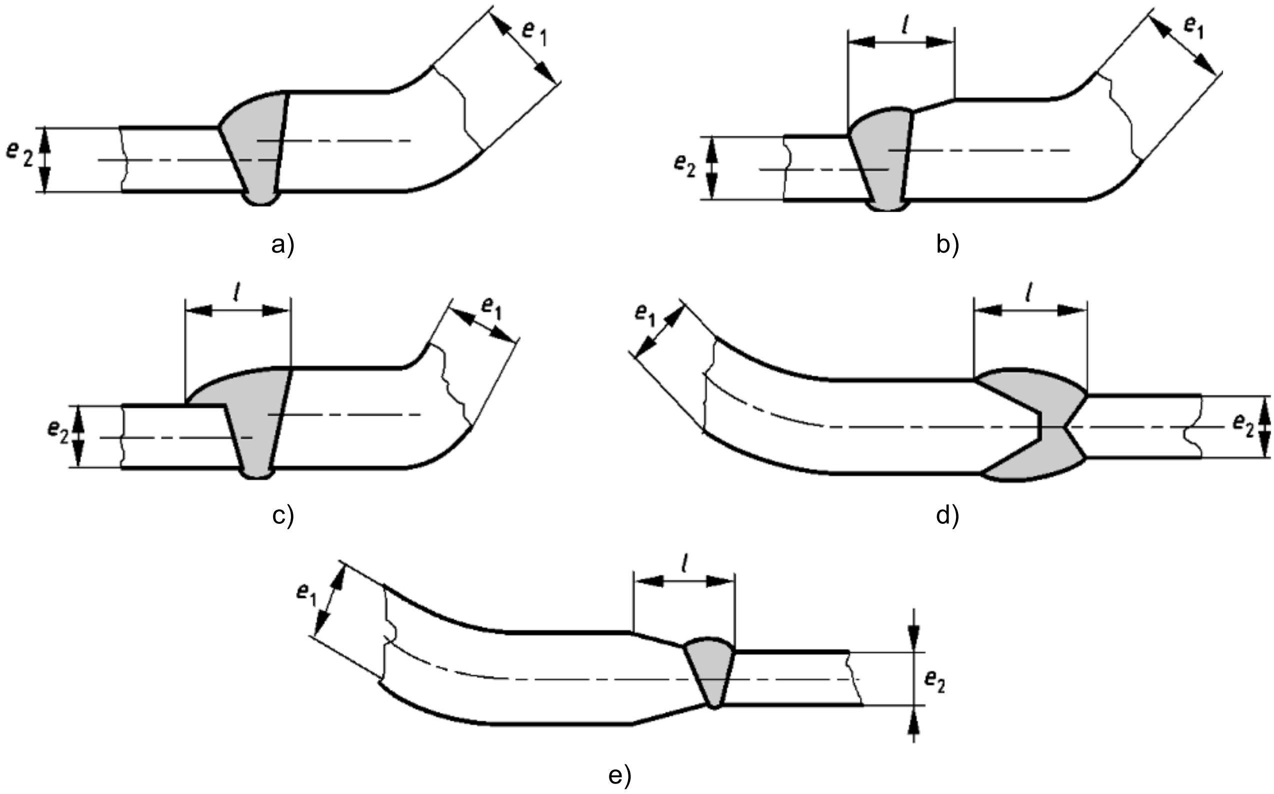


Figure D.4 — Typical examples of end-to-shell butt joints

Permanent backing joints or swaged-edge joints should only be used for the circumferential joining of an end, partition, surge plate or baffle to a shell where internal access is not possible. For swaged-edge joints, the total length of the edge should be at least 2,2 times the thickness of the swaged part and the weld should converge at the base of the seam to a width greater than or equal to 0,7 times the thickness of the swaged part (see Figures D.5).

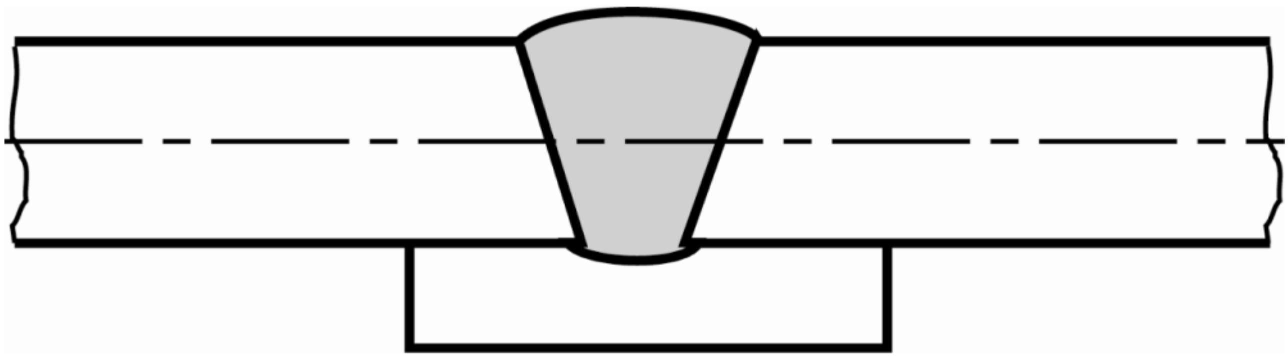


Figure D.5 — Typical butt joint with backing plate

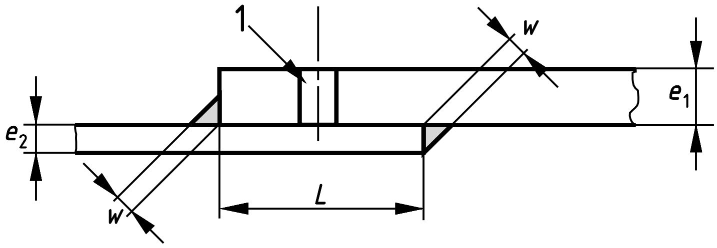
D.2.2.3 Lap joints

The overlap (L) of a lapped joint should be at least three times the thickness of the thinnest part, with a minimum of 15 mm. The joint should include a tell-tale hole.

The welds should be carried out on a perpendicular edge (see Figures D.6, D.7 and D.8).

When a lap joint is used for joining an end to a shell, the dimensions shown in Figure D.7 a) should be used.

Single-weld lap joints are acceptable for ends having an outward facing concavity; the joint should include an overlap of at least 15 mm (see Figure D.8).

