BRITISH STANDARD

BS EN 14015:2004
Incorporating Corrigendum No. 1

Specification for the design and manufacture of site built, vertical, cylindrical, flat-bottomed, above ground, welded, steel tanks for the storage of liquids at ambient temperature and above

The European Standard EN 14015:2004 has the status of a British Standard

ICS 23.020.10

British Standards

National foreword

This British Standard is the official English language version of EN 14015:2004. It supersedes BS 2654:1989 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PVE/15, Storage tanks for the petroleum industry, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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

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EN 14015

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English version

Specification for the design and manufacture of site built, vertical, cylindrical, flat-bottomed, above ground, welded, steel tanks for the storage of liquids at ambient temperature and above

Spécification pour la conception et la fabrication de réservoirs en acier, soudés, aériens, à fond plat, cylindriques, verticaux, construit sur site destinés au stockage des liquides à la température ambiante ou supérieure

Auslegung und Herstellung standortgefertigter, oberirdischer, stehender, zylindrischer, geschweißter Flachboden-Stahltanks für die Lagerung von Flüssigkeiten bei Umgebungstemperatur und höheren Temperaturen

This European Standard was approved by CEN on 2 February 2004.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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Foreword

This document (EN 14015:2004) has been prepared by Technical Committee CEN/TC 265 “Site built metallic tanks for the storage of liquids”, the secretariat of which is held by BSI.

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 May 2005, and conflicting national standards shall be withdrawn at the latest by May 2005.

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

This European Standard reflects the current practice within the oil, petrochemical, chemical, food and general bulk liquid storage industry, both European and world-wide. The practice is based on the theory of design stresses or allowable stresses.

There is a parallel pre-standard, ENV 1993-4-2 Tanks. It is based on the Limit State Theory (LST), which is being used more and more by the structure steel and reinforced concrete industry.

Experience in designing steel storage tanks to LST is limited, and there is little information on which to base the values for load factors, load combinations and serviceability. When sufficient experience has been gained in designing tanks to, and credible values become available for load factors, etc., it is envisaged that there may be a gradual move towards the use of LST for the design of tanks covered by this European Standard.

1 Scope

1.1 This document specifies the requirements for the materials, design, fabrication, erection, testing and inspection of site built, vertical, cylindrical, flat bottomed, above ground, welded, steel tanks for the storage of liquids at ambient temperatures and above, and the technical agreements that need to be reached (see Annex A).

This document does not apply to tanks where the product is refrigerated to maintain it as a liquid at atmospheric pressure (see prEN 14620).

This document is concerned with the structural integrity of the basic tank structure and does not provide requirements for considering process design, operational issues, safety and firefighting facilities, in-service inspection, maintenance or repair. These aspects are covered in detail in other Codes of Practice (see Annex B).

1.2 This document applies to closed-top tanks, with and without internal floating covers (see Annex C) and open-top tanks, with and without floating roofs (see Annexes D and E). It does not apply to 'lift-type' gas holders.

1.3 This document applies to storage tanks with the following characteristics:

a) design pressure less than 500 mbar[1)] and design internal negative pressure not lower than 20 mbar (see **5.1** for pressure limitations);

b) design metal temperature not lower than -40 °C and not higher than +300 °C (see 5.2.2);

c) maximum design liquid level not higher than the top of the cylindrical shell.

1.4 The limits of application of this document terminate at the following locations.

— face of the first flange in a bolted flange connection;

— first threaded joint on the pipe or coupling outside of the tank shell, roof or bottom;

— first circumferential joint in a pipe not having a flange connection.

1.5 This document is applicable to steel tanks with a maximum design strength ≤ 260 N/mm^2.

1.6 In addition to the definitive requirements, this document also requires the items detailed in Annex A to be documented. For compliance with this document, both the definitive requirements and those required in Clause 4 have to be satisfied.

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1) All pressures are in mbar gauge unless otherwise stated.

2 Normative references

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

EN 287-1: 2004, *Qualification test of welders - Fusion welding - Part 1: Steels*

EN 288-2, *Specification and approval of welding procedures for metallic materials — Part 2: Welding procedure specification for arc welding*

EN 444, *Non-destructive testing- General principles for radiographic examination of metallic material by X- and gamma- rays*

EN 462-1, *Non-destructive testing – Image quality of radiographs – Part 1: Image quality indicators (wire type). Determination of image quality value*

EN 462-2, *Non-destructive testing – Image quality of radiographs – Part 2: Image quality indicators (step/hole type). Determination of image quality value*

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

EN 485 (all parts), *Aluminium and aluminium alloys — Sheet, strip and plate*

EN 499, *Welding consumables — Covered electrodes for manual metal arc welding of non alloy and fine grain steels — Classification*

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

EN 754 (all parts), *Aluminium and aluminium alloys — Cold drawn rod/bar and tube*

EN 755 (all parts), *Aluminium and aluminium alloys — Extruded rod/bar, tube and profiles*

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

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

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

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

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

EN 1593, *Non-destructive testing — Leak testing — Bubble emission techniques*

EN 1600, *Welding consumables — Covered electrodes for manual metal arc welding of stainless and heat resisting steels — Classification*

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

prEN 1759-1: 2000, *Flanges and their joints - Circular flanges for pipes, valves, fittings and accessories, Class designated - Part 1: Steel flanges, NPS ½ to 24*

EN 1991-1-3:2003, *Eurocode 1 - Actions on structures - Part 1-3: General actions - Snow loads*

EN 10025:1992, *Hot rolled products of non-alloy structural steels — Technical delivery conditions*

EN 10028-2: 1993, *Flat products made of steels for pressure purposes — Part 2: Non-alloy and alloy steels with specified elevated temperature properties*

EN 10028-3: 1993, *Flat products made of steels for pressure purposes — Part 3: Weldable fine grain steels, normalized*

EN 10029: 1991, *Hot rolled steel plates 3 mm thick or above — Tolerances on dimensions, shape and mass*

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

EN 10088-1, *Stainless steels — Part 1: List of stainless steels*

EN 10088-2: 1995, *Stainless steels — Part 2: Technical delivery conditions for sheet/plate and strip for general purposes*

EN 10088-3: 1995, *Stainless steels — Part 3: Technical delivery conditions for semi-finished products, bars, rods and sections for general purposes*

EN 10113-2: 1993, *Hot-rolled products in weldable fine grain structural steels — Part 2: Delivery conditions for normalized/normalized rolled steels*

EN 10113-3: 1993, *Hot-rolled products in weldable fine grain structural steels — Part 3: Delivery conditions for thermomechanical rolled steels*

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

EN 10210-1: 1994, *Hot finished structural hollow sections of non-alloy and fire grain structural steels — Part 1: Technical delivery requirements*

EN 10216-1, *Seamless steel tubes for pressure purposes — Technical delivery conditions - Part 1: Non-alloy steel tubes with specified room temperature properties*

EN 10216-2, *Seamless steel tubes for pressure purposes - Technical delivery conditions - Part 2: Non-alloy and alloy steel tubes with specified elevated temperature properties*

EN 10216-3, *Seamless steel tubes for pressure purposes - Technical delivery conditions - Part 3: Alloy fine grain steel tubes*

EN 10216-5, *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 5: Stainless steel tubes*

EN 10217-1, *Welded steel tubes for pressure purposes — Technical delivery conditions - Part 1: Non-alloy steel tubes with specified room temperature properties*

EN 10217-2, *Welded steel tubes for pressure purposes - Technical delivery conditions - Part 2: Electric welded non-alloy and alloy steel tubes with specified elevated temperature properties*

EN 10217-3, *Welded steel tubes for pressure purposes - Technical delivery conditions - Part 3: Alloy fine grain steel tubes*

EN 10217-5, *Welded steel tubes for pressure purposes - Technical delivery conditions - Part 5: Submerged arc welded non-alloy and alloy steel tubes with specified elevated temperature properties*

prEN 10217-7, *Welded steel tubes for pressure purposes — Technical delivery conditions — Part 7: Stainless steel tubes*

EN 10222 (all parts), *Steel forgings for pressure purposes*

EN 10250 (all parts), *Open steel die forgings for general engineering purposes*

EN 12874, *Flame arresters - Performance requirements, test methods and limits for use*

ENV 1991-2-1, *Eurocode 1: Basis of design and actions on structures — Part 2-1: Actions on structures — Densities, self-weight and imposed loads*

ENV 1993-1-1, *Eurocode 3: Design of steel structures — Part 1-1: General rules and rules for buildings*

ENV 1993-4-2, *Eurocode 3: Design of steel structures — Part 4-2: Silos, tanks and pipelines — Tanks*

EN ISO 4063, *Welding and allied processes — Nomenclature of processes and reference numbers (ISO 4063:1998)*

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

EN ISO 14122-1, *Safety of machinery — Permanent means of access to machinery - Part 1: Choice of fixed means of access between two levels (ISO 14122-1:2001)*

EN ISO 14122-2, *Safety of machinery -- Permanent means of access to machinery -- Part 2: Working platforms and walkways (ISO 14122-2:2001)*

EN ISO 14122-3, *Safety of machinery -- Permanent means of access to machinery -- Part 3: Stairs, stepladders and guard-rails (ISO 14122-3:2001)*

EN ISO 14122-4, *Safety of machinery -- Permanent means of access to machinery -- Part 4: Fixed ladders (ISO 14122-4:1996)*

EN ISO 15607:2003, *Specification and qualification of welding procedures for metallic materials - General rules (ISO 15607:2003)*

EN ISO 15614-1:2004, *Specification and qualification of welding procedures for metallic materials - Welding procedure test - Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys (ISO 15614-1:2004)*

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

For the purpose of this document, the following terms and definitions apply:

3.1.1
design pressure
maximum permissible pressure in the space above the stored liquid

3.1.2
design internal negative pressure
maximum permissible negative pressure in the space above the stored liquid

3.1.3
set pressure
pressure at which the pressure relief device first opens

3.1.4
set vacuum
internal negative pressure at which a vacuum valve first opens

3.1.5
test pressure
pressure in the space above the test liquid during testing

3.1.6
maximum design metal temperature
temperature used for determining the maximum allowable stress for the material

3.1.7
minimum design metal temperature
temperature used for determining the material toughness requirements

3.1.8
LODMAT (lowest one day mean ambient temperature)
lowest recorded average temperature based over any 24 hour period

NOTE The average temperature is half (maximum temperature plus minimum temperature).

3.1.9
purchaser
company or its agent which prepares and agrees a proposal with a contractor for the design, construction and testing of a storage tank

3.1.10
designer[2)]
person or organization carrying out the engineering design of the tank

3.1.11
contractor[2)]
company with which the purchaser agrees a proposal for the design, construction and testing of a storage tank

3.1.12
manufacturer[2)]
organization carrying out the shop fabrication

3.1.13
erector[2)]
organization carrying out the construction on site

3.1.14
inspector
person or organization carrying out the inspection of the tank on behalf of the purchaser

3.1.15[2)]
welding consumables manufacturer
specific manufacturer of welding consumables

3.1.16
supplier
company manufacturing and supplying sub-assemblies

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2) A single organization may cover two or more of these activities.

3.1.17
oxygenates
oxygen compounds which may be added to fuels used for transport to enhance performance

NOTE Most commonly used ones are methanol, ethanol, methyl tertiary butyl ether (MTBE) and tertiary butyl alcohol (TBA).

3.1.18
static electricity
build-up of an electrical difference of potential or charge, through friction of dissimilar materials or substances e.g. product flow through a pipe

3.1.19
operating basis earthquake (OBE)
earthquake that the tank resists without any damage

3.1.20
safe shutdown earthquake (SSE)
earthquake that damages the tank without causing collapse or imposing serious consequential hazards

3.1.21
floating roof
metallic structure which floats on the surface of a liquid inside an open top tank shell, and in complete contact with this surface

3.1.22
floating cover
structure which floats on the surface of a liquid inside a fixed roof tank, primarily to reduce vapour loss

3.1.23
contact type floating cover
cover which floats in direct contact with the liquid with no space between the underside of the cover and the liquid surface

3.1.24
non-contact type floating cover
cover which is supported by buoyancy chambers or pontoons on the liquid surface causing the floating cover to be raised above the liquid surface, thus creating a void between the underside of the floating cover and the liquid surface

3.1.25
cover
main load bearing structure to which the peripheral (rim) seal is added

3.1.26
peripheral (rim) seal
seal mounted around the periphery of the floating roof or floating cover which contacts the tank shell and seals the annular gap

3.1.27
cover skirt
lightweight structure fitted to the periphery of a floating cover which protrudes above and is partially submerged in the stored liquid who's purpose is to prevent vapour escape from the underside of a non-contact type floating cover

3.1.28
floating suction devices
mechanical device, sometimes articulated, installed in some tanks, which floats on the liquid surface and only permits product to be withdrawn from this point

NOTE Commonly adopted for aviation fuel storage tanks.

