



BSI Standards Publication

Tanks for the transport of dangerous goods — Metallic gravity-discharge tanks — Design and construction

National foreword

This British Standard is the UK implementation of EN 13094:2020+A1:2022. It supersedes BS EN 13094:2020 which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to CEN text carry the number of the CEN amendment. For example, text altered by CEN amendment A1 is indicated by A1 A1.

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Citernes métalliques à vidange par gravité - Conception
et construction

Tanks für die Beförderung gefährlicher Güter -
Metalltanks mit Entleerung durch Schwerkraft -
Auslegung und Bau

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European foreword

This document (EN 13094:2020+A1:2022) has been prepared by Technical Committee CEN/TC 296 “Tanks for the 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of an identical text or by endorsement, at the latest by November 2022, and conflicting national standards shall be withdrawn at the latest by November 2022.

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

This document includes Amendment 1 approved by CEN on 28 April 2022.

This document supersedes A1 EN 13094:2020 A1.

The start and finish of text introduced or altered by amendment is indicated in the text by tags A1 A1.

Compared with EN 13094:2015, the following are the principal changes that have been made:

- a) changes to reflect the change in scope from low pressure to gravity-discharge applications;
- b) updates to the normative references;
- c) changes to the terms, definitions, symbols and abbreviations;
- d) simplification of service equipment requirements by reference to regulatory requirements;
- e) clarification of impact strength required at lower design temperatures;
- f) new requirements on the cross-sectional shapes of shells for non-circular cross-sections, sumps and other external projections and cut-outs within the contour of a side or bottom of the shell;
- g) clearer requirements on design verification;
- h) expansion of provisions for the dynamic conditions used for tank design;
- i) provisions for pressure conditions revised to reflect the change in scope;
- j) clarification that maximum stress refers to maximum membrane stress;
- k) expansion of requirements on shell thickness to clarify and include cut-outs;
- l) addition of preferred location of tank top service equipment;
- m) partial easing of restriction on longitudinal partitions;
- n) additional requirements on pipes passing through the shell;
- o) general revisions on the protection of service equipment mounted on the top of the tank;
- p) new requirements for electrical bonding and earthing;

- q) changes to the assessment criteria for welds not covered by either Annex D or EN 14025;
- r) A1 examination and testing of welds referred to EN 12972:2018;

NOTE 1 Acceptable equivalent requirements for the examination and testing of welds are given in subclause 7.4.4 of this document.

- s) manufacturing tolerances referred to EN 12972:2018 A1;
- t) new requirements for minimum shell marking;
- u) tank plate requirements addressed by reference to regulatory requirements;
- v) clarification and revision of the application of the different methods of design verification in Annex A;
- w) addition of finite element analysis as a method of measurement of specific resilience in Annex B;
- x) changes to clarify the informative examples of welding details in Annex D; and
- y) an addition to the bibliography.

This document has been submitted for reference in:

- the RID; and
- the technical annexes of the ADR.

NOTE 2 These regulations take precedence over any clause of this document. It is emphasized that RID/ADR are being revised regularly at intervals of two years which may lead to temporary non-compliances with the clauses of this document."

A1 *deleted text* A1

Any feedback and questions on this document should be directed to the users' national standards body. A complete listing of these bodies can be found on the CEN website.

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

1 Scope

This document specifies requirements for the design and construction of metallic gravity-discharge tanks intended for the carriage of substances having a vapour pressure not exceeding 110 kPa (1,1 bar) (absolute pressure) at 50 °C.

NOTE 1 Gravity-discharge tanks have no maximum working pressure. However, during operation, pressure in the shell may occur, for example due to flow restrictions in vapour recovery systems or opening pressures of breather devices. It is important that these operating pressures do not exceed the test pressure of the tank or 0,5 bar, whichever is the highest.

This document specifies requirements for openings, closures, pipework, mountings for service equipment and structural equipment.

NOTE 2 This document does not specify requirements for items of service equipment other than pipes passing through the shell.

This document is applicable to aircraft refuelers 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 3 This document is not applicable to fixed rail tank wagons.

2 Normative references

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

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

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

EN 12972:2018 ^{A1}, *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 13445-3:2014, *Unfired pressure vessels - Part 3: Design*

EN 14564, *Tanks for transport of dangerous goods - Terminology*

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 - Calibration and verification of static uniaxial testing machines - Part 1: Tension/compression testing machines - Calibration and verification 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 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, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 14564, EN 13445 and the following apply.