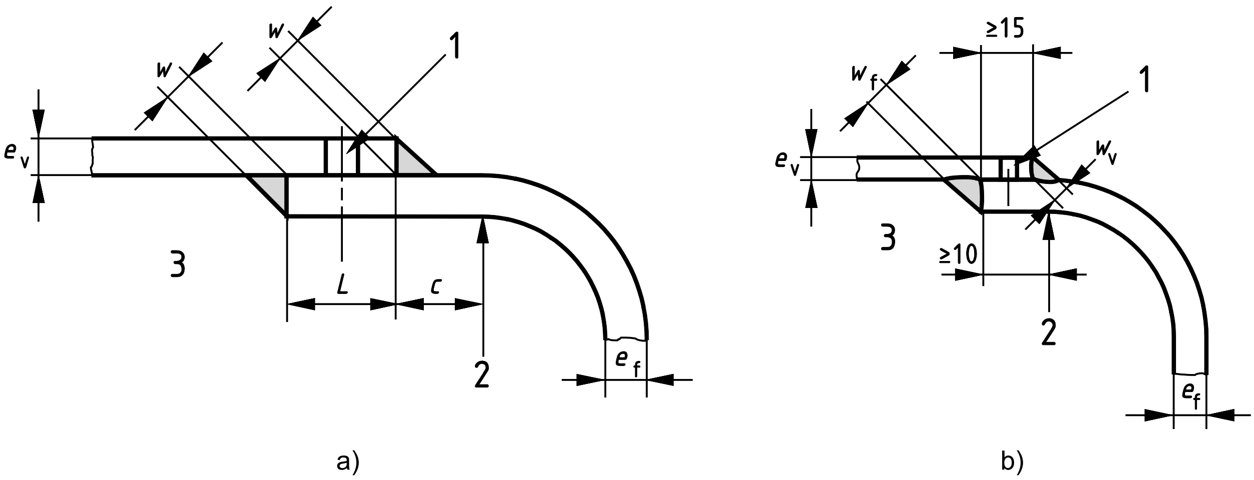


Key

1 tell-tale hole

Figure D.6 — Typical lap joint

Dimensions in millimetres



Key

$c \geq 2\ e_v$

$e_v \leq 8$ mm $W_v \geq 0{,}7\ e_v$

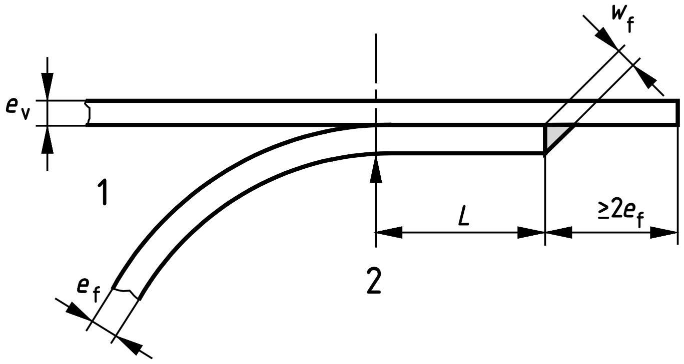
$e_f \leq 8$ mm $W_f \geq 0{,}7\ e_v$

1 tell-tale hole

2 start of radius

3 inside of tank

Figure D.7 — Typical lap joints of an end to a shell



Key

1 inside of tank

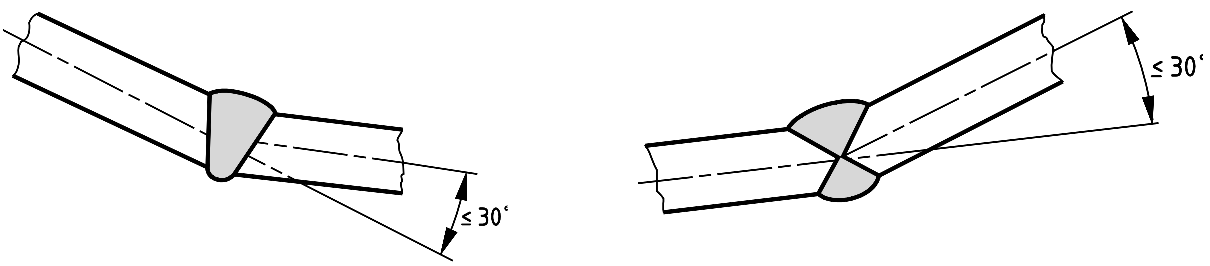
2 start of radius

Figure D.8 — Typical single weld lap joint of an end to a shell

D.2.2.4 Corner joints

D.2.2.4.1 Corner joints forming a component part of the main shell

The weld should be a full-penetration weld (see Figure D.9).



a) b)

Figure D.9 — Typical corner joints

D.2.2.4.2 Other corner joints

For ends, partitions, surge plates and baffles where flanged edges are not used, the shell should be reinforced.

Where a reinforcing plate is used, it should be inserted between the shell and the end, partition, surge plate or baffle (see Figure D.10 a)).

The reinforcing plate should be:

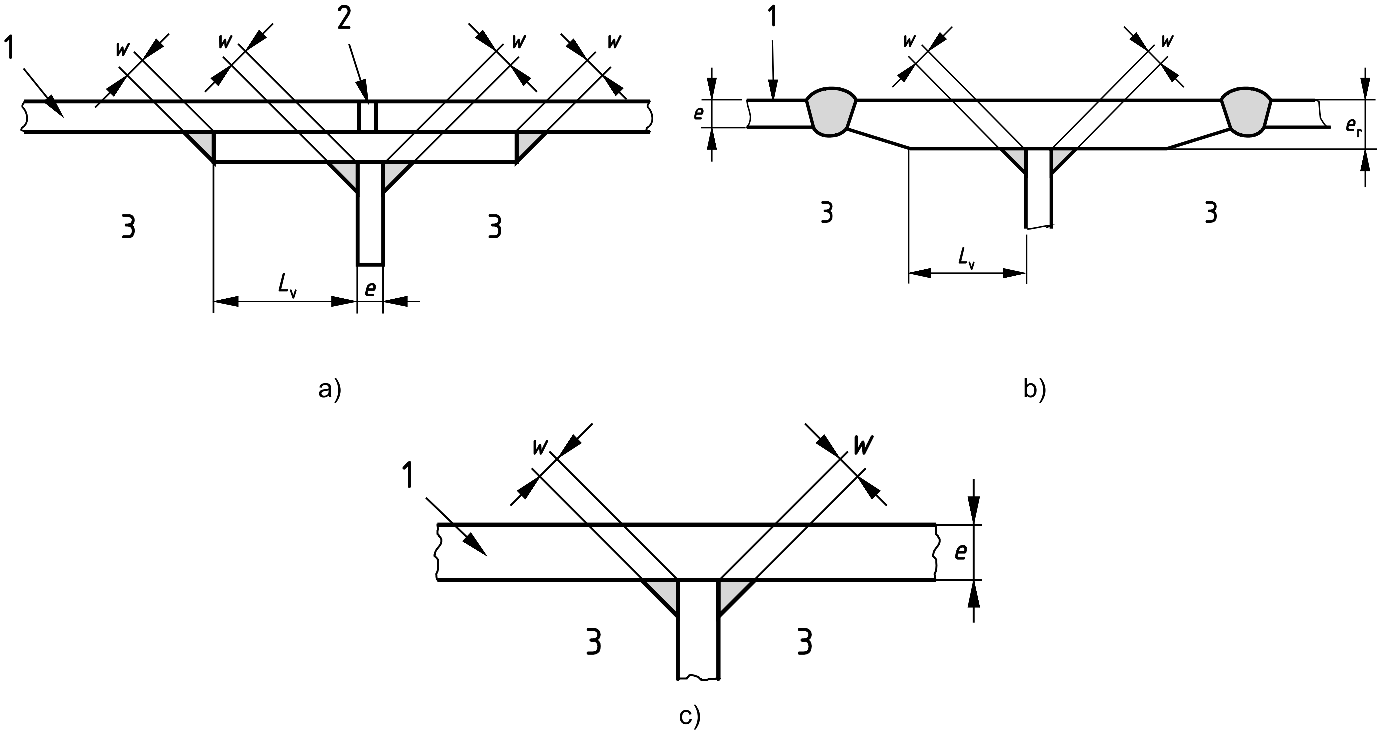
a) at least as thick as the thinnest part of shell, and in any case not less than 3 mm thick;

b) arranged in such a manner that L_r is greater than or equal to 3 e without being less than 15 mm;

c) continuously welded to the part and to the shell.