3.1.29
bleeder vent
device incorporated in a floating cover to permit release of gas from under the floating cover during tank filling, and to allow air to pass back through the floating cover when draining product when the floating cover is stationary on its support legs

3.1.30
buoyancy
ability of a structure to float on liquid

3.1.31
inlet diffuser
component intended to join and extend the inlet pipe within the tank and disperses the incoming product

3.1.32
maximum liquid operating height in tank with floating cover
product height established in a storage tank after installing a floating cover and before allowing it to enter operational service

3.1.33
accumulation
differential pressure between the set pressure of the valve and the tank pressure at which the required flow rate is reached or the set vacuum of the valve and the tank internal negative pressure at which the required flow rate is reached

3.1.34
evaporation venting
outbreathing depending on gas evaporation of the liquid product

3.1.35
normal pressure venting
outbreathing under normal operating conditions (pumping product into the tank and thermal outbreathing)

3.1.36
normal vacuum venting
inbreathing under normal operating conditions (pumping product out of the tank and thermal inbreathing)

3.1.37
emergency venting
outbreathing in case of fire, or inbreathing and outbreathing in case of malfunction of tank equipment

3.1.38
thermal outbreathing
pressure venting capacity influenced by atmospheric heating of the tank

3.1.39
thermal inbreathing
vacuum venting capacity influenced by atmospheric cooling down of the tank

3.1.40
free vents
open vents

3.1.41
pressure/vacuum valves
valves used to relief excess pressure or internal negative pressure in the tank

3.1.42
venting system with flame arresting capability
free vents or pressure and/or vacuum valves combined with a flame arrester or with integrated flame arresting elements

3.1.43
emergency venting valves
pressure or vacuum relief valves for emergency venting

3.1.44
pipe away valves
pressure or vacuum valves to which a vent pipe may be connected

3.1.45
vent pipes
pipes connected to pipe away valves

3.2 Symbols

For the purpose of this document, the symbols given in Table 1 shall apply:

Table 1 — Symbols *(continued)*

Symbol	Description	Unit
c	Corrosion allowance	mm
D	Diameter of tank	m
d	Diameter of hole	mm
d_h	Diameter of hole in roof	mm
d_i	Diameter (inside) of nozzle	mm
d_n	Diameter (outside) of nozzle	mm
d_o	Diameter (outside) of manhole insert	mm
d_r	Diameter (outside) of reinforcement	mm
e	Nominal thickness of plate	mm
e_a	Nominal thickness of annular plate	mm
e_b	Thickness of bottom plate	mm
e_{br}	Thickness of bottom reinforcing plate (flush type clean out door)	mm
e_c	Calculated minimum thickness of plate including corrosion allowance	mm
e_f	Thickness of flange	mm
e_i	Thickness of insert plate	mm
e_n	Thickness of nozzle	mm
e_p	Thickness of roof plate	mm
e_r	Thickness of reinforcement plate	mm
e_s	Thickness of any shell plate	mm
e_t	Thickness of shell plate for test conditions	mm
e_1	Thickness of first shell course	mm
F	Overstress factor	—
H	Design liquid height	m
H_c	Height from the bottom of the course under consideration to design liquid level	m
h_n	Height of nozzle	mm
L_r	Effective roof length	mm
L_s	Effective shell length	mm

Table 1 — Symbols (*concluded*)

Symbol	Description	Unit
l_a	Width of the annular plate between the edge of the bottom plate and the inner surface of the shell	mm
l_d	Distance from the outer surface of the shell to the outer edge of the bottom plate or annular plate	mm
l_w	Lap of the bottom plates over the annular plate	mm
p	Design pressure	mbar
p_i	Internal pressure minus pressure exerted by roof	mbar
p_t	Test pressure	mbar
R	Radius of tank	m
R_1	Radius of curvature of roof	m
r_i	Inside radius of nozzle	mm
r_m	Mean radius for nozzle	mm
r_o	Outside radius of nozzle	mm
S	Allowable design stress	N/mm^2
S_c	Allowable compressive stress	N/mm^2
S_t	Allowable test stress	N/mm^2
t	Total thickness tolerance	mm
T_{DM}	Design metal temperature	°C
V	Design wind speed	m/s
W	Density of contained liquid	kg/l
W_t	Density of test medium	kg/l
Z	Section modulus	cm^3

3.3 Abbreviations

For the purpose of this document, the abbreviations given in Table 2 shall apply.

Table 2 — Abbreviations

Abbreviation	Description
HAZ	Heat affected zone
LODMAT	Lowest one day mean ambient temperature
NDE	Non-destructive examination
NDT	Non-destructive test(ing)
PCD	Pitch circle diameter
PWHT	Post-weld heat treatment

4 Information and requirements to be documented

4.1 Information to be specified by the purchaser

The information to be specified by the purchaser, in accordance with A.1, shall be fully documented.

4.2 Information to be agreed between the purchaser and the tank manufacturer

The information to be agreed between the purchaser and the tank manufacturer, in accordance with A.2, shall be fully documented.

4.3 Information to be supplied by the tank manufacturer

The information to be supplied by the tank manufacturer, in accordance with A.3, shall be fully documented.

4.4 Information to be supplied by the steel manufacturer

The information to be supplied by the steel manufacturer, in accordance with A.4, shall be fully documented.

4.5 Information to be agreed between the steel manufacturer and the tank manufacturer

The information to be agreed between the steel manufacturer and the tank manufacturer, in accordance with A.5, shall be fully documented.

4.6 Information to be agreed between the purchaser and the cover supplier

The information to be agreed between the purchaser and the cover supplier, in accordance with A.6, shall be fully documented.

4.7 Information to be agreed between the tank manufacturer and the cover supplier

The information to be agreed between the tank manufacturer and the cover supplier, in accordance with A.7, shall be fully documented.

4.8 Information to be supplied by the cover supplier

The information to be supplied by the cover supplier, in accordance with A.8, shall be fully documented.

5 Requirements

5.1 Design pressure

The design pressure and the design internal negative pressure shall be within the limits specified in Table 3 for the particular tank designation specified (see 10.6.4.1, 10.6.4.2, and A.1).

The set pressure of the relief device plus the accumulation to permit the required throughput to be achieved shall not exceed the design pressure.

The set vacuum of the relief device plus the accumulation to permit the required throughput to be achieved shall not exceed the design internal negative pressure.

Table 3 — Design pressure limits for tanks

Tank designation	Design pressure p mbar (g)	Design internal negative pressure p_v mbar (g)
Open top tanks or		
floating roof tanks [a]	0	5
Closed top tanks		
i) non-pressure tanks [b]	≤ 10	≤ 5
ii) low-pressure tanks [b c]	≤ 25	≤ 8,5
iii) high-pressure tanks [b c]	≤ 60	≤ 8,5
iv) very high-pressure tanks [b c d e]	≤ 500	≤ 20

The requirements of this document for roof plating and for roof nozzle reinforcement may not be adequate for some combinations of tank diameter and design pressure. Additional requirements necessary with regard to these aspects shall be subject to agreement (see A.2).

[a] Design internal negative pressure required for shell stability calculations only (see 9.3.)

[b] The design pressures specified are those that give rise to load conditions stated in Clause 7.2. and will be used in the calculation of shell thickness (see 9.2), shell stability (see 9.3.), roof thickness (see 10.4), shell/roof compression area (see 10.5), selection and sizing of vents (see 10.6), tank anchorage (see Clause 12), selection of type of roof and its detailed design.

[c] The requirements of 9.3. for shell stability do not apply for design internal negative pressures > 5,0 mbar. The design methodology and fabrication tolerances, for design internal negative pressures > 5,0 mbar shall be subject to agreement (see A.2).

[d] Actual design pressure and actual design internal negative pressure to be specified within the quoted ranges (see A.1).

[e] Practical considerations will limit the maximum diameter of tank which can be designed for very high-pressure tanks. The limiting diameter will depend upon the actual design pressure and design internal negative pressure selected when used for the design analysis identified in note 2) above.

5.2 Design metal temperature

5.2.1 Maximum design metal temperature

The maximum design metal temperature shall not exceed 300 °C.

5.2.2 Minimum design metal temperature

The minimum design metal temperature shall be the minimum temperature of the contents or the temperature given in Table 4, whichever is the lower. If the ambient temperature is lower than –40 °C, the minimum design metal temperature shall be –40 °C.

Table 4 — Minimum design metal temperature based on LODMAT

Lowest one day mean ambient temperature (LODMAT) T_1 °C	Minimum design metal temperature	
	10 years data °C	**30 years data** °C
Warmer than or equal to -10	$T_1 + 5$	$T_1 + 10$
Warmer than or equal to –25 and below –10	T_1	$T_1 + 5$
Below -25	$T_1 - 5$	T_1
The minimum design metal temperature for the tank shall not take into account the beneficial effect of heating or insulation for design metal temperatures warmer than or equal to 0 °C. For minimum design metal temperatures below 0 °C, then the beneficial effect of insulation or heating shall be agreed but the design metal temperature should not be warmer than 0 °C.		

5.3 Design density

The design density shall be the maximum specified density of the contents.

NOTE Where flexibility of operation in a tank or within a group of tanks is required, the design density should be the maximum envisaged density of the products.

5.4 Yield strength

The yield strength of the material shall be the minimum specified value of:

- room temperature yield strength or 0,2 % proof strength for carbon and carbon manganese steels;
- elevated temperature (> 100 °C) 0,2 % proof strength for carbon and carbon manganese steels;
- room temperature 1,0 % proof strength for stainless steels;
- elevated temperature (> 50 °C) 1,0 % proof strength for stainless steels.

6 Materials

6.1 Carbon and carbon manganese steels

6.1.1 Plate materials

6.1.1.1 All carbon and carbon manganese steel plate used in the manufacture of tanks conforming to this document shall be in accordance with the minimum requirements of Tables 5 to 7 in conjunction with Table 9 and Figure 1 unless otherwise agreed (see A.2). When a steel grade other than those given in Tables 5 to 7 is to be used, it shall satisfy the requirements of Annex F.

Table 5 — Hot rolled products ≤ 275 N/mm^2 yield strength

Standard	Designation	Options	Steel type as given in Figure 1	Maximum thickness[a)] mm
EN 10025 1993	S235 JRG2	1, 12	Type I	12
	S235 JO	1, 5, 12	Type II	30
	S235 J2G3	1, 5, 12	Type III	40
	S235 J2G4	1, 5, 12	Type III	40
	S275 JR	1, 12	Type I	12
	S275 JO	1, 5, 12	Type II	30
	S275 J2G3	1, 5, 12	Type III	40
	S275 J2G4	1, 5, 12	Type III	40

Option 1 Steelmaking process to be reported

Option 5 CEV from ladle analysis ≤ 0.42 for plates thicker than 20 mm

Option 12 Inspection documentation shall be in accordance with EN 10204:2004, Cert. 3.1B except for nominal thickness plates (e.g. roof, bottom, nominal thickness shell plates) where documentation shall be in accordance with EN 10204: 2004, Test report 2.2

Standard	Designation	Options	Steel type as given in Figure 1	Maximum thickness[a] mm
EN 10113-2 1993	S275 N	1, 2, 19a	Type IV	40
	S275 NL	1, 2, 19a	Type IV	40
EN 10113-3 1993	S275 M	1, 2, 19a	Type IV	40
	S275 ML	1, 2, 19a	Type IV	40

Option 1 Steelmaking process to be reported

Option 2 CEV from ladle analysis ≤ 0.42 for plates thicker than 20 mm

Option 19a Charpy Impact test to be carried out on each plate thicker than 20 mm

[a] The maximum thickness shall be the lower of that specified in this table and that derived from Figure 1.

Table 6 — Hot rolled products > 275 N/mm^2 **and** ≤ 355 N/mm^2 **yield strength**

Standard	Designation	Options	Steel type as given in Figure 1	Maximum thickness[a] mm
EN 10025 1993	S355 JR	1, 6, 12	Type V	10
	S355 JO	1, 6, 12	Type VI	15
	S355 J2G3	1, 5, 6, 12, 20	Type VII	40
	S355 J2G4	1, 5, 6, 12, 20	Type VII	40
	S355 K2G3	1, 5, 6, 12, 20	Type VIII	40
	S355 K2G4	1, 5, 6, 12, 20	Type VIII	40

Option 1 Steelmaking process to be reported

Option 5 CEV from ladle analysis ≤ 0.42 for plates thicker than 20 mm

Option 6 Cr, Cu, Mo, Nb, Ni, Ti and V to be recorded

Option 12 Inspection documentation shall be in accordance with EN 10204: 2004, Cert. 3.1B except for nominal thickness plates (e.g. roof, bottom, nominal thickness shell plates) where documentation shall be in accordance with EN 10204: 2004, Test report 2.2

Option 20 Charpy Impact test to be carried out on each plate thicker than 20 mm

Standard	Designation	Options	Steel type as given in Figure 1	Maximum thickness[a]
EN 10113-2 1993	S355 N	1, 2, 19a	Type VIII	40
	S355 NL	1, 2, 19a	Type IX	40
EN 10113-3 1993	S355 M	1, 2, 19a	Type VIII	40
	S355 ML	1, 2, 19a	Type IX	40

Option 1 Steelmaking process to be reported

Option 2 CEV from ladle analysis ≤ 0.42 for plates thicker than 20 mm

Option 19a Charpy Impact test to be carried out on each plate thicker than 20 mm

[a] The maximum thickness shall be the lower of that specified in this table and that derived from Figure 1.

Table 7 — Hot rolled products > 355 N/mm^2 **yield strength**

Standard	Designation	Options	Steel type as given in Figure 1	Maximum thickness[a] mm
EN 10113-2 1993	S420 N	1, 2, 19a	Type X	40
	S420 NL	1, 2, 19a	Type XI	40
EN 10113-3 1993	S420 M	1, 2, 19a	Type X	40
	S420 ML	1, 2, 19a	Type XI	40
Option 1	Steelmaking process to be reported			
Option 2	CEV from ladle analysis ≤ 0.42 for plates thicker than 20 mm			
Option 19a	Charpy Impact test to be carried out on each plate thicker than 20 mm			

[a] The maximum thickness shall be the lower of that specified in this table and that derived from Figure 1.

Table 8 — Hot rolled products for use at elevated temperatures (> 100 °C**)**

Standard	Designation	Steel type as given in Figure 1	Maximum thickness[a] mm
EN 10028-2 1993	P235 GH	Type II A	30
	P265 GH	Type II A	30
	P295 GH	Type VI A	40
	P355 GH	Type VI A	40
EN 10028-3 1993	P275 NH	Type IV	40
	P275 NL2	Type IV	40
	P355 NH	Type VIII	40
	P355 NL2	Type IX	40

NOTE CEV from ladle analysis ≤ 0,42 for plates thicker than 20 mm.

[a] The maximum thickness shall be the lower of that specified in this table and that derived from Figure 1.

Table 9 — Charpy V-notch impact energy for steel types

Steel type	Charpy V-notch impact energy
I	27 J at +20 °C
II	27 J at 0 °C
II A	27 J at -10 °C
III	27 J at -20 °C
IV	27 J at -30 °C
V	40 J at +30 °C[a]
VI	40 J at +10 °C[b]
VI A	40 J at 0 °C
VII	40 J at -10 °C[c]
VIII	40 J at -20 °C
IX	40 J at -30 °C
X	55 J at +20 °C
XI	55 J at 0 °C

NOTE 1 The impact energy requirements are longitudinal values of:

27 J for grade 235 and 275 steels

40 J for grade 355 steel

55 J for higher than grade 355 steel

NOTE 2 There is no need under the atmospheric conditions in Europe to use steels with better toughness than line 6, but rather than leave out grades 275 ML etc., these were included since they will meet the requirements of Type IV.