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

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

NOTE See also Figure A.1.

3.1.1

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

3.1.2

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

3.1.3

global resilience

ability of a shell with reinforcement(s) to withstand a sideways impact with a beam

3.1.4

mild steel

steel which has a minimum tensile strength between 360 N/mm² and 440 N/mm², and a steel referred to in EN material standards as “mild steel”, with a minimum tensile strength between 360 N/mm² and 490 N/mm² and a minimum elongation at fracture conforming to 5.2.2.3.1 calculated using the formula in 5.2.2.3.2

3.1.5

maximum design mass

sum of the unladen mass of the tank and the mass of the maximum permissible load for which the tank is designed

A1 3.1.6

reference steel

steel which has the properties defined in EN 14564 **A1**

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 6.8.1)
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 an 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_{vn}	adopted thickness(es) of a shell, in millimetres (mm)
$e_{v, \min}$	minimum thickness of a shell according to 6.8.1, 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 $9,81 \text{ m/s}^2$.
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_{ta}	static pressure (gauge pressure), in MegaPascals (MPa)
P_e	tank test pressure, in MegaPascals (MPa)
P_{ec}	compartment test pressure, in MegaPascals (MPa)
P_c	calculation pressure of the tank, in MegaPascals (MPa)
P_{dyn}	dynamic pressure, in MegaPascals (MPa)
P_{ts}	opening pressure of the breather device, 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)

3.3 Abbreviations

FEM Finite element method

4 Service equipment

As a minimum, the service equipment shall be in conformance with the relevant regulations.

[A1] Tanks shall be equipped with a breather device and a safety device to prevent the contents from spilling out if the tank overturns. For compartmented tanks, each compartment shall be so equipped.

NOTE 1 Referenced standards for service equipment are listed in ADR 6.8.2.6. **[A1]**

NOTE 2 For pipework passing through the shell, see 6.13.

5 Materials

5.1 General

5.1.1 The designer shall select the materials to be used in the construction of the shell 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 document, 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 only be used when the material standard (e.g. EN 10028-2) guarantees an impact strength of at least 34 J/cm² at -20 °C. If a lower design temperature is prescribed, this strength shall be achieved at the lower temperature.

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 and R_m 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 or 3.2 issued in accordance with EN 10204; and
- the value of R_e and R_m used in the calculation does not exceed 1,15 multiplied by the value of R_e $\overline{A_1}$ and R_m $\overline{A_1}$ 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/mm² and the value of R_m shall not exceed 725 N/mm² 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 shells. The values specified in certificate 3.1 or 3.2 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; and
- 12 % for aluminium alloys.

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

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

NOTE For A and R_d 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 tank 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 as applicable, its lining. The substances or group of substances approved in the certificate shall be compatible with the characteristics of the tank.

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 shell, 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 6.8.1).

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  In RID/ADR (7.5.10), this requirement is also applicable to UN No. 1361 carbon and UN No. 1361 carbon black, packing group II. 

6 Design

6.1 Shell cross-section

6.1.1 General

A shell may have a circular, elliptical or other cross-section shape (including box-shaped) or combinations thereof.

Where a combination of shapes is used for a cross-section, the required minimum thickness for the whole cross-section at that point according to 6.8.1 shall be the greatest minimum thickness required for the shapes used.

6.1.2 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.

NOTE A.5.2.2.2, Table A.4, footnote a provides a calculation for an equivalent diameter to be calculated.

6.1.3 Sumps and other projections outside the shell

6.1.3.1 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 unless it is provided by vehicle components (e.g. chassis members, suspension components, axles, etc.).

The cross-sectional area of each projection shall not exceed 10 % of the cross-sectional area of the shell at that point without the projection.

When the projection is not protected, the thickness shall not be less than the thickness specified for the shell given in 6.8.1.

When the projection is protected, the thickness shall be the same thickness as the shell.

6.1.3.2 Shells and their compartments may be provided with sumps and/or internal channelling in order to:

- assist the complete discharge of the substance carried;
- facilitate the removal of entrained water from the substance carried; or
- locate a foot valve away from an area where there exists a risk of damage, for example near the coupling section on a semi-trailer.