Where a stiffening ring is used, welded between sheets that form the shell, its thickness should be at least 3 mm greater than the minimum required by 6.9.1 [see Figure D.10 b)].

Where the thickness of the shell is increased, it should be at least 1,5 times the minimum thickness required by 6.9.1, and in any case not less than 3 mm greater than that minimum [see Figure D.10 c)].



Key

1 shell

2 tell-tale hole

3 inside of tank

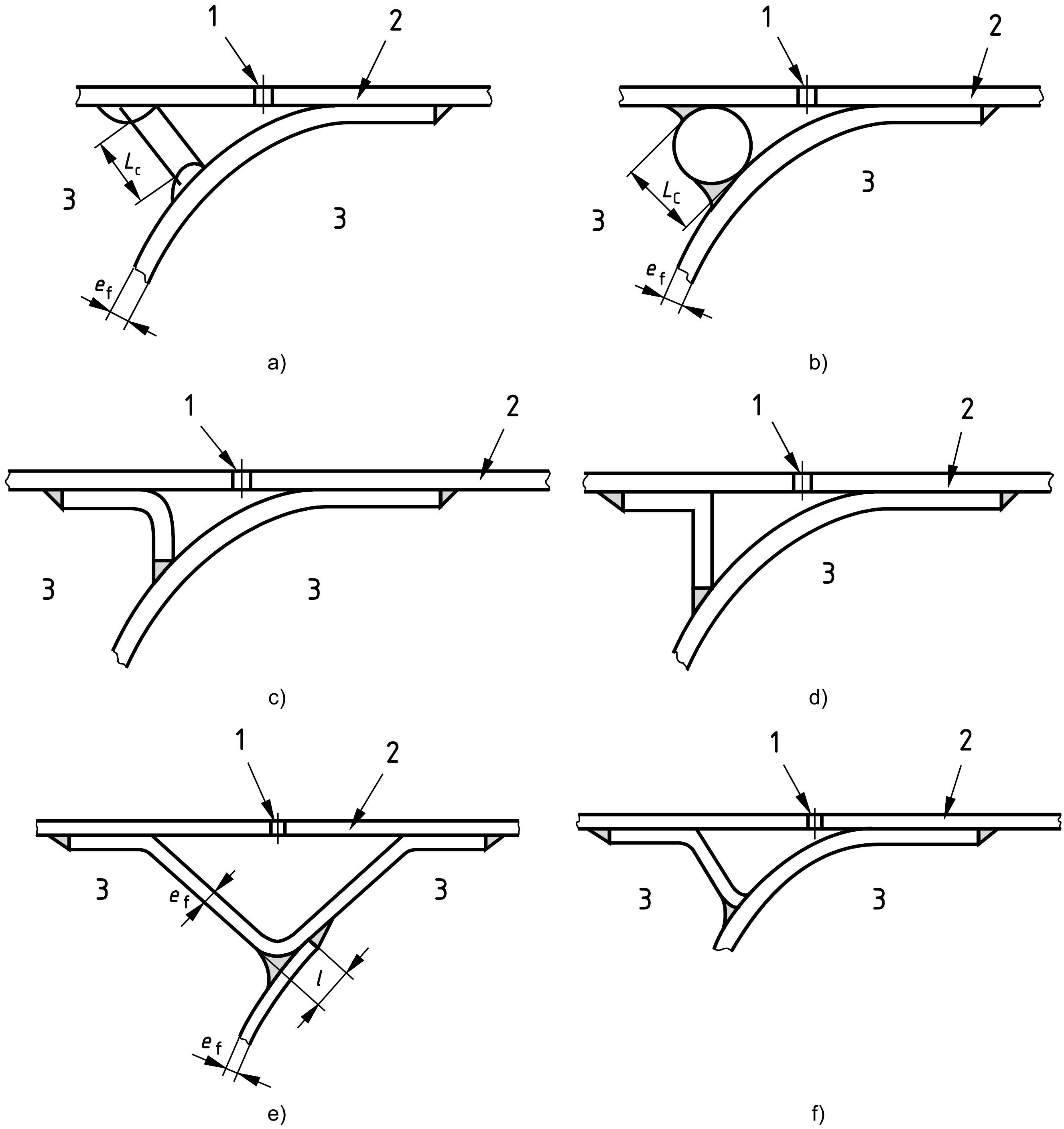
Figure D.10 — Typical corner joints for bulkheads and ends

D.2.2.5 Joints, other than corner joints, of internal partitions and surge plates

D.2.2.5.1 Reinforced joints

Examples of typical reinforced joints are shown in Figure D.11.

Where a reinforcing piece is used (see Figure D.11) its length L_c shall be greater than or equal to $3e_f$ without being less than 15 mm.