[a] extrapolation from 27 J at +20 °C

[b] extrapolation from 27 J at 0 °C

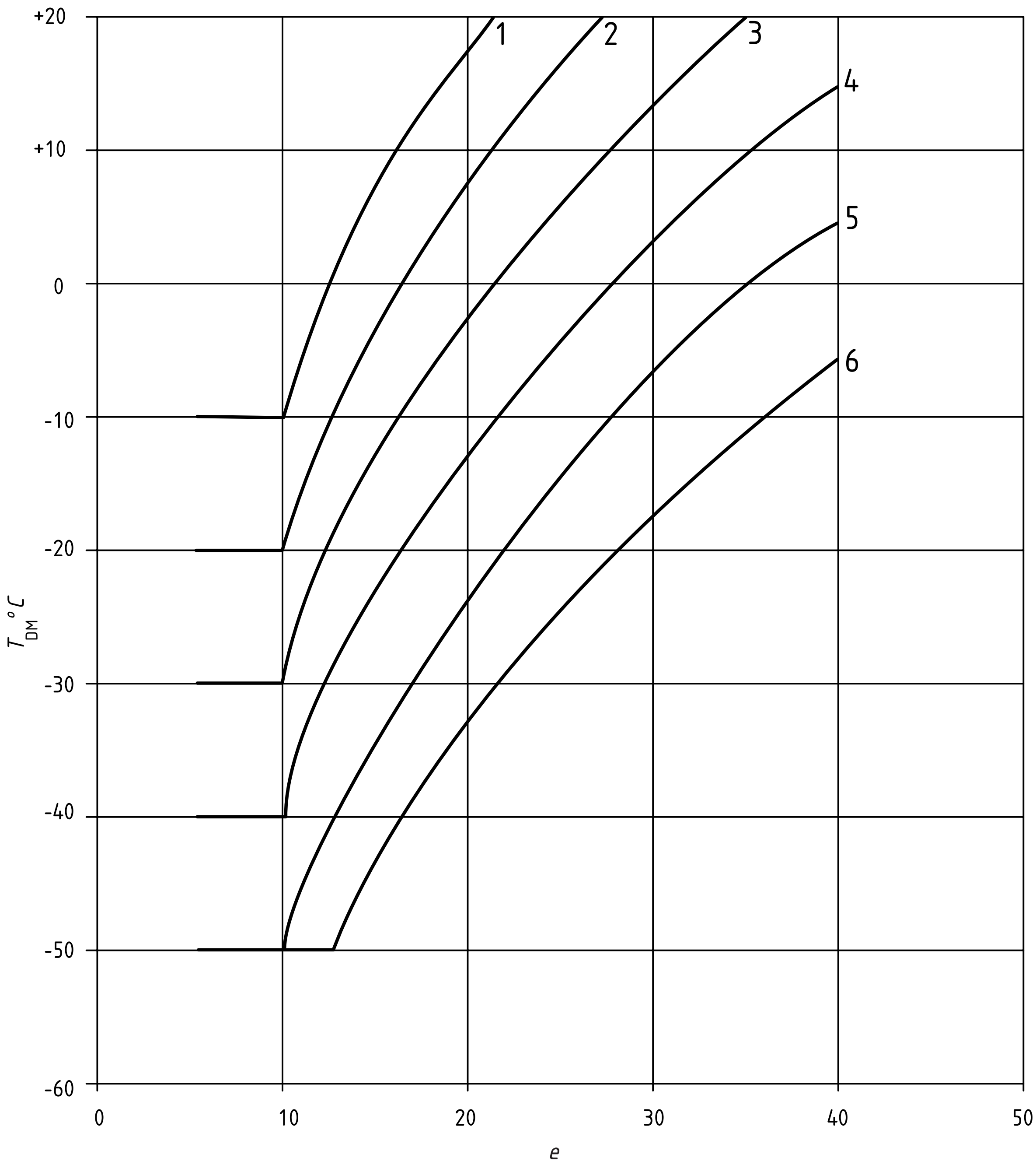
[c] extrapolation from 27 J at –20 °C

6.1.1.2 For design metal temperatures in excess of 100 °C, steels with elevated temperature yield strength values shall be in accordance with Table 8.

Other steel grades for which elevated temperature yield strength values are not specified in the material standard may also be used, provided the actual value of each cast of the material delivered shall be certified by the steel manufacturer (see A.4) in accordance with EN 10025.

The test results shall be reported in an inspection document in accordance with EN 10204:2004, Cert. 3.1B.

6.1.1.3 When the maximum design metal temperature exceeds 250 °C, steels which are proven to be unaffected by ageing shall be used. The method of proof shall be subject to agreement (see A.5).



Key

T_{DM}	Design metal temperature		*e*	Nominal thickness	
1	Steel types I, V and X	(Impact test at +20 °C)	4	Steel types IIA and VII	(Impact test at -10 °C)
2	Steel types VI	(Impact test at +10 °C)	5	Steel types III and VIII	(Impact test at -20 °C)
3	Steel types II, VIA and XI	(Impact test at 0 °C)	6	Steel types IV and IX	(Impact test at -30 °C)

Figure 1 — Minimum temperature at which each type of steel can be used

6.1.2 Structural steel sections

6.1.2.1 All carbon and carbon manganese structural steel sections used in the manufacture of tanks conforming to this document shall be in accordance with Tables 5 to 7 or Table 10.

Table 10 — Structural steel products

Standard	Designation	Steel type
EN 10210-1	S235 JRH	Type I
1994	S275 JOH	Type II
	S275 J2H	Type III
	S275 NH	Type IV
	S275 NLH	Type IV
	S355 JOH	Type VI
	S355 J2H	Type VII
	S355 NH	Type VIII
	S355 NLH	Type IX

6.1.2.2 Structural steel shall have inspection documentation in accordance with EN 10204:2004, Test report 2.2, except for steels S275 NH/NLH and S355 NH/NLH which shall have Inspection certificate 3.1.B

6.1.2.3 Pads, gussets etc. shall be from steel in accordance with 6.1.1.

6.1.3 Forgings

6.1.3.1 Forgings shall be manufactured from steel products by open die forging or ring rolling in accordance with EN 10250 and EN 10222.

6.1.3.2 The mechanical properties of forgings shall also be in accordance with 6.1.6 and 6.1.7.

6.1.3.3 Flanges provided for shell nozzles shall be marked by stamping or indelible paint. Marking shall include the following information:

— manufacturer’s name or mark;

— size and pressure rating;

— steel grade;

— identification number;

— stamp of the manufacturer’s inspector.

6.1.3.4 Inspection documentation in accordance with EN 10204:2004, Cert. 3.1B shall be supplied with flanges used in nozzles attached to materials requiring inspection documentation in accordance with EN 10204:2004, Cert 3.1B. This shall include the name of the producer of the initial material and the mechanical properties of the finished forging.

Inspection documentation in accordance with EN 10204:2004, Test report 2.2 shall be supplied with other flanges.

NOTE Flanges for roof nozzles, manholes and clean-out doors may be cut from plates. The quality of the cut flange should be guaranteed by the manufacturer of the flange, either by using plate with specified transverse properties in accordance with Z15 of EN 10164, or by ultrasonic inspection to ensure the absence of laminations.

6.1.4 Pipes

6.1.4.1 Pipes used for nozzle bodies shall be either seamless tubes or longitudinal welded tubes in accordance with the appropriate parts of EN 10216 or EN 10217.

6.1.4.2 The mechanical properties of pipes shall also be in accordance with 6.1.6 and 6.1.7.

6.1.4.3 Pipes provided for piping connected to the shell shall be marked in accordance with the appropriate parts of EN 10216 or EN 10217.

6.1.4.4 Inspection documentation in accordance with EN 10204:2004, Cert 3.1B shall be supplied with pipes used in nozzles attached to materials requiring inspection documentation in accordance with EN 10204:2004, Cert 3.1B. This shall include the name of the producer of the initial material and mechanical properties of the finished piping.

Inspection documentation in accordance with EN 10204:2004, Test report 2.2 shall be supplied with other piping.

6.1.4.5 Pipes provided for the manufacture of heating coils shall be in accordance with an appropriate European material Standard and, if necessary, should conform to EN 13480.

6.1.5 Welding consumables

Welding consumables shall be in accordance with EN 499, and, shall be used in the approval procedures in accordance with Clause 17. Appropriate inspection documentation shall be supplied.

The approval procedure test shall demonstrate that the yield strength and tensile strength of the welded joint exceeds the strength of the base materials being joined.

The welded joint shall also be chemically compatible with the materials being joined and the stored product.

6.1.6 Charpy V-notch impact energy requirements of carbon and carbon manganese steels

6.1.6.1 General

When specified in the relevant clause of this document, Charpy V-notch impact energy testing shall be carried out in accordance with EN 10045-1. The impact energy value shall be in accordance with the requirements of the relevant material specification or weld metals in accordance with 6.1.6.3.

The specified Charpy V-notch impact test values for plates, forgings, pipe and weld metal are determined from three specimens, the value taken shall be the average of the three results. The individual value of only one specimen shall be not less than 70 % of the specified minimum average value. When the material is less than 10 mm thick, 10 mm × 5 mm specimens shall be used and they shall demonstrate 50 % of the values specified for full size specimens.

6.1.6.2 Plates

The required impact test temperatures and levels of impact energy for the shell plates, bottom annular plates and roof compression areas shall conform to the requirements of the material specifications specified in 6.1.1. For shell plates and bottom annular plates purchased to an alternative specification, then the impact test temperature and levels of impact energy shall conform to the requirements of Annex F.

Impact testing shall not be required for bottom plates other than annular plates.

Impact testing of bottom annular plates shall not be required when the shell plates attached to them are not required to be impact tested.

Impact testing shall not be required for shell plates, or materials attached to shell plates, less than 6 mm thick, nor when the minimum design metal temperature and the thickness are within the limits given in Table 11.

NOTE Roof plates do not normally require impact testing, but it may be required for roofs for very high pressure tanks where the plate thickness exceeds 6 mm (see Figure 1).

Table 11 — Conditions for waiving impact testing

Minimum design metal temperature °C	**Thickness** mm
≥ + 10	≤ 20
≥ 0	≤ 13
≥ – 10	≤ 10
< – 10	≤ 6

6.1.6.3 Weld metals

6.1.6.3.1 Weld metals for carbon and carbon manganese steels shall be impact tested when the materials they are joining are required to be impact tested at 0°C or lower. Impact testing of weld metals shall not be required where plate materials are exempt from impact testing in accordance with 6.1.6.2. When impact testing is required, weld metal specimens shall be removed from the welding procedure test plates required by Clause 17 and shall meet the requirements of 6.1.6.3.2 or 6.1.6.3.3 as appropriate.

6.1.6.3.2 Vertical shell welds shall be impact tested at the test temperature required for the plate material and shall show not less than the value required for the thicker plate material. When connections are made between materials of different thicknesses or different grades, then the impact requirements for the weld metal shall be the more stringent of the two.

6.1.6.3.3 Horizontal shell welds shall be impact tested at the test temperature of the thicker plate material being joined or at –10 °C, whichever is the least stringent, and shall show not less than 27 J.

6.1.7 Mountings

6.1.7.1 Unless otherwise agreed (see A.2), reinforcing plates, insert plates, nozzle bodies and flanges shall be of the same general type of material as the shell plates to which they are welded. They shall also conform to the impact energy requirements of 6.1.6. The nominal thickness, *e*, for use in Figure 1 shall be taken as the nominal thickness of the component except for the following:

a) **Weld-neck flanges**

The nominal thickness shall be taken as the thickness at the weld or 25 % of the flange thickness, whichever is greater.

b) **Hubbed or plain slip-on flanges**

The nominal thickness shall be taken as the nominal thickness of the branch, e_n, to which the flange is welded or 25 % of the flange thickness, whichever is greater.

6.1.7.2 Insert plates of ferritic steel which exceed 40 mm thickness shall show Charpy V-notch impact energy values ≥ 27 J at -50 °C, irrespective of the design metal temperature.

6.1.7.3 Reinforcing plates and insert plates shall have a minimum specified yield strength ≥ 90 % of the minimum specified yield strength for the shell plates to which they are welded. Nozzle bodies shall also conform to these requirements when the nozzle body is used in the reinforcement calculation.

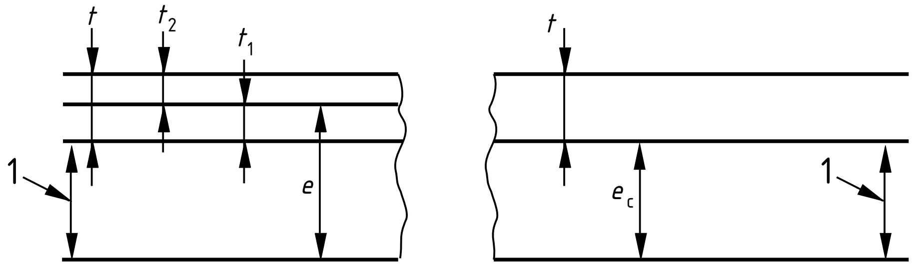
6.1.7.4 Permanent attachment materials shall show the same Charpy V-notch impact energy values as the shell plates to which they are welded.

6.1.8 Thickness tolerances

6.1.8.1 The measured thickness at any point more than 25 mm from the edge of any nominal thickness[3)] bottom, shell, roof or annular plate (*e*) shall be not less than the specified thickness less half the total thickness tolerance specified in EN 10029:1991, Table 1: class D (see Figure 2 a)).

6.1.8.2 The measured thickness at any point more than 25 mm from the edge of shell plates and roof plates whose thickness has been calculated shall not be less than the calculated minimum thickness (e_c), e.g. EN 10029:1991, Table 1: class C, i.e. only positive tolerances are permitted (see Figure 2 b)).