Sumps shall not protrude more than 150 mm from the contour of the shell.

Internal channelling and sumps shall be manufactured from the same material as the shell to which they are fitted; flat material may be used. Their minimum thickness shall be at least equal to that of the shell.

A sump may consist of a vertical cylindrical section combined with internal or external channelling sections to lower the mounting flange of the foot valve.

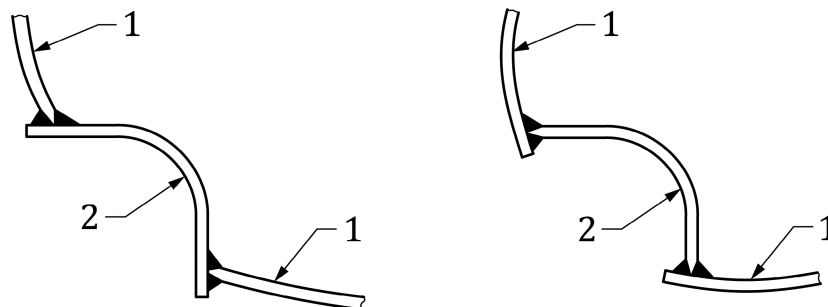
6.1.4 Cut-out sections within the contour of a side or bottom of the shell

6.1.4.1 Side cut-outs to accommodate service equipment

Side cut-outs to provide space for service equipment such as flow meters shall be designed in accordance with the following criteria:

- the total cross-sectional area of cut-outs at any point shall not exceed 20 % of the total cross-sectional area of the shell without cut-outs where the cut-outs are located;
- the length of the cut-out shall not exceed 40 % of the length of the shell and in any case not exceed 1 400 mm;
- the minimum distance from the sides of the cut-outs to the ends shall be at least 200 mm;
- the height and depth of the cut-out shall be such that it does not encroach within 50 mm of the centre lines of the shell;
- the thickness shall not be less than the thickness specified in 6.8.1;
- the welds shall be fully penetrated (or made of lap joints);
- the cut-out shall not extend beyond one compartment or a section of shell.

See Figure 1 for examples of side cut-outs.



Key

- 1 shell wall
- 2 side cut-out

Figure 1 — Examples of side cut-outs

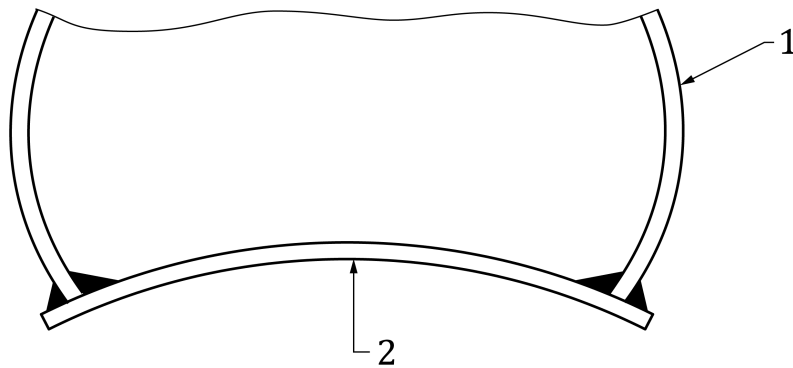
6.1.4.2 Cut-outs to accommodate tank mountings or other structural equipment

Cut-outs to accommodate structural equipment (e.g. coupling devices for trailers or semi-trailers), shall be designed in accordance with the following criteria:

- the cross-sectional area of the cut-out shall not exceed 30 % of the total cross-sectional area of the shell without cut-out, where it is located;
- the length of the cut-out shall not exceed 35 % of the length of the tank;
- service equipment shall not be welded directly to a concave surface within the cut-out;

- the weld shall be fully penetrated;
- the minimum thickness shall not be less than the thickness specified in 6.8.1;
- the joint of the end of the structural plate to the shell shall be to a partition or surge plate whose design complies with that for an end;
- the design shall not compromise complete drainage of the product to be carried.

See Figure 2 for example of a bottom cut-out.



Key

- 1 shell wall
- 2 cut-out of bottom of the shell

NOTE Full-penetration welds are used.

Figure 2 — Example of a bottom cut-out

6.2 Design verification

The minimum thickness of the shell shall conform to:

- a) Annex A, A.5 for:
 - cylindrical parts;
 - parts other than cylindrical taken as an equivalent diameter;
 - spherical parts;
 - ends and conical parts.
- b) Annex C
 - for neck rings, flanges and closures.