Key

1 tell-tale hole

2 shell

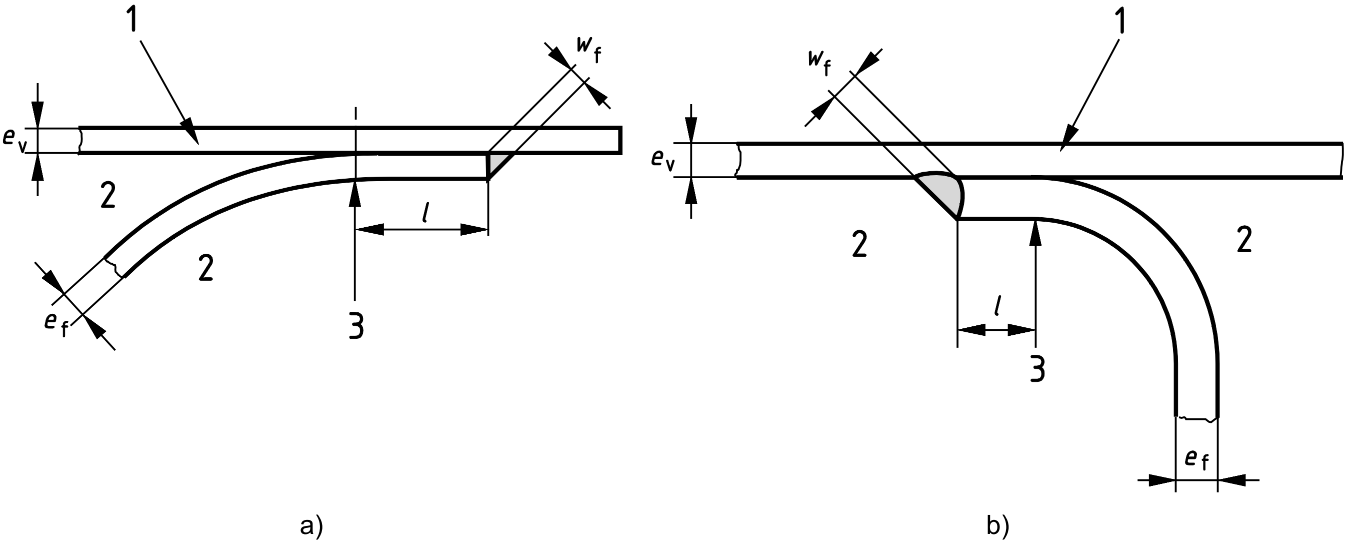
3 inside of tank

Figure D.11 — Typical reinforced joints

D.2.2.5.2 Single-weld joints

Examples of typical single-weld joints are shown in Figure D.12.

The overlap (L) of a lapped joint should be at least three times the thickness of the thinnest part, with a minimum of 15 mm.



Key

1 shell

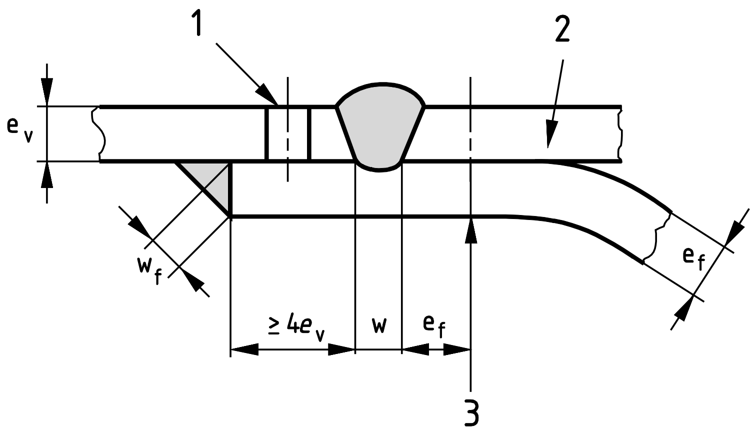
2 inside of tank

3 start of radius

Figure D.12 — Typical single-weld joints

D.2.2.5.3 Double-weld joints

An example of a typical double-weld joint is shown in Figure D.13.



Key

1 tell-tale hole

2 shell

3 start of radius

Figure D.13 — Typical double-weld joint

D.2.2.5.4 Partition and end plate to shell joints

Where partition joints incorporate a stiffening ring, welded between sheets that form the shell, its thickness (*t*) should be at least 3 mm greater than the minimum required by 6.9.1 (see Figure D.14). Examples of some typical end plate to shell joints are shown in Figure D.15.

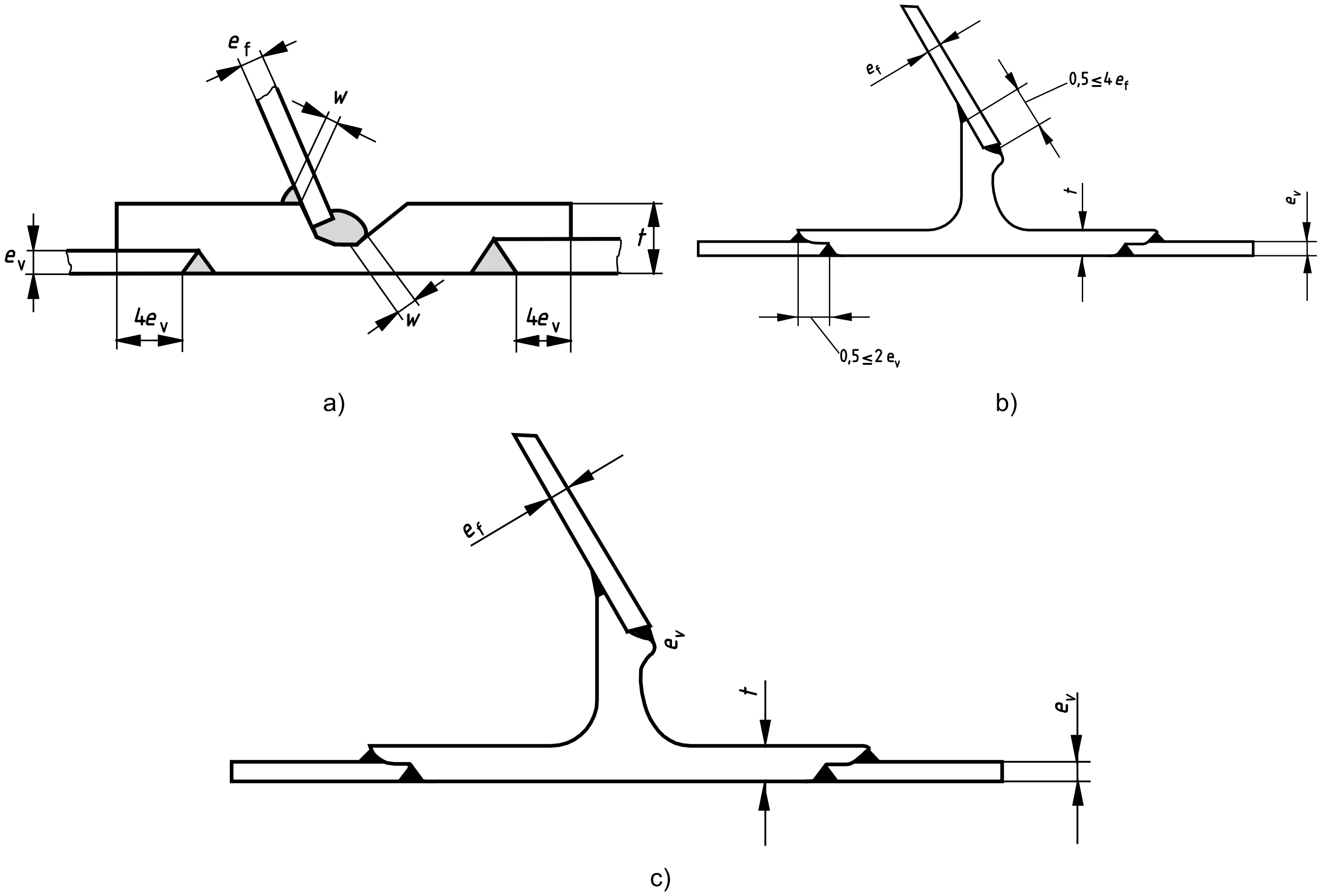
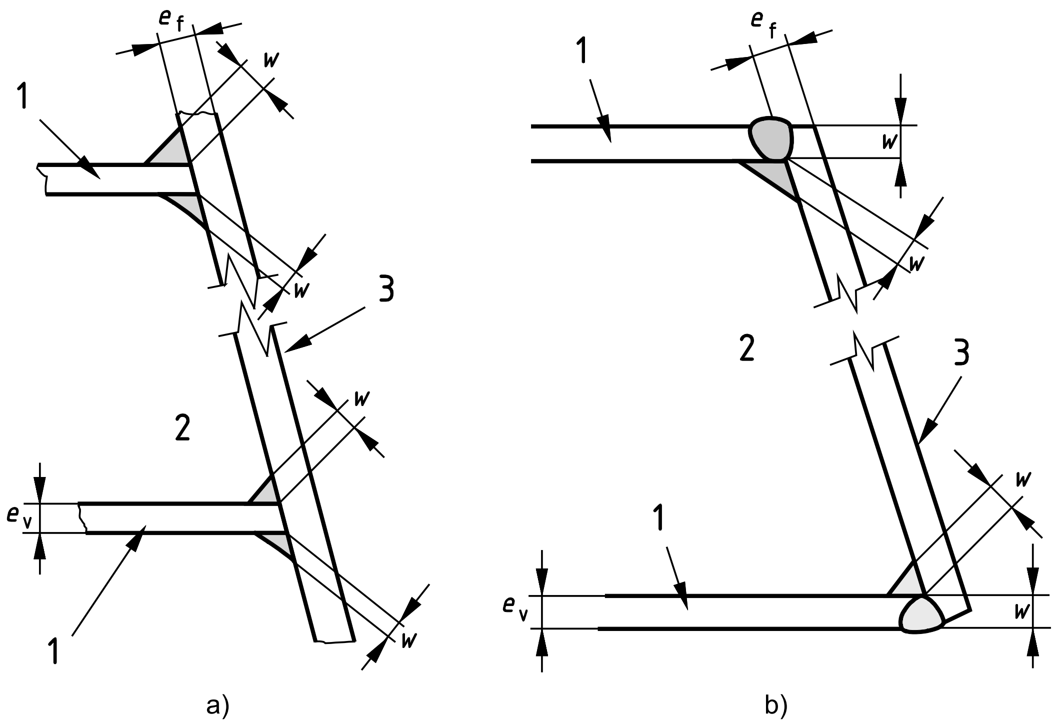