[3)] Those plates whose thickness is determined by minimum specified values.



a) Nominal plates (see 6.1.8.1)

b) Calculated thickness plates (see 6.1.8.2)

e - nominal thickness (bottom, annular, shell or roof plates)

e_c - calculated minimum thickness of plate including any corrosion allowance

t - total thickness tolerance

t_1 - minus ½ total thickness tolerance

t_2 - plus ½ total thickness tolerance

1 - minimum allowed thickness

Figure 2 — Plate thickness tolerances

6.2 Stainless steels

6.2.1 General

6.2.1.1 Selection of materials

All stainless steel plates and structural sections used in the manufacture of tanks conforming to this document shall be in accordance with the minimum requirements given in EN 10088-1 and -2.

Martensitic stainless steels shall not be used.

Ferritic stainless steels shall be limited to a maximum thickness of 10 mm.

Austenitic and austenitic-ferritic stainless steels shall be selected from Table 12.

6.2.1.2 Chemical properties

The stainless steel grades specified (see A.1) shall be suitable for the product to be stored, and shall be in accordance with EN 10088-2 or –3:1995, Tables 7, 10 and 11.

6.2.1.3 Mechanical properties

The minimum specified mechanical properties shall conform to those given in the appropriate part of EN 10088. For tanks intended to operate at elevated temperatures, the required values of yield strength shall be determined by interpolation of the values specified in EN 10088-2 or –3:1995, Tables 10 and 15.

Table 12 — Stainless steels for tank fabrication

Steel designation	
Grade	**Number**
Austenitic	
X2CrNi18-9	1.4307
X2CrNi19-11	1.4306
X2CrNiN18-10	1.4311
X5CrNi18-10	1.4301
X6CrNiTi18-10	1.4541
X6CrNiNb18-10	1.4550
X1CrNi25-21	1.4335
X2CrNiMo17-12-2	1.4404
X2CrNiMoN17-11-2	1.4406
X5CrNiMo17-12-2	1.4401
X1CrNiMoN25-22-2	1.4466
X6CrNiMoTi17-12-2	1.4571
X6CrNiMoNb17-12-2	1.4580
X2CrNiMo17-12-3	1.4432
X2CrNiMoN17-13-3	1.4429
X2CrNiMo17-13-3	1.4436
X2CrNiMo18-14-3	1.4435
X2CrNiMoN18-12-4	1.4434
X2CrNiMoN18-15-4	1.4438
X2CrNiMoN17-13-5	1.4439
X1NiCrMoCu31-27-4	1.4563
X1NiCrMoCu25-20-5	1.4539
X1CrNiMoCuN25-25-5	1.4537
X1CrNiMoCuN20-18-7	1.4547
X1CrNiMoCuN25-20-7	1.4529
Austenitic-ferritic	
X2CrNiN23-4	1.4362
X2CrNiMoN22-5-3	1.4462
X2CrNiMoCuN25-6-3	1.4507
X2CrNiMoN25-7-4	1.4410
X2CrNiMoCuWN25-7-4	1.4501
Stainless steels selected from EN 10088-1: 1995	

6.2.1.4 Surface finish

Depending on the stored product, all information which will allow the manufacturer to order the materials, taking into account the information given in EN 10088-2 or –3:1995, Table 6 shall be specified (see A.1).

6.2.2 Plate materials

The materials shall be marked as required by the tank manufacturer (see A.5) with reference to EN 10088-2:1995, Table 20.

Inspection documentation in accordance with EN 10204:2004, Cert 3.1B shall be supplied for all plate materials.

6.2.3 Structural steel sections

Unless otherwise specified, inspection documentation in accordance with EN 10204:2004, Test report 2.2 shall be supplied for structural stainless steel sections.

6.2.4 Forgings

6.2.4.1 Forgings shall be manufactured from stainless steel products by open die forging or ring rolling in accordance with EN 10222-4 and EN 10250-4.

6.2.4.2 The mechanical properties of forgings shall be equivalent to the properties used in the tank design.

6.2.4.3 Flanges provided for shell nozzles shall be marked by stamping or indelible paint. Marking shall include the following information:

- manufacturer’s name or mark;
- size and pressure rating;
- steel grade;
- identification number;
- stamp of the manufacturer’s inspector.

6.2.4.4 Flanges shall be supplied with inspection documentation in accordance with EN 10204:2004, Cert 3.1B, including the name of the producer of the initial material and mechanical properties of the finished flange.

NOTE Flanges for roof nozzles, manholes and clean-out doors may be cut from plate.

6.2.5 Pipes

6.2.5.1 Pipes used for nozzles shall be either stainless steel seamless tubes or longitudinal welded tubes in accordance with EN 10216-5 or prEN 10217-7.

6.2.5.2 Mechanical properties of pipes shall be equivalent to the properties used in the tank design.

6.2.5.3 Pipes for piping connected to the shell shall be marked by stamping or indelible paint. Marking shall include the following information:

— manufacturer’s name or mark;

— steel grade;

— identification number;

— stamp of the manufacturer’s inspector.

6.2.5.4 Pipes shall be supplied with inspection documentation in accordance with EN 10204:2004 Cert 3.1B, including the name of the producer of the initial material.

6.2.5.5 Pipes provided for the manufacture of heating coils shall be in accordance with EN 10216-5 or prEN 10217-7 and, if necessary shall be designed and fabricated in accordance with EN 13480.

6.2.6 Welding consumables

Welding consumables shall be in accordance with EN 1600, shall be supplied with the appropriate inspection documentation, and shall be used in the approval procedures in accordance with Clause 17.

The approval procedure tests shall demonstrate that the yield strength and tensile strength of the welded joint exceeds the strength of the base materials being joined.

The welded joint shall be chemically compatible with the materials being joined and the stored product.

7 Design loads

7.1 Loads

The design shall take account of the loads listed below and specified in 7.2.1 to 7.2.14.

a) Liquid induced loads during operation and testing;

b) Internal pressure loads during operation and testing;

c) Thermally induced loads;

d) Dead loads;

e) Insulation loads;

f) Live loads;

g) Concentrated live loads;

h) Snow loads;

i) Rainfall induced loads;

j) Wind loads;

k) Seismic loads;

l) Loads resulting from connected piping and attachments;

m) Foundation settlement loads;

n) Emergency loads.

7.2 Load values

7.2.1 Liquid induced loads

During operation, the load due to the contents shall be the design weight of the product to be stored from the maximum design liquid level to empty.

During test, the load due to the contents shall be the weight of the test medium from the maximum test liquid level to empty.

7.2.2 Internal pressure loads

During operation, the internal pressure load shall be the load due to the specified design pressure and design internal negative pressure.

During test, the internal pressure load shall be the load due to the specified test pressure and test internal negative pressure.

7.2.3 Thermally induced loads

When the stored product has to be kept at an elevated temperature, the resulting thermal loads shall be evaluated.

NOTE For tanks designed to operate at 100 °C or less, loads resulting from temperature effects can be ignored.

7.2.4 Dead loads

The loads shall be considered as those resulting from the weight of all component parts of the tank and components permanently attached to the tank.

7.2.5 Insulation loads

The loads shall be those resulting from the self weight of the insulation.

7.2.6 Live load

The distributed live load shall be taken from ENV 1991-2-1 and shall be subject to agreement (see A.2).

7.2.7 Concentrated live load

The concentrated live load shall be subject to agreement (see A.2).

7.2.8 Snow loads

The loads shall be taken from EN 1991-1-3.

7.2.9 Rainfall

The loads applied to floating roofs shall be in accordance with D.3.2.

7.2.10 Wind

The 3 second wind gust velocity to be used in the design shall be not less than 45 m/s. Where wind gust velocities are expected to exceed 45 m/s, national data shall be consulted to establish an appropriate value which shall be subject to agreement (see A.2).

NOTE Careful consideration should be given to open top tanks without any form of roof, since wind effects could produce severe movement of the contents resulting in spillage and excessive loads on the tank. If these loads cannot be quantified, it is recommended that a roof be provided unless previous experience with similar conditions has proved satisfactory.

7.2.11 Seismic loads

The tank shall be designed to withstand seismic loads derived from local seismic data. The vertical and horizontal accelerations to be used in the design shall be specified (see A.1).

NOTE 1 Seismic design provisions should be in accordance with Annex G.

NOTE 2 For OBE, calculations should be based upon seismic loads which have up to 10 % probability of being exceeded during the lifetime of the tank.

NOTE 3 For SSE, calculations should be based upon seismic loads which have up to 1 % probability of being exceeded during the lifetime of the tank.

7.2.12 Loads resulting from connected piping and attachments

Loads resulting from pipes, valves and other items connected to the tank and loads resulting from settlement of independent item supports relative to the tank foundation shall be included in the design. Pipework shall be designed to minimise loads applied to the tank.

7.2.13 Foundation settlement loads

Settlement loads to be used in the design shall be subject to agreement (see A.2) and are only required to be taken into consideration where uneven settlement may be expected during the lifetime of the tank (see I.3.4).

7.2.14 Emergency loads

The emergency loads to be used in the design shall be subject to agreement (see A.2) and may include loads from events such as external blast, fire, etc.

7.3 Load combinations

The tank shall be designed for the most severe combination of the loads specified in 7.2, except that the following shall not be considered to act simultaneously:

a) design wind and seismic loads;

b) test loads and design wind loads;

c) test and seismic loads;

d) live and snow loads.

8 Tank bottoms

8.1 General

Tanks shall be designed with a single bottom unless otherwise specified by the purchaser (see A.1).

NOTE 1 For other types of bottoms, see Annex H.

NOTE 2 Typical layouts are given in Figure 3.

NOTE 3 Tank bottoms should have a design gradient no greater than 1:100 unless otherwise specified (see A.1). For tank bottoms with a gradient greater than 1:100, the design and foundation should be subject to agreement (see A.2). Consideration should be given to the operating conditions, the anticipated level of settlement, and the type of foundation employed

Full support of the tank bottom by the tank foundation shall be assumed for design purposes.

NOTE 4 Tank foundations and typical pads should be in accordance with Annex I.

8.2 Materials

8.2.1 Materials for tank bottoms shall conform to 6.1 or 6.2, as appropriate.

8.2.2 Where Charpy V-notch impact testing of the bottom shell course is required, the annular plate material shall also be impact tested and shall achieve the same minimum energy level (corrected for sub-standard specimen size if necessary) at the same impact test temperature as the bottom shell course to which it is attached (see 6.1.6.2).

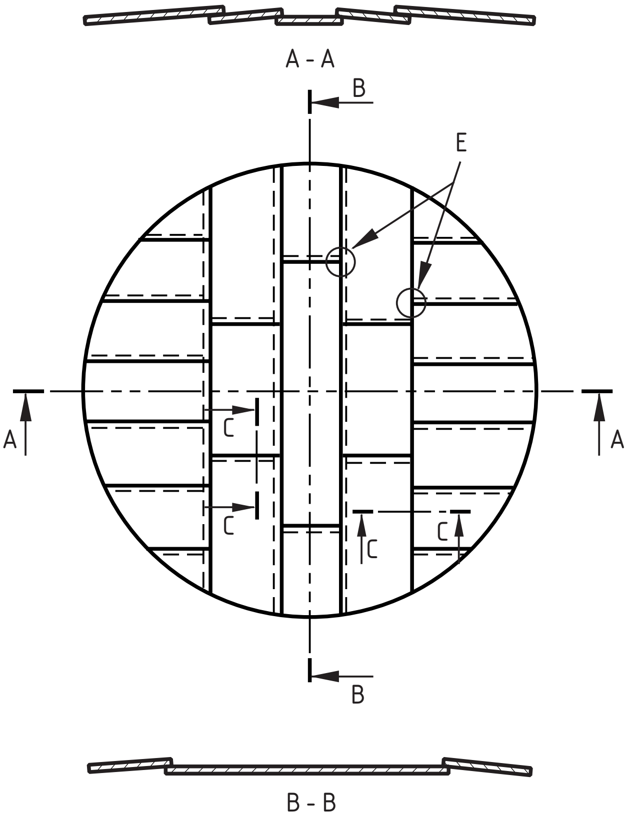
8.2.3 The specified nominal thickness of both the rectangular bottom plates and the bottom sketch plates shall be not less than that specified in Table 13 excluding the corrosion allowance. In addition, the bottom plate thicknesses in the corroded condition shall be sufficient to resist uplift due to the design internal negative pressure.

NOTE It is permissible to utilize a minimum guaranteed residual liquid level to assist in resisting this uplift if this is agreed (see A.2).

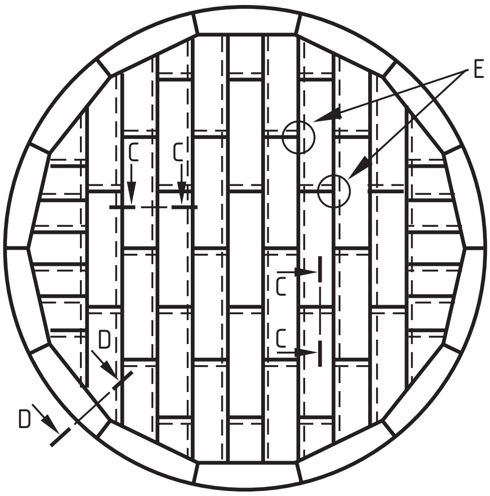
Table 13 — Minimum nominal bottom plate thickness

Material	Lap welded bottoms	Butt welded bottoms
C and C Mn steels	6 mm	5 mm
Stainless steels	5 mm	3 mm

8.2.4 The annular plate shall have the same specified minimum yield strength as the bottom shell course to which it is attached.