When Annex A, A.5, Annex C and Annex D cannot be fully applied, and for other aspects of the design of the tank (for example attachments, structural equipment, projections and cut-outs), Annex A, A.2 to A.4 or an analytical method or a combination of these methods shall be used in addition to Annex A, A.5.

The manufacturer shall provide documentation which gives evidence of the design verification.

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

6.3 Dynamic conditions

6.3.1 The dynamic conditions appropriate to the design temperature specified in 6.6, and requirements of the pressure test in **EN 12972:2018**, shall be met without exceeding the stress levels specified in 6.7.

6.3.2 Shells, their attachments and their structural equipment shall be designed to withstand the forces and dynamic pressures resulting from the combination of $P_{ta} + P_{ts}$ with, separately, each of the following, without exceeding the design stress in 6.7:

- in the direction of travel, an acceleration of $2 g$ on the maximum design mass (for the front end, only the maximum mass of the substance carried in the first (front) compartment shall be taken into account);
- 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; and
- vertically downwards, an acceleration of $2 g$ acting on the maximum design mass.

Calculations may be performed on the whole structure or on individual substructures provided that the boundary conditions are respected.

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

If any account is taken of baffles in calculations, their effect shall be proven according to one or a combination of the methods given in Annex A.

Where a fastening is subjected to shear stress, the maximum stress shall not exceed 0,8 times the design stress for the fastening.

In addition, for longitudinal accelerations ($2 g$) of self-supporting tanks (trailers without a longitudinal framework upon which the tank is supported), the following shall be taken into account:

- a) for front attachments, the maximum design mass of the trailer shall be deemed to act where the coupling device is attached to the tank; and
- b) for rear attachments, the maximum design mass of the tank shall be deemed to act on the attachments of the tank to the running gear. The non-uniform mass distribution on the tank saddles shall be taken into account.

6.3.3 With the following exceptions, a shell which has a maximum length of less than 2,9 m shall be designed to withstand the forces specified in 6.3.2, 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.

6.4 Pressure conditions

6.4.1 The 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 shell multiplied by the relative density of the densest substance to be carried;
- b) the pressure created by a column of water equal to twice the depth of the shell.

6.4.2 Except for tanks for inter-modal tanks, compartments of compartmented shells shall be designed to withstand a test pressure which subjects all parts of a compartment to a pressure at least equal to $\max(0,02 \text{ MPa}; 1,3 \times P_{\text{ta water}}; 1,3 \times P_{\text{ta}})$.

NOTE The requirements for withstanding a pressure test are given in [A1](#) EN 12972:2018 [A1](#).

6.5 Partial vacuum conditions

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

6.6 Design temperature

The minimum design temperature range shall be -20°C to $+50^\circ\text{C}$. Where the shell is likely to be subjected to more severe conditions, the design temperature range shall be extended to range from -40°C to $+50^\circ\text{C}$, as applicable. The design temperature range of shells intended for substances to be carried at elevated temperatures shall be extended at least to the maximum working temperature.

6.7 Design stress

The maximum membrane stress in the material of the shell 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 [A1](#) *deleted text* [A1](#) shall not exceed $0,66 R_e$.

6.8 Shell thicknesses

NOTE Minimum thicknesses apply after the forming or shaping of the material. See 7.3.1.1.

6.8.1 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 6.8.2 are met:

- 5 mm if the shell diameter is not more than 1,8 m;
- 6 mm if the shell diameter is greater than 1,8 m (except in the case of shells intended for the carriage of powdery or granulated substances).

For non-circular shells, an equivalent diameter shall be calculated on the basis of the cross-sectional area. For shells with sections having different cross-sectional areas, equivalent diameters shall be calculated for each section.

NOTE See also 6.1.1.

For tapered shells, the largest diameter or largest equivalent diameter of the section shall be used to calculate the minimum thickness of the shell section.

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

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

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 or Table 2 as applicable.

6.8.2 Reduction of shell thickness

6.8.2.1 Where protection against damage of the shell is provided in accordance with 6.8.2.2 to 6.8.2.3, 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 6.8.1, 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 6.8.1. ^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.					