Figure D.14 — Typical partition joints



Key

1 shell

2 inside of tank

3 radiused end (sloping or vertical)

Figure D.15 — Typical examples of end-plate-to-shell joints

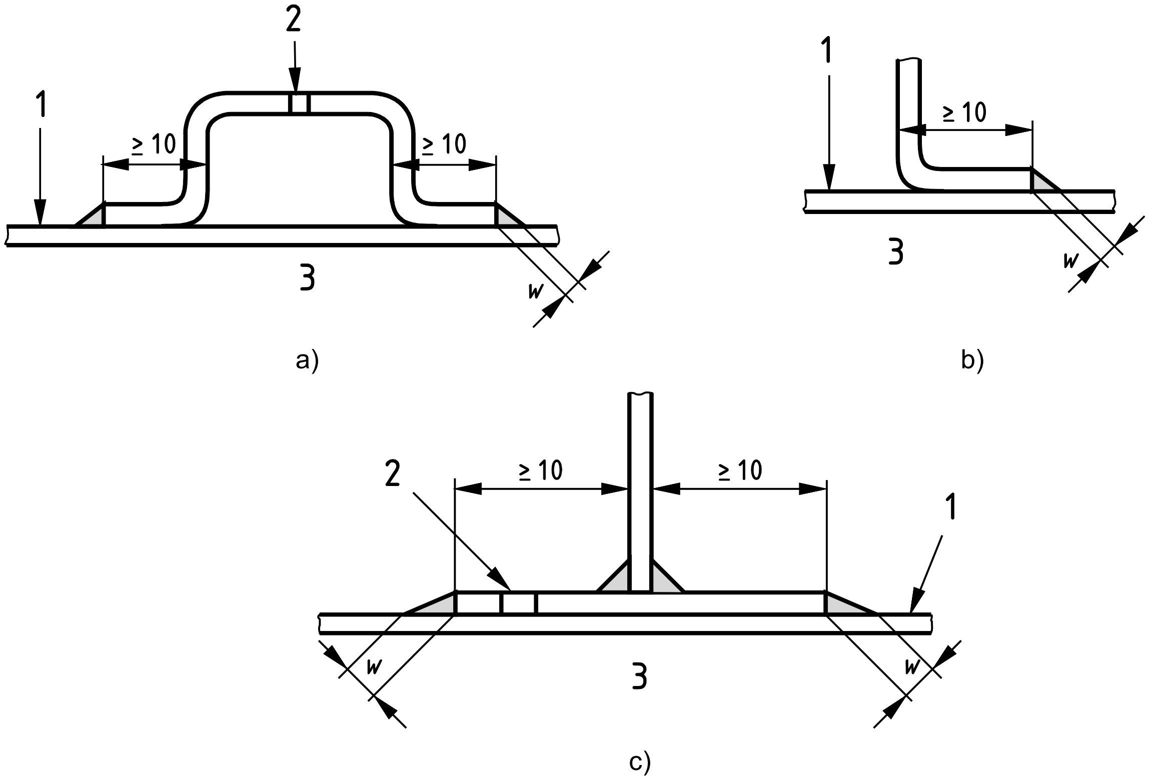
D.3 Attachment of reinforcements

D.3.1 Attachment of reinforcements designed to absorb dynamic stress

External reinforcements can be welded on to the tank, either by continuous or discontinuous welding.

Typical examples of reinforcement attachment joints are shown in Figure D.16.