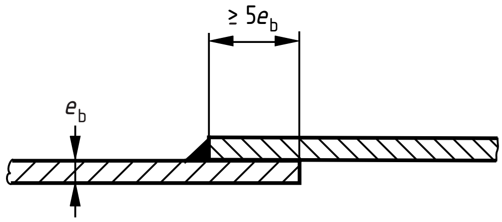


a) with bottom plates at the perimeter

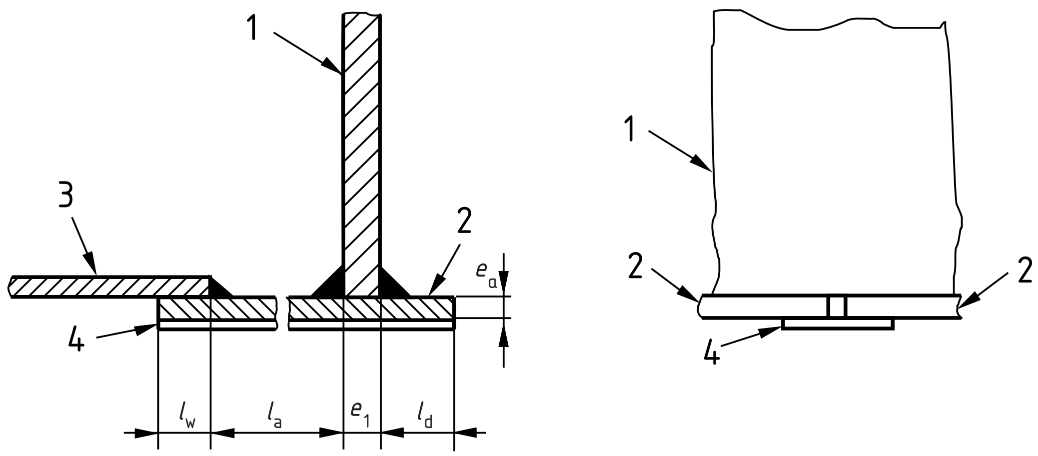


b) with annular plates at the perimeter

Figure 3 — Typical bottom layouts of tanks (continued)



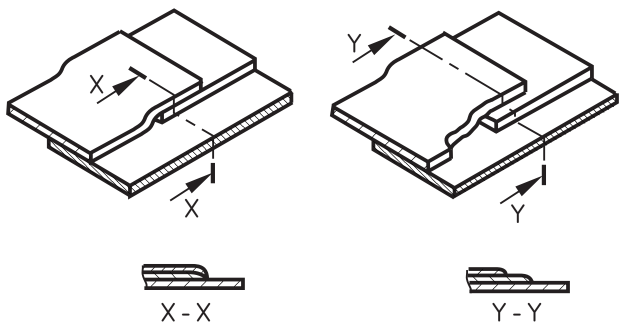
c) Section C-C, Overlap of bottom plates



Key

1. Shell plate
2. Annular plate
3. Bottom plate
4. Backing strip

d) Section D-D, Annular plates



e) View E, Typical cross joints in bottom plates where three thicknesses coincide

Figure 3 — Typical bottom layouts of tanks (concluded)

8.3 Design

8.3.1 Bottoms of tanks greater than 12,5 m diameter, shall have a ring of annular plates (see Figure 3 b)) having a minimum nominal thickness, e_a, excluding corrosion allowance either:

a) not less than that given by the following equation;

$$e_a = 3,0 + e_1/3 \tag{1}$$

where

e_1 is the thickness of the first course excluding corrosion allowance, in mm; or

b) not less than 6 mm;

whichever is the larger.

NOTE Bottoms of tanks up to and including 12,5 m diameter may be constructed without a ring of annular plates (see Figure 3 a)).

8.3.2 Bottoms of tanks that will be fitted with floating covers or floating roofs shall be reinforced in the area where the support legs rest on the bottom (see C.3.3.2 and D.3.13).

8.3.3 The minimum width, l_a as shown in Figure 3 d) shall be either:

a) as given by the following equation:

$$l_a > \frac{240}{\sqrt{H}} e_a \tag{2}$$

where

e_a is the thickness of the annular plate, in mm;

H is the maximum design liquid height, in m; or

b) 500 mm

whichever is the larger.

The distance, I_d from the outer surface of the shell plate to the outer edge of the bottom plates or annular plates shall be not less than 50 mm and not more than 100 mm (see Figure 3 d)).

8.3.4 The minimum distance between vertical joints in the lowest shell course and the annular butt joints shall be ten times the thickness of the lowest shell course.

8.4 Fabrication

8.4.1 All bottom plates shall be lap welded unless butt welding is specified by the purchaser or the designer (see A.1).

All joints in bottom plates to be lap welded shall be welded on upper side only with a continuous fillet weld and with a minimum lap of five times the thickness of the plate (see Figure 3 c)).

The bottom plates shall be lapped over the annular plates where they are used, shall be welded on the upper side only with a continuous fillet weld and shall have a minimum lap, I_w of 60 mm (see Figure 3 d)).

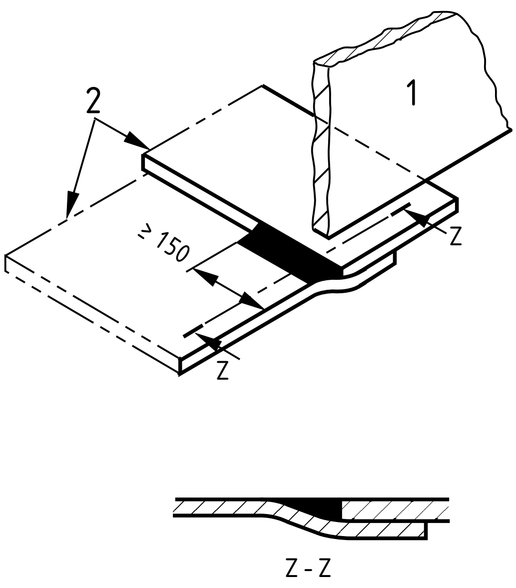
At the end of cross joints in lap welded bottom plates where three thicknesses occur, the upper plate shall be hammered down and welded as indicated in detail X-X or Y-Y in Figure 3 e), cutting back the upper plate if the upper plate overlaps the intermediate plate.

8.4.2 Where butt welding is specified for bottom plate welds and bottom to annular plate welds, backing strips (permanent or temporary) shall be used. Where permanent backing strips are used, consideration shall be given to the effect of thermal movement and type of foundation, where applicable.

8.4.3 For tanks without annular plates, the ends of lap welded joints in the bottom plates under the lowest course of shell plates shall be welded flush with the surface for a minimum distance of 150 mm as shown in Figure 4.

8.4.4 For tanks with annular plates, the radial seams connecting the ends of the annular plates shall be full penetration butt welded.

NOTE A backing strip of the form shown in Figure 5 is acceptable.



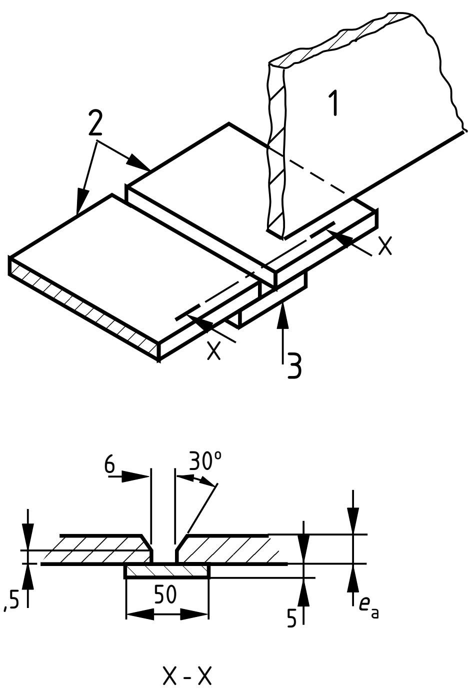
Key

1 Shell plate

2 Bottom plates bottom

Dimensions in millimetres

Figure 4 — Typical bottom plate joint under shell plates for tanks without annular plates



Key

1 Shell plate

2 Annular plates

3 Backing strip

Linear dimensions in millimetres

Figure 5 — Typical annular plate joint under shell plates for tanks with annular plates

8.4.5 The attachment between the bottom edge of the lowest course of shell plates and the bottom plates or annular plates shall be continuous fillet welds on both sides of the shell plate.

The minimum throat thickness of each fillet weld shall be equal to the thickness of the sketch plate or annular plate (see Figure 3 d)) except that the specified throat thickness need not exceed 9,5 mm and where the shell plate thickness is less than the bottom plate or annular plate thickness, the specified throat thickness need not exceed the appropriate value given in Table 14.

Table 14 — Fillet weld throat thickness when shell plate is thinner than bottom plate or annular plate thickness

Shell plate thickness mm	Fillet weld throat thickness mm
< 5	3,0
5	4,5
> 5	6,0

9 Shell design

9.1 Design and test stress

9.1.1 The stresses used in calculations for tanks with a maximum design metal temperature less than or equal to 100 °C shall be the appropriate value from a) and b).

a) The maximum allowable design stress in shell plates shall be two thirds of the yield strength of the material with a maximum design stress of 260 N/mm^2;

b) The maximum allowable test stress in shell plates shall be 75 % of the yield strength of the material with a maximum design stress of 260 N/mm^2.

9.1.2 Where the maximum design metal temperature of carbon and carbon manganese steel is greater than 100 °C, the design stress shall be two thirds of the certified yield strength (0,2 % proof strength) of the steel at the maximum design metal temperature.

9.1.3 When the maximum design density of the contained liquid, W, is less than or equal to 1,0 kg/l, the shell of the tank will be subjected to a stress during the hydrostatic test to the maximum design liquid level which is equal to, or greater than, the stress during service, and this shall be allowed for.

When the maximum design density of the contained liquid, W, exceeds 1,0 kg/l, the shell of the tank shall not be subjected to an overstress during the hydrostatic test to the maximum design liquid level. In this cases, one of the following options shall be selected subject to agreement (see A.2):

a) A temporary extension of the shell shall be constructed to allow the hydrostatic test water level to be increased above the maximum design liquid level.

NOTE It is recommended that this temporary extension is sufficient to create an overload of at least 10 %.

b) The first filling with liquid of the maximum design density shall be undertaken under careful supervision observing the same caution as would apply to the hydrostatic test, and the requirements of 19.13 shall be followed. In the case of tanks constructed of carbon and carbon manganese steels, consideration shall be given to using materials with enhanced levels of notch ductility, i.e. use a type of steel one or two types higher than would otherwise be required, (see Table 15).

Table 15 — Steels with enhanced levels of notch ductility

Steel required as given in 6.1	One grade higher for test stress between 100 % and 85 % design stress	Two grades higher for test stress < 85 % design stress
Type I	Type II	Type III
Type II	Type III	Type IV
Type III	Type IV	Special steel
Type IV	Special steel	Special steel
Type V	Type VI	Type VII
Type VI	Type VII	Type VIII
Type VII	Type VIII	Type IX
Type VIII	Type IX	Special steel

9.1.4 In calculating the thickness of plate required, the joint efficiency factor shall be taken as 1,0.

9.1.5 The specified thickness of the shell plates shall be not less than the specified nominal thicknesses specified in Table 16.

Table 16 — Minimum specified nominal shell thickness

Tank diameter D	Minimum specified nominal shell thickness e	
	Carbon and carbon manganese steels	Stainless steels
M	mm	mm
$D < 4$	5	2
$4 \leq D < 10$	5	3
$10 \leq D < 15$	5	4
$15 \leq D < 30$	6	5
$30 \leq D < 45$	8	6
$45 \leq D < 60$	8	-
$60 \leq D < 90$	10	-
$90 \leq D$	12	-

For stainless steel tanks of diameter 45 m and greater, the minimum shell thickness shall be subject to agreement (see A.2).

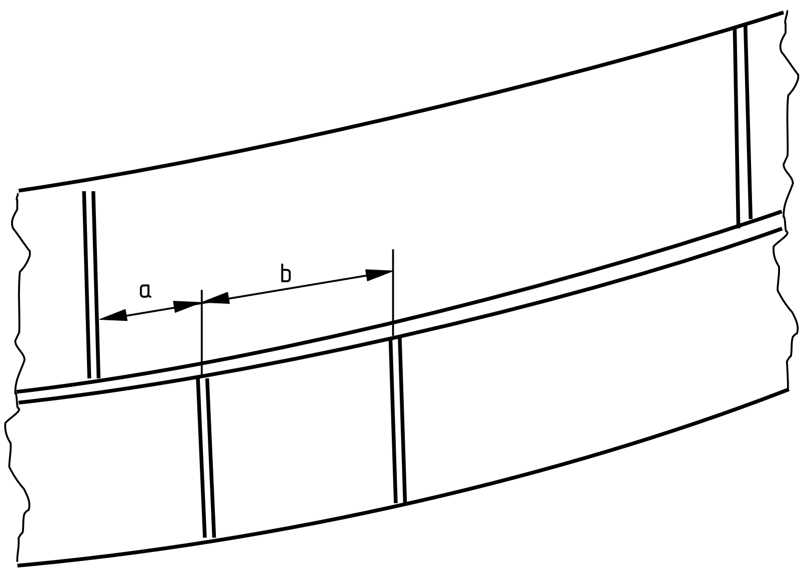
NOTE 1 These specified thickness requirements are needed for construction purposes and therefore may include any corrosion allowance, provided that the shell is shown by calculation to be safe in the corroded condition in accordance with 9.2.

NOTE 2 For large diameter tanks with low heights, the lowest shell course may be rather thin, so that the stability should be checked taking into account the vertical loads and possible uneven settlement of the foundations.

9.1.6 In no case shall the specified thickness of the shell or reinforcing plate be greater than 40 mm

9.1.7 No course shall be constructed at a thickness less than that of the course above, irrespective of the materials of construction, except for the top compression area.

9.1.8 The minimum circumferential dimensions of a shell plate shall be 1 m (see Figure 6).



Key

a. Minimum distance between vertical joints in adjacent courses (see 9.4).

b. Minimum circumferential dimension of shell plate.

Figure 6 — Shell plate arrangements

9.2 Internal loads

9.2.1 The tank shell thickness shall be computed on the basis that the tank is filled to the top of the shell. When the height of the shell includes a wind skirt with overflow openings and/or seismic freeboard, the maximum product height for calculation purposes shall be the overflow height or the height less the seismic freeboard. The calculation shall be based on the design density of the stored product and the design density of the test medium.