6.8.2.2 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 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 shall be met:

- 1) the distance between two adjacent strengthening elements is less than or equal to 1,75 m;
- 2) the capacity 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 cm³ 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.

For shells with concave radii and cut-outs of the shell, the thickness of these concave and cut-out parts shall have the full thickness specified in 6.8.1.

- 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 6.8.1, and the thickness of the inner wall of the combination shall be not less than the minimum value specified in 6.8.2.1.

- 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 6.8.1 or this area consists of the same material as the shell with a thickness not less than the minimum shell thickness specified in 6.8.1; 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 6.8.1, 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 capacity 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 capacity 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 6.8.2.1 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 shall all be met:
- 1) the capacity contained between adjacent strengthening elements does not exceed 7 500 l;
 - 2) the capacity 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 shall conform to one of the following requirements:
 - i) single end having the full thickness specified in 6.8.1;
 - ii) double ends with a distance between 100 mm to 200 mm in which the inner end shall have a thickness at least equal to the minimum specified in 6.8.2.1, 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).
- 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 shall all be met:
- 1) the capacity contained between adjacent strengthening elements does not exceed 7 500 l;
 - 2) the capacity of the 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 conforms to d) or e);
 - 7) 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 6.8.1: 40 kNm;
- ii) for partitions or surge plates with a minimum thickness specified in 6.8.2.1: 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.6 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 elastoplastic analysis.

The manufacturer shall provide to the Competent Authority the relevant validation examples (comparisons between calculation results and real test results). For shell cross-sections which do not fulfil the requirement of 6.1.2 especially concave radii and cut-outs of the shell with smaller radii than 250 mm, the thickness of these concave and cut-out parts shall have the full thickness specified in 6.8.1.

- j) For shells of forms other than in a), the following conditions shall all be 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 capacity 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 6.8.2.1);
 - iv) capacity 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.

6.8.2.3 Shells of fixed tanks and demountable tanks that are either of not more than 5 000 l capacity or are divided into 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 shells

Capacity of shell or shell compartment	Maximum radius of convexity top and bottom	Maximum radius of convexity of sides	Minimum thickness					
			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:

- the shell is made with double walls in accordance with 6.8.2.2 b); or
- 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.

6.9 Shell openings, neck rings and closures

6.9.1 General

Mountings for the attachment of cover plates and service equipment to the shell shall be in accordance with the equipment manufacturer's requirements which may include strength and flatness requirements.  Any thermal insulation shall be so designed as not to hinder access to, or the operation of, filling and discharge devices and safety valves. 

6.9.2 Inspection openings and manholes

Each shell and compartment with a capacity of 3 000 l or greater shall be provided with a manhole to allow inspection of the interior. Shells 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.

6.9.3 Neck rings and closures

The neck ring 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.

6.9.4 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.

6.9.5 Mountings for service equipment

The mountings of service equipment shall be arranged or protected so as to permit protection against the risk of the equipment being wrenched off or damaged.

For shells and compartments with a capacity exceeding 10 000 l, the mountings for service equipment mounted on top of the shell which may open to atmosphere including breather devices, emergency pressure relief valves and relief valves shall be located as close as practicable to the shell or compartment's volumetric centreline to ensure that during transport they remain connected to the ullage space of the compartment and to avoid the valves being opened by the effects of surge of the contents.

6.10 Shell partitions, surge plates and baffles

6.10.1 Surge plates and partitions shall be either:

- a) dished, with a dish depth 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.

6.10.2 Partitions and surge plates, including any backing plates, shall be continuously welded to the shell except as required by 6.10.4.

6.10.3 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.

6.10.4 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 shell 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 mm² 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.

6.10.5 Except for front compartments each with a capacity of 1 500 l or less of fixed tanks fitted to rigid chassis, 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 shell at any point.

6.11 Shell supporting structure

6.11.1 Shell supporting structures shall be designed such that the stresses specified in 6.7 are not exceeded when they are subjected to the static and dynamic loading forces specified in 6.3.1, 6.3.2 and 6.3.3.

6.11.2 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 6.11.1. 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.

6.12 Other attachments to the shell

6.12.1 Reinforcements for attachments to the shell shall be designed such that the stress specified in 6.7 is not exceeded.

6.12.2 How 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.

6.13 Pipework passing through the shell

6.13.1 General

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.