Dimensions in millimetres



Key

1 shell

2 tell-tale hole

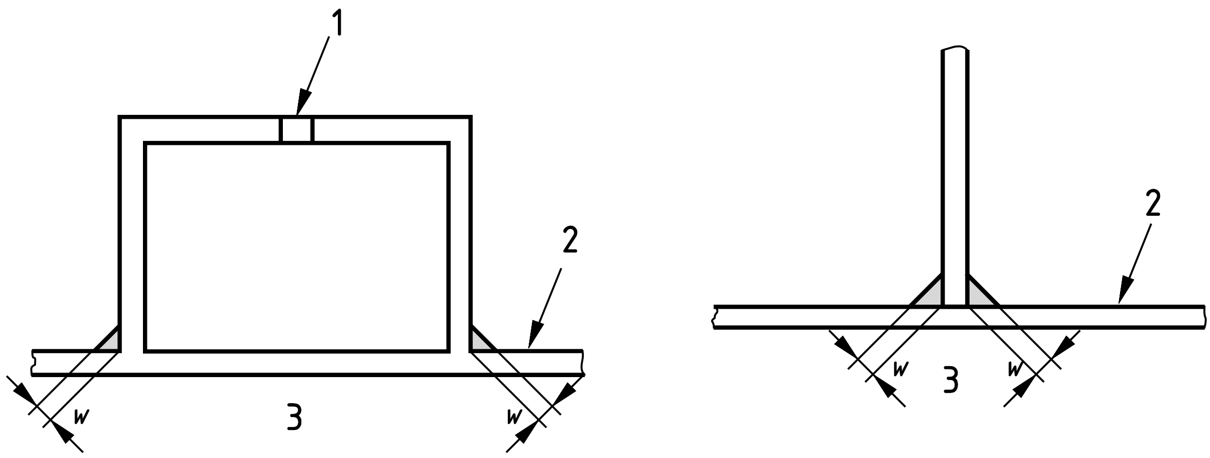
3 inside of tank

Figure D.16 — Typical reinforcement attachment joints

D.3.2 Attachment of reinforcements not designed to absorb dynamic stress

Reinforcements can be welded without either a distribution zone or a distribution plate. Where the reinforcement is external, the welds can be continuous or discontinuous; where the reinforcement is internal the welds should be continuous.

Typical examples of non-absorbent reinforcement attachment joints are shown in Figure D.17.



a) b)

Key

1 tell-tale hole (when weld is continuous)

2 shell

3 inside of tank

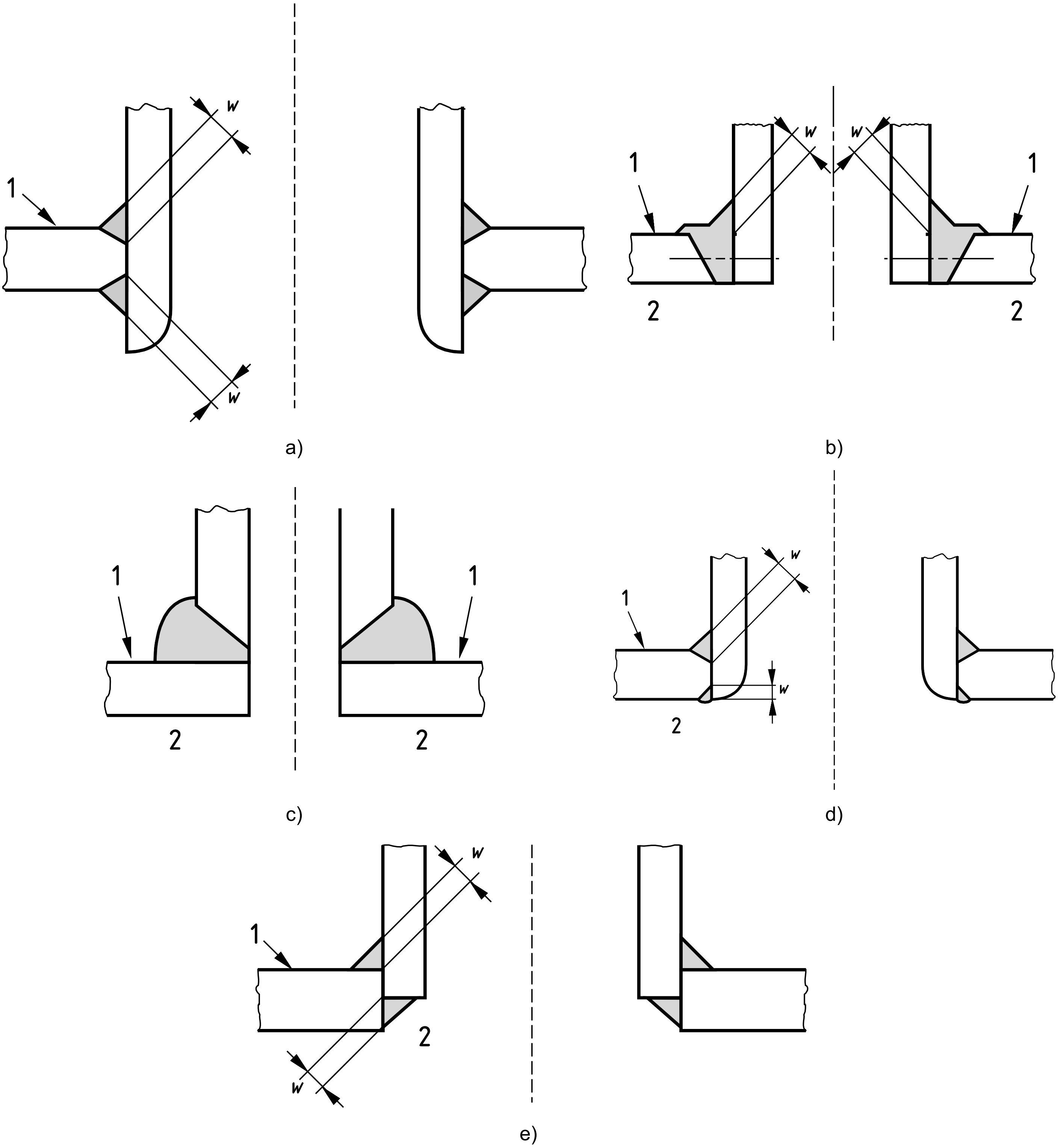
Figure D.17 — Typical non-absorbent reinforcement attachment joints

D.4 Attachment of branches

When joining branches or branch pipes onto shells:

a) for double weld corner joints, the throat depth of each weld should be at least 0,7 times the thickness of the thinnest part (see Figures D.18 and D.19);

b) for lap joints or sleeve joints (see Figure D.20), w should be at least 0,7 times the thickness of the thinnest part, and the overlap length (L) should be at least 3 times the minimum thickness.