9.2.2 The required minimum thickness of shell plates shall be the value in 9.1.5, or the values computed by the following formulae, whichever is the greatest:

$$e_c = \frac{D}{20S}\{98W(H_c - 0,3) + p\} + c \quad (3)$$

$$e_t = \frac{D}{20S_t}\{98\,W_t(H_c - 0,3) + p_t\} \quad (4)$$

where

c is the corrosion allowance, in mm;

D is the tank diameter, in m;

e_c is the shell thickness required for design conditions, in mm;

e_t is the shell thickness required for test conditions, in mm;

H_c is the distance from the bottom of the course under consideration to the height defined in 9.2.1, in m;

p is the design pressure (this can be neglected for tanks with a design pressure less than or equal to 10 mbar), in mbar;

p_t is the test pressure (and is equal to the design pressure times 1,1 for design pressures greater than 10 mbar), in mbar;

S is the allowable design stress (see 9.1.1.1), in N/mm^2;

S_t is the allowable test stress (see 9.1.1.2), in N/mm^2;

W is the maximum design density of the contained liquid under storage conditions, in kg/l;

W_t is the maximum design density of the test medium, in kg/l;

NOTE See 6.1.8 for the interpretation of thickness tolerances.

9.2.3 The hoop stress in each course shall be computed at 0,3 m above the centre line of the horizontal joint in question.

When the adjacent upper and lower courses are made from materials with different specified minimum yield strengths and specified minimum ultimate tensile strengths, and when:

$$\frac{H_U - 0,3}{H_U} \geq \frac{H_L - 0,3}{S_L} \quad (5)$$

where

H_L is the distance from the bottom of the lower course to the height defined in 9.2.1, in m;

H_U is the distance from the bottom of the upper course to the height defined in 9.2.1, in m;

S_L is the allowable design stress of the lower course, in N/mm^2;

S_U is the allowable design stress of the upper course, in N/mm^2;

then the thickness of the upper course shall be calculated using the modified formulae:

$$e_c = \frac{D}{20S}(98\,WH_c + p) + c; \qquad e_t = \frac{D}{20S_t}(98\,W_t H_c + p_t) \qquad (6)$$

9.3 Wind and vacuum loads

9.3.1 Stiffening rings

9.3.1.1 Open top tanks shall be provided with a primary stiffening ring to maintain roundness when the tank is subjected to wind loads. The primary stiffening ring shall be located at or near the top of the top course and preferably on the outside of the tank shell.

9.3.1.2 Fixed roof tanks with roof structures shall be considered to be adequately stiffened at the top of the shell by the structure, and a primary stiffening ring is not therefore considered necessary.

9.3.1.3 In certain cases, for both open-top and fixed roof tank shells designed in accordance with this document, secondary stiffening rings shall be required to maintain roundness over the full height of the tank shell under wind and/or vacuum conditions of loads (see 9.3.3).

9.3.1.4 In so far as the primary stiffening ring is designed to stabilize the full tank height, the secondary stiffening rings are not required to carry panel loads, but shall prevent preferential local buckling of the tank shell.

9.3.1.5 Stiffening rings shall comprise:

a) structural sections or formed plate sections;

b) sections built up by welding;

c) a combination of such types of sections assembled by welding.

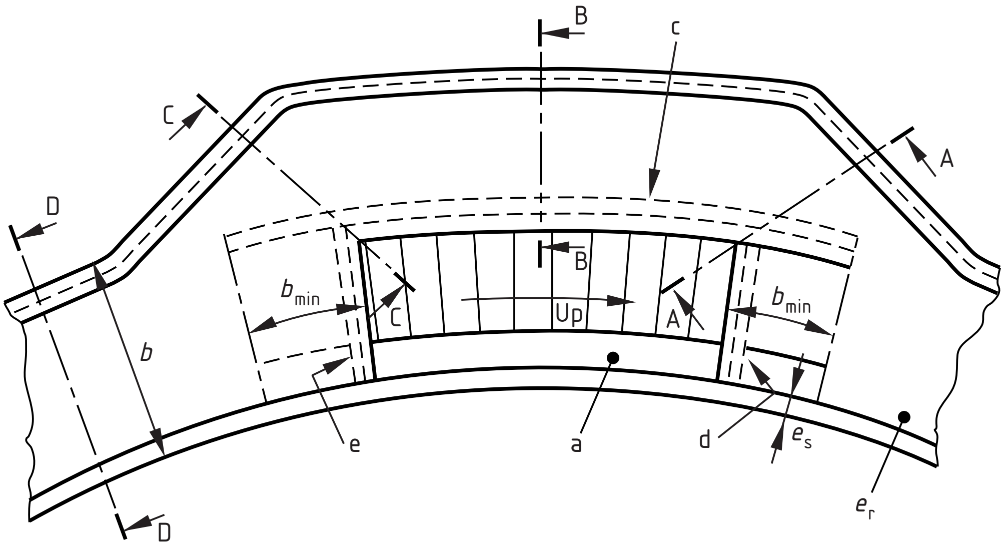
The outer periphery of stiffening rings shall be circular or polygonal.

9.3.1.6 The minimum size of angle for use alone, or as a component in a built-up stiffening ring, shall be 60 mm × 60 mm × 5 mm. The minimum nominal thickness of plate for use in formed or built-up stiffening rings shall be 5 mm, when its width does not exceed 600 mm, and shall be 6 mm if over 600 mm wide.

9.3.1.7 Stiffening rings or portions thereof which are to be regularly used as walkways shall have a width of not less than 600 mm clear of the projecting top corner ring on the top of the tank shell, shall be located 1 m below the top of the top corner ring, and shall be provided with handrailing on the otherwise unprotected side and at the ends of the section to be used as a walkway.

9.3.1.8 When a stairway opening is installed through a primary stiffening ring, adequate compensation shall be provided to ensure the section modulus at any section through the opening conforms to 9.3.2.1.

The shell adjacent to such an opening shall be stiffened with a horizontally placed angle or bar. The other edges of the opening shall be stiffened with an angle or vertically placed bar or plate. The cross-sectional area of these edge stiffeners shall be at least equivalent to the cross-sectional area of that portion of shell included in the section modulus calculation of the stiffening ring (see 9.3.2.2). These stiffeners, or additional members, shall be positioned and designed so as to provide a suitable toe-board around the opening. The stiffening members shall extend beyond the end of the opening for a distance equal to, or greater than, the minimum depth of the rectangular ring sections. The end stiffening members shall be connected into the side stiffening members and shall be connected to them in such a manner as to develop their full strength (see Figure 7).



NOTE 1 The cross-sectional area of a, c, d, and e shall equal $32e_s^2$. The section of the figure designated "a" may be a bar or an angle whose wide leg is horizontal. The other sections may be bars or angles whose wide legs are vertical.

NOTE 2 Bars c, d, and e may be placed on the top of the girder web, provided they do not create a tripping hazard.

NOTE 3 The section modulus of sections A-A, B-B, C-C and D-D shall conform to 9.3.2.1.

NOTE 4 The stairway may be continuous through the stiffening ring or may be offset to provide a landing.

NOTE 5 See 9.3.1.8 for toeboard requirements.

Figure 7 — Stairway opening through a stiffening ring

9.3.1.9 Brackets shall be provided for all primary stiffening rings when the dimension for the horizontal leg or web exceeds 16 times the leg or web thickness. Such brackets shall be placed at intervals as required for the dead load and vertical live load that may be placed upon the ring. However, the spacing shall not exceed 24 times the width of the outside compression flange.

9.3.1.10 Stiffening rings which may trap liquids shall be provided with adequate drain holes.

9.3.1.11 Stiffening rings shall be attached to the tank shell by continuous fillet welds on the top edge.

Continuous or intermittent underside welds shall be specified (see A.1).

Continuous welds shall be used for all joints which, because of their location, might be subjected to corrosion from entrapped moisture.

The end-to-end joints in ring sections (see 16.7.6) shall be full penetration butt welds.

9.3.2 Primary stiffening ring (wind girder) design

9.3.2.1 The required minimum sections modulus Z, in cm^3 of the primary stiffening ring (see details d) and e) of Figure J.1) shall be determined by the equation.

$$Z = 0{,}058\, D^2\, H_\mathrm{f}\, \frac{{V_\mathrm{w}}^2}{45^2} \tag{7}$$

where

- D is the diameter of the tank (tanks in excess of 60 m diameter shall be considered to be of this dimension when determining the section modulus), in m;
- H_f is the height of the tank shell including any freeboard provided above the maximum filling height (see 9.2.1), in m;
- V_w is the wind gust velocity specified in 7.2.10, in m/s.

9.3.2.2 The section modulus of the primary stiffening ring shall be based upon the geometry of the applied members. The maximum portion of the tank shell in the corroded condition that can be included shall be a distance of 16 plate thicknesses below and, where applicable, above the ring shell attachment.

9.3.2.3 When the primary stiffening rings are located more than 600 mm below the top of the shell, the tank shall be provided with a top corner ring conforming to detail a) or b) of Figure J.1.

The minimum sizes of the top corner ring shall be:

60 mm × 60 mm × 5 mm for top shell courses 5 mm and thinner

80 mm × 80 mm × 6 mm for top shell courses 6 mm and thicker.

9.3.2.4 When top corner rings are being used as primary wind girders and are attached to the top edge of the shell ring by butt welding, the maximum portion of the tank shell to be included in the section modulus shall be 16 plate thicknesses less the vertical leg length of the angle.

9.3.3 Secondary stiffening ring (wind girder) design

9.3.3.1 The sizes of angles for the secondary stiffening rings are not related to the design loads, but shall be determined with respect to tank diameter, in accordance with the values given in Table 17.

The orientation and fixing of such secondary rings shall be as shown in detail c) of Figure J.1.

Table 17 — Minimum dimensions of angles

Tank Diameter D m	Minimum dimensions of angles mm × mm × mm
$D \leq 20$	100 × 65 × 8
$20 < D \leq 36$	120 × 80 × 10
$36 < D \leq 48$	150 × 90 × 10
$48 < D$	200 × 100 × 12
NOTE Other shapes may be used provided they have equivalent modulii.	

9.3.3.2 Junctions between adjacent parts of the secondary stiffening rings shall develop the full strength of the section at the point of junction.

Butt welds are preferred, and shall have complete penetration.

Whether or not adjacent sections are butt welded, the welding of such a joint shall be such that it produces fusion between the adjacent sections only and not fusion to the shell plate surface. Mouse holes (approximately 20 mm radius) shall be provided for drainage purposes.

9.3.3.3 The vertical positioning of secondary stiffening rings shall be calculated by first determining the height of a complete tank shell of equivalent stability, of the same diameter and of the same thickness as the top course of shell plating. An analysis of this equivalent tank shell in association with the required wind and vacuum design criteria shall determine the number of secondary rings required. These rings shall be located on the top course, or on a course of similar thickness, but if the location is not on such courses, the actual positioning shall be determined by converting back the equivalent shell course heights to their actual values.

NOTE The full analysis is illustrated by way of the examples given in Annex J.

A secondary stiffening ring shall not be located within 150 mm of a main circumferential tank seam.

9.3.3.4 The wind velocity used in the calculations shall be that specified in 7.2.10.

9.3.3.5 The internal negative pressure or vacuum (p_v) to be used for the design of secondary stiffening rings shall be as follows:

a) Open top tanks: 5 mbar irrespective of the design wind speed;

b) Fixed roof tanks: the design internal negative pressure, (see Table 3).

9.3.3.6 The formulae to be used in the design of secondary stiffening rings for tanks with a design internal negative pressure not exceeding 5,0 mbar shall be as follows:

$$H_e = h\left(\frac{e_{min}}{e}\right)^{5/2} \tag{8}$$

$$H_E = \sum H_e \tag{9}$$

$$K = \frac{95\,000}{3,563 V_w^{\;2} + 580\; p_v} \tag{10}$$

$$H_p = K\left(\frac{e_{min}^{\;5}}{D^3}\right)^{1/2} \tag{11}$$

where

D is the tank diameter, in m;

e_{min} is the thickness of the top course (corroded condition where applicable), in mm;

e is the thickness of each course in turn (corroded condition where applicable) in mm;

h is the height of each course in turn below any primary stiffening ring, in m;

H_e is the equivalent stable height of each course at e_{min}, in m;

H_E is the equivalent stable full shell height at e_{min}, in m;

H_p is the maximum permitted spacing of secondary stiffening rings on shells of minimum thickness, in m;

K is a factor;

p_v is the design internal negative pressure, in mbar (see Table 3);

V_w is the wind gust velocity specified in 7.2.10, in m/s.

NOTE Examples of calculations using these formulae are given in J.4 and J.5.

9.3.3.7 For tanks operating at elevated temperatures (> 100 °C), H_p shall be multiplied by the ratio of the modulus of elasticity of steel at elevated temperature to its modulus of elasticity at ambient temperature.

9.3.3.8 For tanks with a design internal negative pressure exceeding 5,0 mbar, the design methodology to be adopted shall be agreed (see A.2).

9.3.3.9 Where the combination of snow loads and internal negative pressure, or live loads and internal negative pressure, exceeds 1.2 kN/m^2, causing increased vertical axial loads, the shell shall be checked for stability. The design methodology and load combinations shall be subject to agreement (see A.2).

9.4 Shell plate arrangement

The tank shall be designed to have all courses vertical. The minimum distance between vertical joints in adjacent courses (see Figure 6 Key a)) shall be:

for plates up to and including 5 mm thick	100 mm
for plates above 5 mm thick	300 mm

9.5 Shell joints

All vertical and horizontal seams shall be butt joints in accordance with Clauses 17 and 18.

10 Fixed roof design

10.1 Loads

Roofs shall be designed to support the loads specified in Clause 7.2 including wind suction effects.

10.2 Type of roof

10.2.1 One of the two following types of roof shall be specified:

a) a self supporting cone or dome roof with or without roof structure; or

b) a column supported roof.

NOTE Where significant settlement of the foundations is anticipated, special design provisions should be made for column supported roofs.

10.2.2 The roof slope of a self-supporting cone roof shall be 1 in 5 unless otherwise specified (see A.1).

Where a dome roof is adopted, the radius of curvature shall be between 0,8 and 1,5 times the diameter of the tank unless otherwise specified (see A.1).

The roof slope for a column supported roof shall be 1 in 16 unless otherwise specified (see A.1).

10.3 Roof plating with supporting structure

10.3.1 Roof supporting structures for cone, dome or column supported roofs shall be designed in accordance with ENV 1993-1-1. The spacing of roof plate supporting members for cone roofs shall be such that the span between them does not exceed 2,0 m where one edge of the panel is supported by the top corner ring of the tank. Where this support is not present, the span shall not exceed 1,7 m. For dome roofs, this spacing shall be permitted to be increased to 3,25 m in accordance with ENV 1993-4-2.