Pipework permanently attached to the shell shall be designed to prevent additional stress and loads being applied to its mountings and the shell caused by the expansion or compression of the shell or pipework itself.

Pipes shall be of metallic construction; materials used for their construction shall be suitable for the substances being carried within the shell and shall comply with the applicable product standard.

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 shell, the external section of the pipe breaks away without damaging the shell.

Reducers shall be used for all pipework diameter changes.

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

6.13.2 Tank top drainage tubes passing through the shell

Tank top drain tubes shall:

- comply with the requirements of 6.14.1.3 and 6.14.2;
- have a minimum internal diameter of 38 mm and be the same diameter throughout except for recessed ring containing a single item of service equipment, where drain tubes having a minimum internal diameter of 30mm may be used;

- be designed or fitted with devices to prevent the ingress of foreign bodies which could cause a blockage; and
- be unobstructed throughout and either drain directly to ground or via an unsealed interceptor container.

NOTE Shut-off valves may be required to be fitted for operational purposes, subject to the approval of the competent authority.

6.13.3 Service tubes passing through the shell

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

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 top of the shell, housing service equipment mounted on the top of the shell that connects with the inside of it.

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 maximum design mass of the tank vehicle, and a representative static load applied at right angles to the direction of travel. This calculation is not required when the protecting device conforms to the requirements specified in 6.14.2.

6.14.1.5 Covers shall not be fitted where emergency pressure relief valves are fitted unless they are designed to take account of the full venting capacity of the valve and do not restrict it.

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.

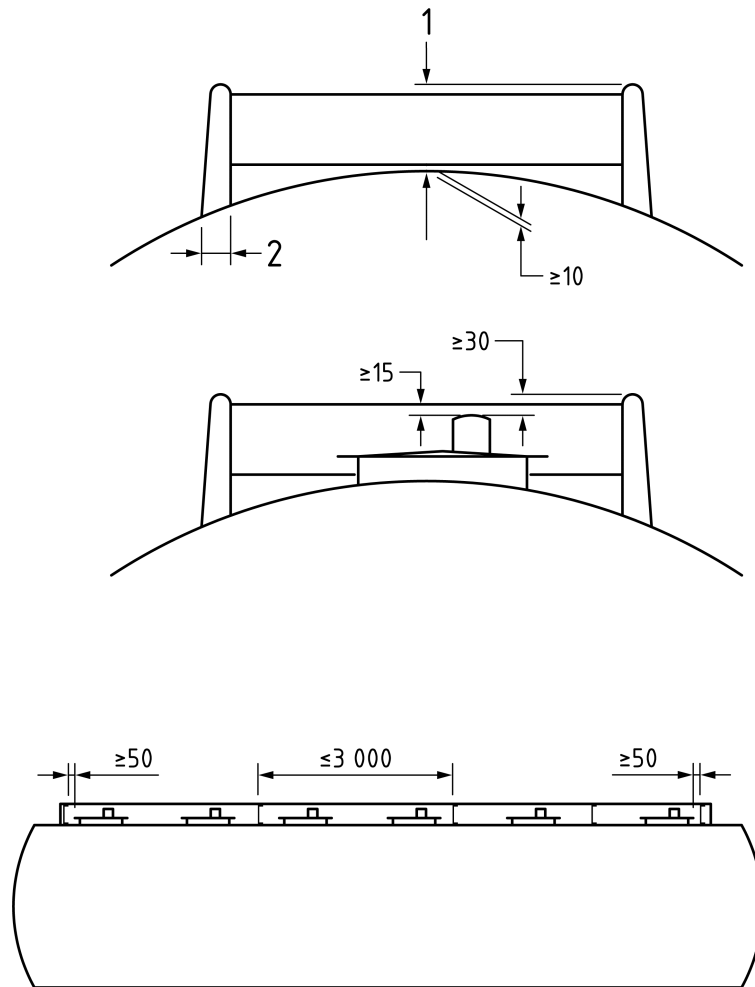
6.14.2.2 Longitudinal and transverse members

NOTE 1 A typical arrangement of service equipment protected by longitudinal and transverse members is shown in Figure 3.

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) the transverse members shall support both longitudinal members and the spacing between them shall not exceed 3 000 mm;
- e) the 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 shell 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 cm³ 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 their 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 shell vertical centre line and shall consider 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.

**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 3 — 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 4.

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;