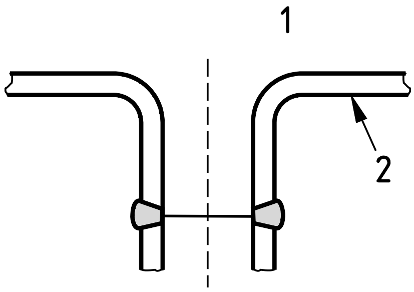


Key

1 shell

2 inside of tank

Figure D.18 — Typical double-weld branch attachment joints

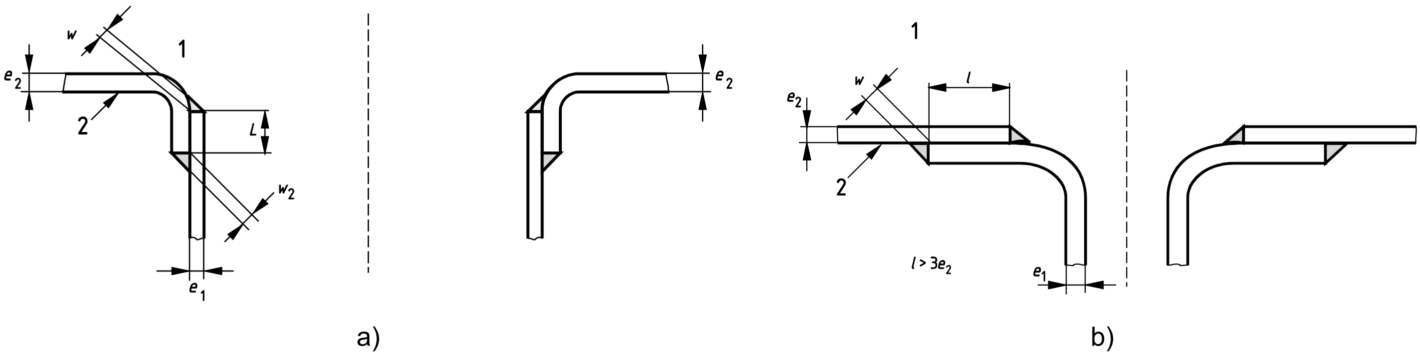


Key

1 inside of tank

2 shell

Figure D.19 — Typical branch butt joint



Key

1 inside of tank

2 shell

Figure D.20 — Typical sleeve attachment joints

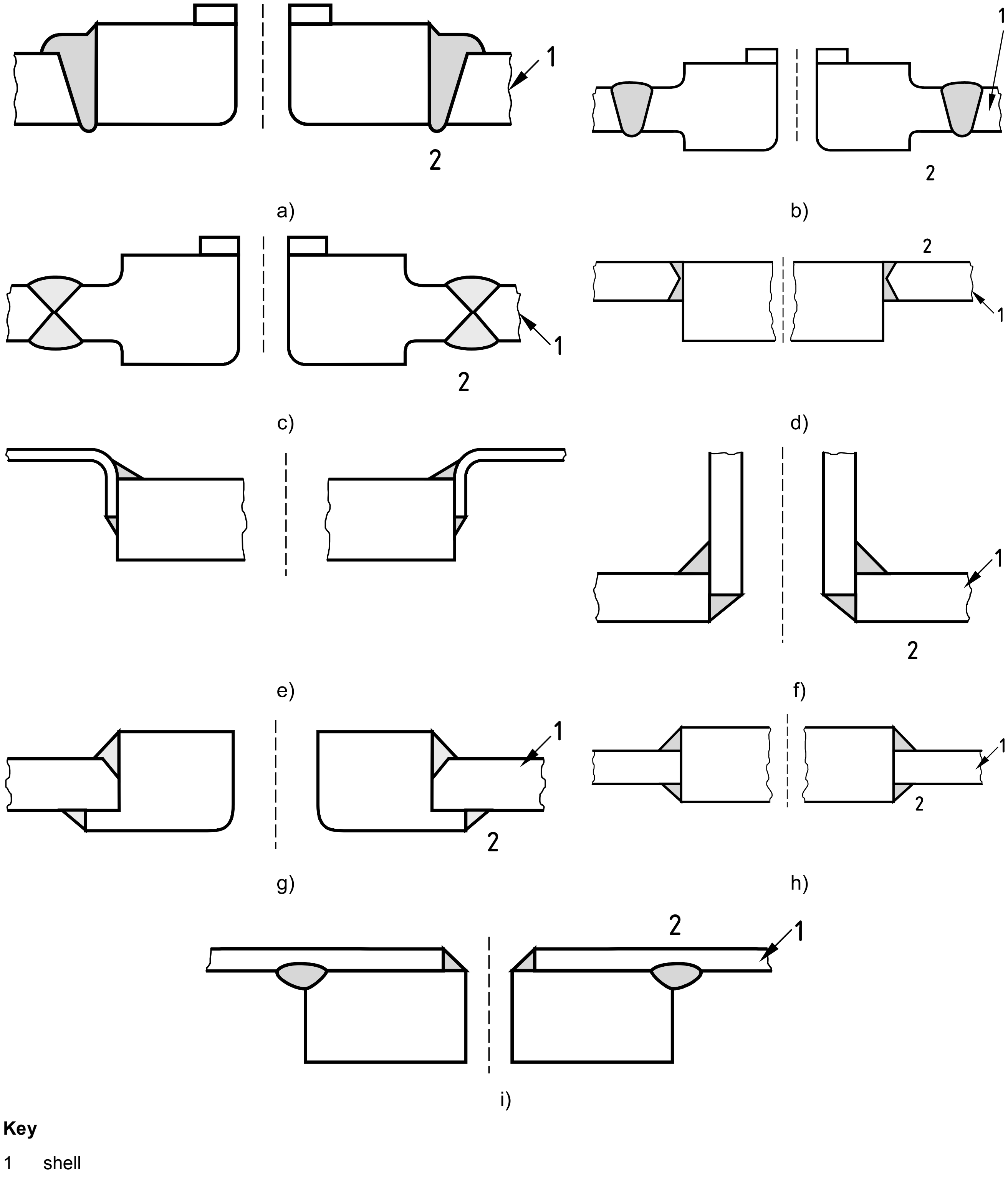
D.5 Attachment of flanges, collars and reinforcing pads to the shell

Flanges, collars and reinforcing pads should be joined by one of the following means:

a) full-penetration weld (see Figure D.21 a) and b));

b) two interpenetrated welds (see Figure D.21 c) and d));

c) two welds, the throats of which are greater than or equal to 0,7 times the thickness of the thinnest part (see Figure D.21 e) to i)).



Key

1 shell

2 inside of tank

Figure D.21 — Typical attachment joints for collars, flanges and pads

D.6 Attachment of flanges onto branches

Typical examples of branch-to-flange attachment joints are shown in Figure D.22.