10.3.2 Roof plates shall be continuously fillet welded to the top corner ring of the tank. Where roof frangibility is required, roof plates shall not be attached to the internal roof-supporting structure.

Frangible roof-to shell junctions shall be in accordance with Annex K.

10.3.3 The specified thickness of all roof plating shall be not less than the following excluding any corrosion allowance.

5 mm for carbon and carbon manganese steels, and

3 mm for stainless steels.

10.3.4 The material used for the construction of roof structural members shall have a specified thickness of not less than:

5 mm for carbon and carbon manganese steels, and

3 mm for stainless steels.

NOTE This does not apply to the webs of rolled joists and channel sections, or to structures in which special provisions against corrosion are made.

10.3.5 Plates shall be lapped and continuously fillet welded on the outside with a minimum lap of 25 mm unless otherwise specified (see 18.6 and A.1).

NOTE The plates should be lapped so that the lower edge of the uppermost plate is beneath the upper edge of the lower plate in order to minimize the possibility of condensation entering the lap joint. Depending on the tank contents, it may sometimes be necessary for the lap joint to be double-welded or made as a butt joint.

10.3.6 The joint efficiency factor, J, shall be either:

1,0	for butt welds;
0,35	for lapped joints with fillet welds on one side only;
0,5	for lapped joints with fillet welds on both sides.

Increases in joint efficiency for a lap welded roof plate shall be permitted subject to agreement (see A.2) provided this can be justified by special procedure tests simulating the actual configuration to be used on site.

The allowable design stress shall be taken as two thirds of the plate material yield stress.

10.3.7 All roof framing shall be provided with bracing in the plane of the roof surface conforming to the following.

a) Cross bracing in the plane of the roof surface shall be provided in at least two bays, i.e. between two pairs of adjacent rafters, on all roofs exceeding 15 m diameter. Sets of braced bays shall be spaced evenly around the tank circumference;

b) Additional vertical ring bracing, on trussed roofs only, shall be provided in an approximately vertical plane between trusses as follows:

   1) roofs over 15 m, up to and including 25 m diameter: one ring bracing;

   2) roofs over 25 m diameter: two ring bracings.

10.4 Roof plating without supporting structure (membrane roofs)

10.4.1 All membrane roofs shall be of either butt welded or double fillet welded lap construction.

10.4.2 Membrane roofs shall be designed to withstand the internal design pressure and to resist buckling due to external loads.

For pressure

$$e_p = \frac{pR_1}{20SJ} \quad \text{for spherical roofs} \qquad (12)$$

$$e_p = \frac{pR_1}{10SJ} \quad \text{for conical roofs} \qquad (13)$$

for buckling

$$e_p = 40\,R_1\sqrt{\frac{10\,p_e}{E}} \qquad (14)$$

where

e_p is the roof plate thickness excluding any corrosion allowance, in mm;

E is Young's modulus, in N/mm^2;

J is the joint efficiency factor as specified in 10.3.6;

p is the design pressure, (see Table 3), in mbar;

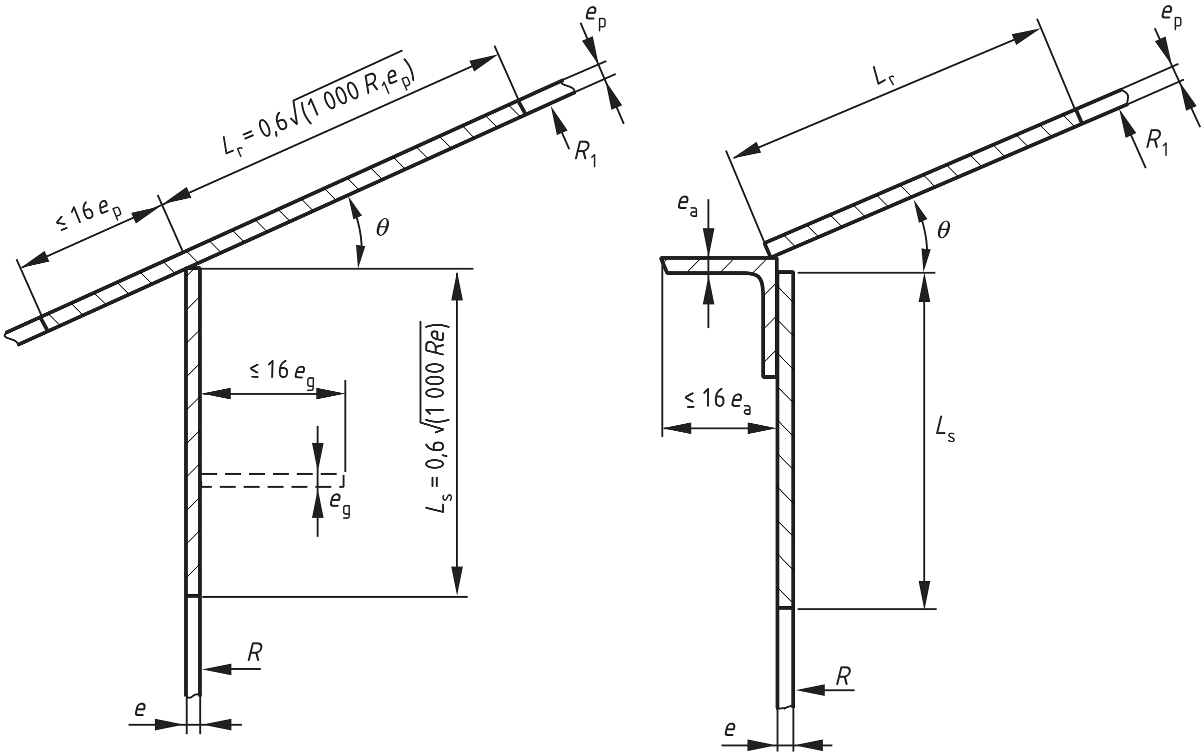
p_e is the external loads plus self weight of the plates plus the design internal negative pressure where applicable, in kN/m^2;

R_1 is the radius of curvature of roof, in m (for conical roofs, $R_1 = R/\sin\theta$ (see Figure 8);

S is the allowable design stress, (see 10.3.6) in N/mm^2.

10.5 Compression area at the junction of the shell and roof

10.5.1 The compression area is the region at the junction of the shell and the roof which is considered to resist forces imposed by the design pressure, and the maximum dimensions making up the compression region shall be as shown in the shaded area of Figure 8.



a) Without corner ring

b) With corner ring

Key

e is the thickness of shell, in mm;

e_a is the thickness of top corner ring (see Table 18), in mm;

e_g is the thickness of the horizontal girder, in mm;

e_p is the thickness of roof plate at compression ring, in mm;

L_r is the effective roof length, in mm;

L_s is the effective shell length, in mm;

R is the radius of tank shell, in m;

R_1 is the radius of curvature of roof , in m (for conical roofs = $R/\sin \theta$).

Figure 8 — Typical shell-roof compression areas

10.5.2 The compression area to be provided, A (in mm^2), excluding any corrosion allowance, shall be not less than that determined by the following equation:

$$A = \frac{50 p_c R^2}{S_c \tan\theta} \qquad (15)$$

where

- p_c is the internal pressure, and is equal to the design pressure p (see 5.1) less the weight of the roof plates, in mbar;
- R is the radius of the tank, in m;
- S_c is the allowable compressive stress which (unless otherwise specified) shall be taken as 120 N/mm^2 for all steels.
- θ is the slope of roof meridian at roof to shell connection, in degrees (see Figure 8);

10.5.3 If a horizontal girder is required to provide additional cross-sectional area, this girder shall be placed as close to the junction as possible (see Figure 8 a)).

Additional compression area shall be provided by thickening the roof or shell plate, by adding a bar or structural member, or by a combination of these. The additional compression area shall be arranged such that the centroid of the compression area falls within a vertical distance equal to 1,5 times the average thickness of the two members intersecting at the intersection point above or below the horizontal plane through the intersection point.

10.5.4 The compression area shall be checked for tension loads due to external loads and/or design internal negative pressure conditions, and the allowable design stress S, as defined in 9.1.1, shall not be exceeded.

10.5.5 When a structurally supported roof is used, the compression area shall be checked for tension forces applied from the roof structure.

Care shall also be taken to avoid excessive bending in the compression region at the rafter connection to the shell periphery.

10.5.6 Fixed roof tanks shall be provided with a minimum area A as calculated in 10.5.2, and shall have a top corner ring in accordance with Table 18.

Table 18 — Minimum size of top corner ring

Tank diameter D m	**Minimum size of top corner ring** mm × mm × mm
$D \le 10$	60 × 60 × 6
$10 < D \le 20$	60 × 60 × 8
$20 < D \le 36$	80 × 80 × 10
$36 < D \le 48$	100 × 100 × 12
$48 < D$	150 × 150 × 12

10.6 Venting requirements

10.6.1 General

The precise requirements for the venting of fixed roof tanks designed to this document shall be in accordance with 10.6.2 to 10.6.4 inclusive or as specified (see A.1).

Venting systems shall be in accordance with Annex L.

10.6.2 Scope of venting provided

The venting system provided shall cater for the following:

a) normal vacuum relief;

b) normal pressure relief;

c) emergency pressure relief, unless it is specified that it is not to be included (see A.1).

Where emergency pressure relief is required, it shall be provided by vents or by the provision of a frangible roof-to-shell joint (see Annex K).

10.6.3 Venting capacity

The number and size of vents provided shall be based on the venting capacity obtained from Annex L and shall be sufficient to prevent any accumulation of pressure or vacuum exceeding the values specified in 10.6.4.

NOTE 1 These vents may be fitted with mesh screens to prevent the ingress of foreign matter. The use of fine mesh is not recommended because of the danger of blockage, especially under winter conditions.

NOTE 2 Consideration should be given to the possibility of corrosion when selecting material for the wire mesh screen as it could adversely effect the venting capacity.

10.6.4 Accumulation of pressure and vacuum

10.6.4.1 The set pressure plus the accumulation to permit the valve to achieve the required throughput for normal pressure relief shall not exceed the design pressure (see 5.1).

10.6.4.2 The chosen set vacuum plus the actual accumulation to permit the valve to achieve the required throughput shall not exceed the design internal negative pressure (see 5.1).

10.7 Floating covers

When specified (see A.1), tanks shall be provided with floating covers (see Annex C).

11 Floating roof design

When specified (see A.1), open top tanks shall be provided with floating roofs designed in accordance with Annex D, and floating roof seals in accordance with Annex E.

12 Tank anchorage

12.1 General

Tank anchorage shall be provided if, under one of the following conditions, there may be a tendency for the shell and the bottom plate close to the shell, to lift off its foundations:

a) Uplift of an empty tank due to internal design pressure counteracted by the effective weight of the corroded roof, shell and permanent attachments;

b) Uplift due to internal design pressure in combination with wind loads counteracted by the effective corroded weight of roof, shell and permanent attachments plus the effective weight of product considered by the purchaser to be always present in the tank (see A.1);

c) Uplift on an empty tank due to wind loads counteracted by the effective weight of the corroded roof, shell and permanent attachments;

d) If required by Annex G.

NOTE When calculating the uplift due to wind, the load should be calculated based on a minimum wind speed of 45 m/s and a shape factor for the tank shell of 0,7.

12.2 Anchorage attachment

The effects of the bending moments at the anchorage connection to the shell shall be evaluated.

The anchorage shall not be attached to the bottom plate only, but principally to the shell. The design shall accommodate movements of the tank due to thermal changes and changes in hydrostatic pressure, and minimize any induced stresses in the shell.

NOTE Examples of typical anchorage designs are shown in Annex M.

12.3 Holding down bolt or strap

12.3.1 Allowable tensile stress

For the design conditions given, the allowable tensile stress in the holding down bolt or strap shall not exceed one half of the specified minimum yield strength or one third of the minimum specified tensile strength of the bolt or strap material, whichever is the lower.

12.3.2 Cross-sectional area

Each holding down bolt or strap shall have a minimum cross-sectional area of 500 mm^2 and, if corrosion is anticipated, a minimum corrosion allowance of 1 mm shall be added, i.e. 2 mm on diameter of bolt or 2 mm on thickness of strap.

NOTE 1 The cross-sectional area of threaded bolts is the area at the root of the threads.

NOTE 2 It is recommended that anchor points are spaced at a maximum of 3 m intervals and should, as far as possible, be spaced evenly around the circumference.

NOTE 3 It is recommended that no initial tension be applied to the holding down bolt or strap, so that it becomes effective only should an uplift force develop in the shell of the tank (see also 16.3).

NOTE 4 Steps should be taken before the tank goes into service to ensure that the holding down bolts or straps cannot work loose, or become ineffective over a long period.

12.4 Resistance to uplift during test

The anchorage shall be capable of resisting the uplift produced by the test loads applied to the tank. For this condition, the stresses in the holding down bolt or strap shall not exceed 85 % of the specified minimum yield strength of the bolt or strap material, taking into account any initial tension in the bolt or strap resulting from pre-tensioning loads.

13 Mountings

13.1 Shell nozzles O/D 80 mm and above

13.1.1 Set on nozzles shall not be permitted in sizes O/D 80 mm and above.

Where nozzles are used as manholes, they shall have a minimum internal diameter of 600 mm, unless otherwise agreed (see A.2).