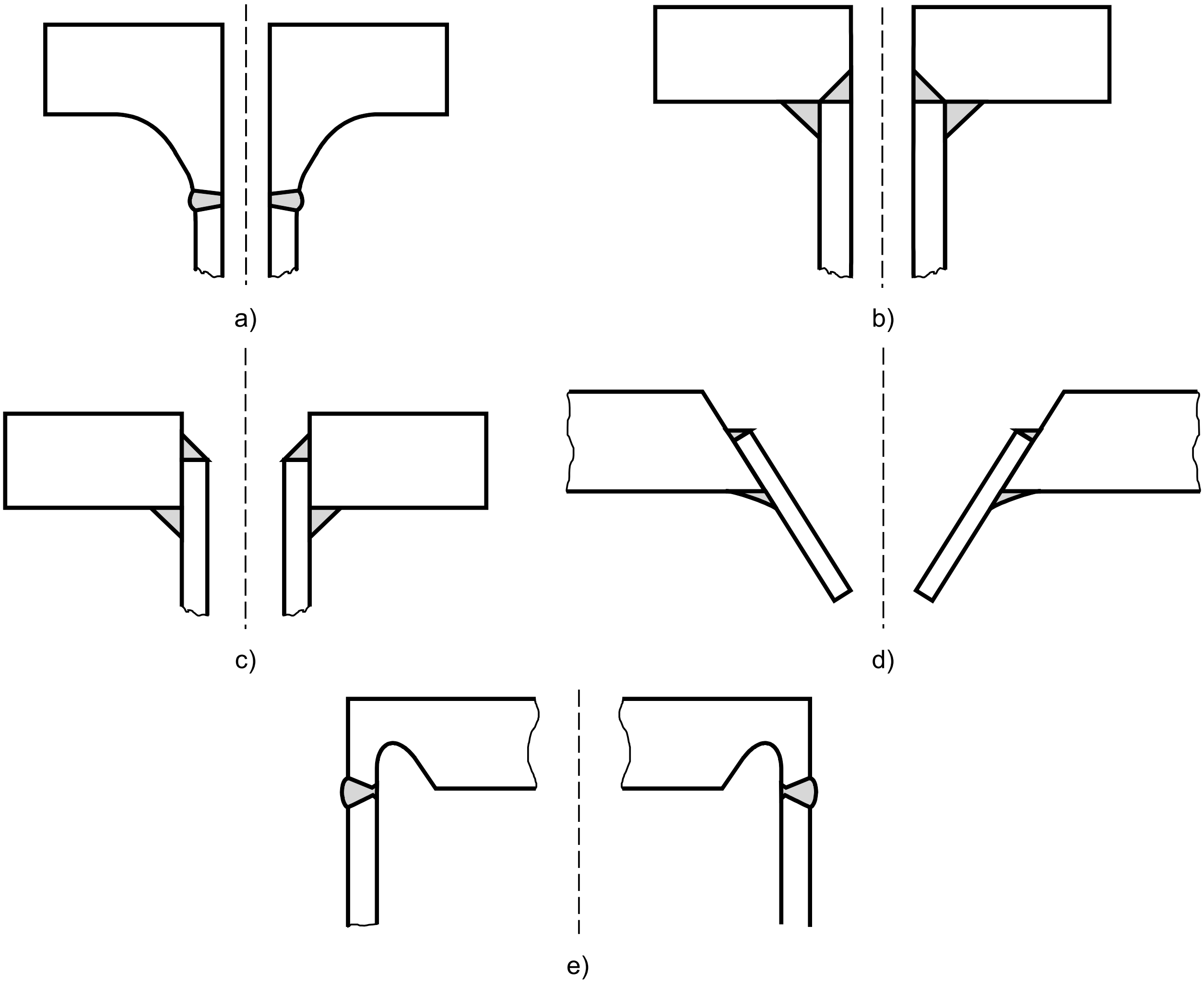


Figure D.22 — Typical branch-to-flange attachment joints

D.7 Attachment of heating channels to shells

Attachments should not be load bearing. The method of attachment, the shell, and the heating channel should be designed to withstand the pressure applied by the heating media.

Attachments can be joined to the shell by one of the following means:

a) with one single weld on a worked edge (see Figure D.23 a) and b));

b) with the aid of a welded intermediate part (see Figure D.23 c) to e)).

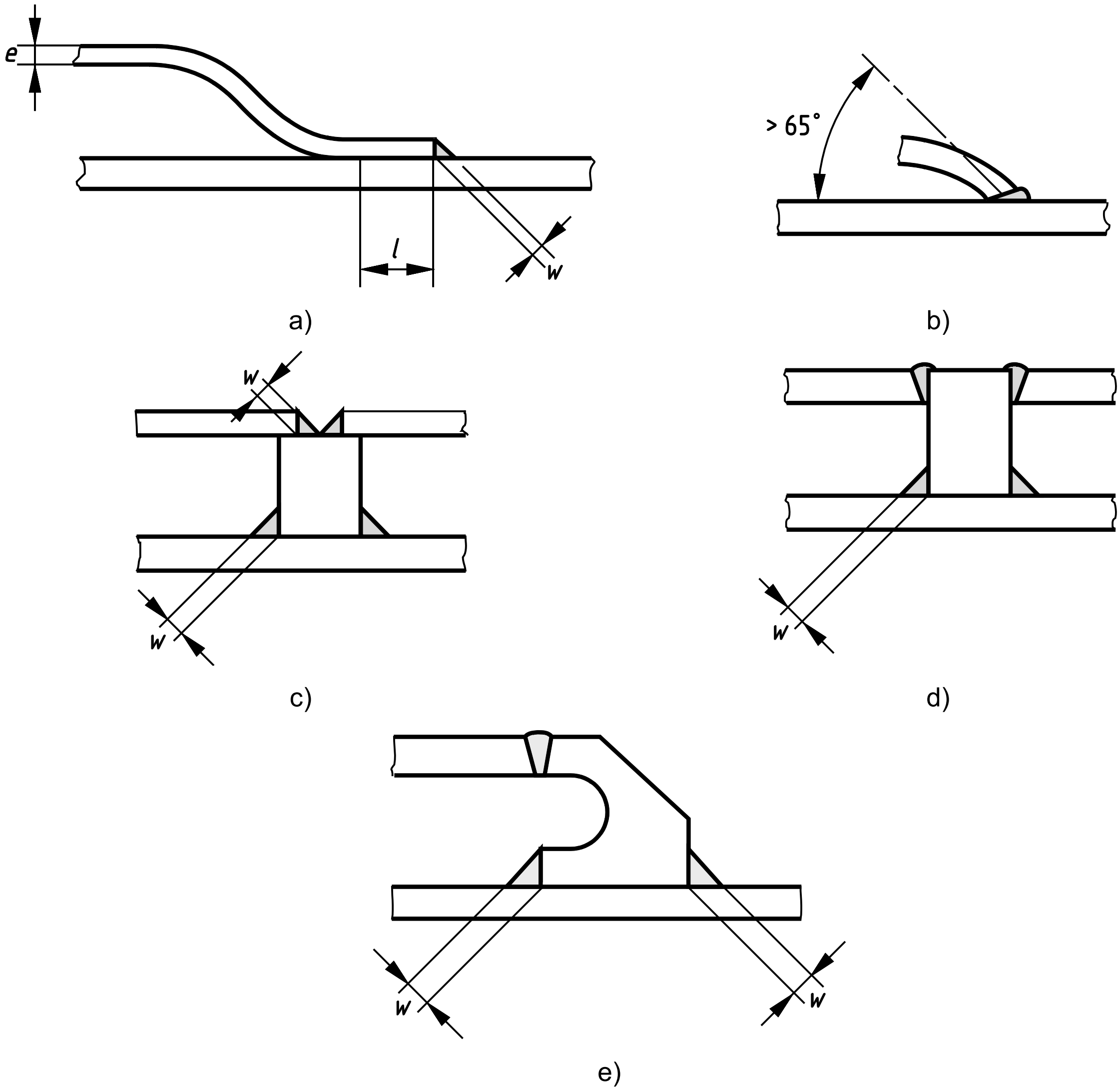


Figure D.23 — Typical attachment of heating channels to shells

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1) Commonly known as ADR.

2) Commonly known as RID.

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