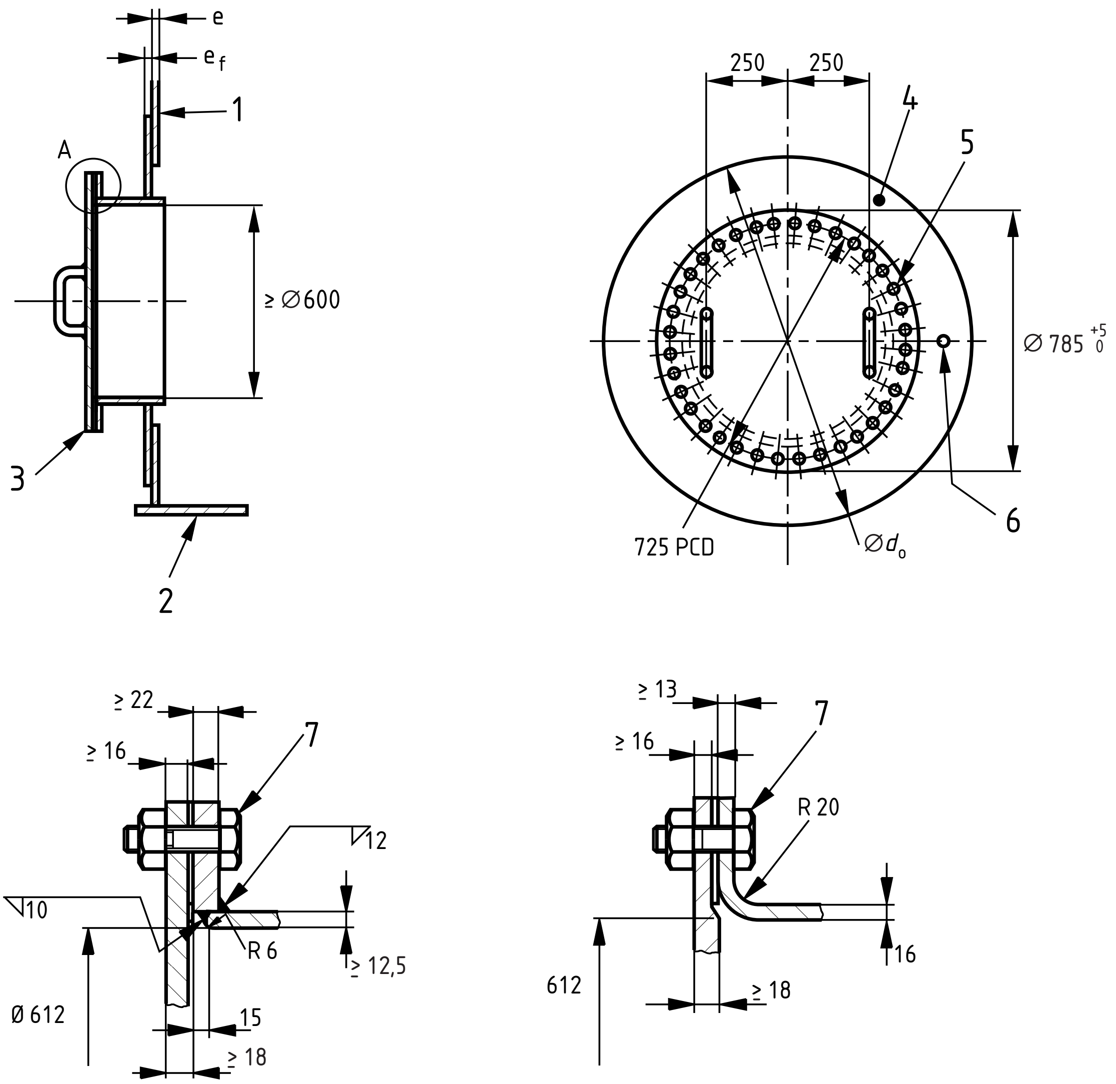
NOTE The typical details and dimensions of shell manholes for tanks where the pressure (design or test) does not exceed 25 m water gauge are given in Figure 9. These dimensions include a nominal 3 mm corrosion allowance.

13.1.2 The minimum nozzle body thickness shall be not less than that given in Table 19.

Table 19 — Minimum shell nozzle body thickness

Outside diameter of nozzle d_n	**Minimum shell nozzle body thickness** e_n	
	Carbon and carbon manganese steel	**Stainless steel**
mm	mm	mm
$80 \leq d_n \leq 100$	7,5	6,0
$100 < d_n \leq 150$	8,5	7,0
$150 < d_n \leq 200$	10,5	8,0
$200 < d_n$	12,5	9,0
Flanges should conform to prEN 1759-1: 2000, class 150 or EN 1092-1: 1994, PN 25		

13.1.3 Reinforcement shall be provided as specified in 13.1.4 or 13.1.5.



A | Alternative construction for neck ring **A**

Key

1 Tank shell
2 Tank bottom
3 Joint faces to be machined
4 Reinforcing plate
5 36 x ∅ 22 holes for M20 bolts
6 ∅ 6 tell tale hole in reinforcing plate
7 M20 bolt

Fillet weld dimensions refer to throat thickness

Dimensions in millimetres

Figure 9 — Typical shell manhole

13.1.4 The cross-sectional area of reinforcement provided (area replacement method), measured in the vertical plane containing the axis of the mounting, shall be not less than:

$$0{,}75\ d \times e_1 \quad (16)$$

where

d is the diameter of the hole cut in the shell plate, in mm.

e_1 is the greater of e_c or e_t derived from 9.2.2, or the nominal thickness in accordance with Table 16, in mm.

NOTE The reinforcement may be provided by any one or any combination of the following three methods.

a) The addition of a thickened shell insert plate (see Figure 10 and 11), or a circular reinforcing plate, the limit of reinforcement being such that:

$$1{,}5\ d < d_r < 2d \quad (17)$$

where

d_r is the effective diameter of reinforcement, in mm.

A non-circular reinforcing plate may be used provided these minimum requirements are conformed to.

b) The provision of a thickened nozzle or manhole body. The portion of the body which may be considered as reinforcement is that lying within the shell plate thickness and within a distance of four times the body thickness from the shell plate surface (see Figure 12) unless the body thickness is reduced within this distance, when the limit is the point at which the reduction begins.

c) The provision of a shell plate thicker than that required by 9.2.2 subject to the lower limits specified in 9.1.5 and upper limits specified in Tables 5 to 8. The limit of reinforcement area is that described in a).

13.1.5 As an alternative to the area replacement methods specified in 13.1.4, the reinforcement shall be made by the provision of thickened nozzle body protruding both sides of the shell plate as shown in Figure 13.

The minimum length L of nozzle providing reinforcement shall be:

$$L \geq 1{,}17\sqrt{r_m e_n} \quad (18)$$

where

$$r_m = \frac{r_o + r_i}{2} \quad (19)$$

The thickness of the nozzle shall be determined by reference to Figure 14 such that the stress concentration factor of S_{cf} does not exceed 2.

The replacement factor, y, shall be:

$$y = 1{,}56\sqrt{\frac{e_n^3}{r_m e_s^2} + \frac{e_n}{2r_m}} \quad (20)$$

where

e_s is the shell plate thickness (in mm);

e_n is the nozzle body thickness (in mm);

r_m is the mean radius for the nozzle (in mm).

13.1.6 The width of the plate containing the mounting and its reinforcement shall be at least equal to the full width of the course and its length shall be not less than its width.

13.1.7 An extension pipe or flange welded to either the inside or outside of the nozzle and not forming part of the required reinforcement shall not be considered part of the assembly.

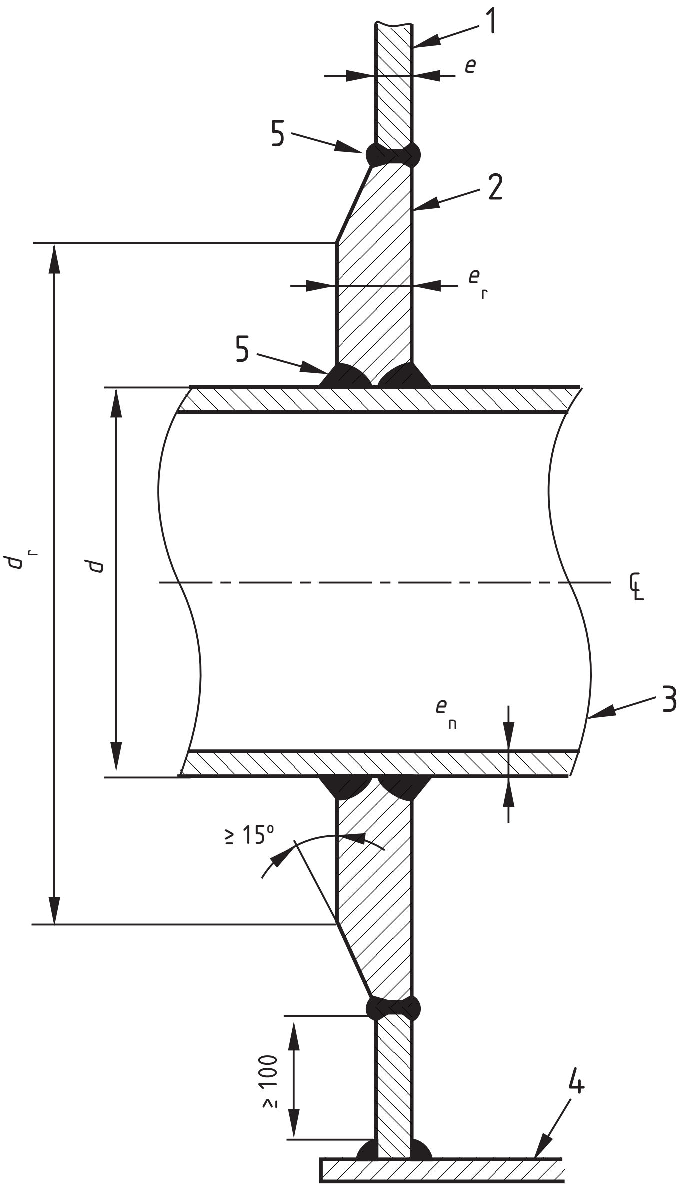
13.1.8 Subsequent welds to nozzle bodies shall not be closer to any weld which has been post-weld heat treated than:

$$2{,}5\sqrt{r_i e_n} \quad (21)$$

where

e_n is the wall thickness of the nozzle, in mm;

r_i is the inside radius of the nozzle, in mm.



Key Linear dimensions in millimetres

1 Shell plate

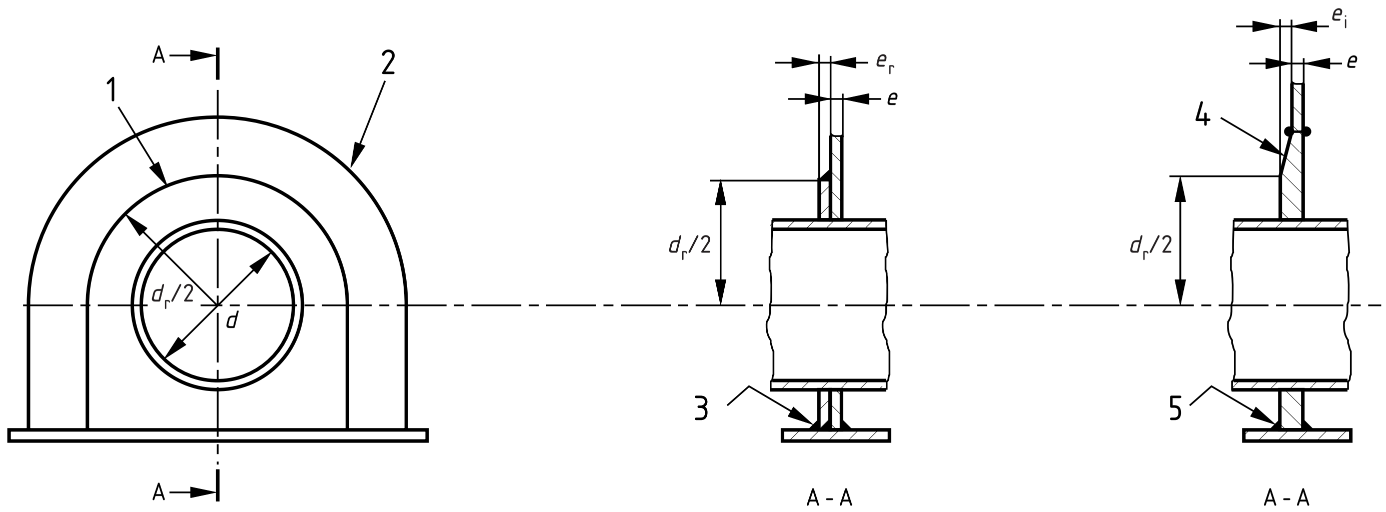
2 Insert plate

3 Nozzle

4 Bottom plate

5 For welding details see **13.7**

Figure 10 — Shell insert-type reinforcement (see 13.1.4)



a) Elevation 0 b) External reinforcing plate c) Insert reinforcing plate

Key

1 External reinforcing plate

2 Insert reinforcing plate

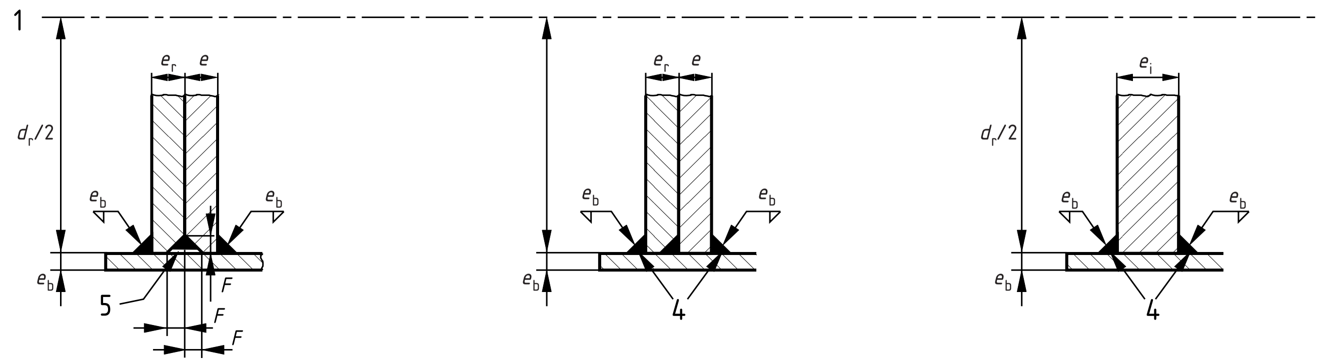
3 See details d), e) and f)

4 1:4 transition

5 See detail g)

Figure 11 — Reinforcing details for low type nozzles *(continued)*

Dimensions in millimetres



d) External reinforcing plate
Shop PWHT nozzle assembly

e) External reinforcing plate
Non-PWHT nozzle assembly

f) Insert reinforcing plate
PWHT or non-PWHT nozzle assembly

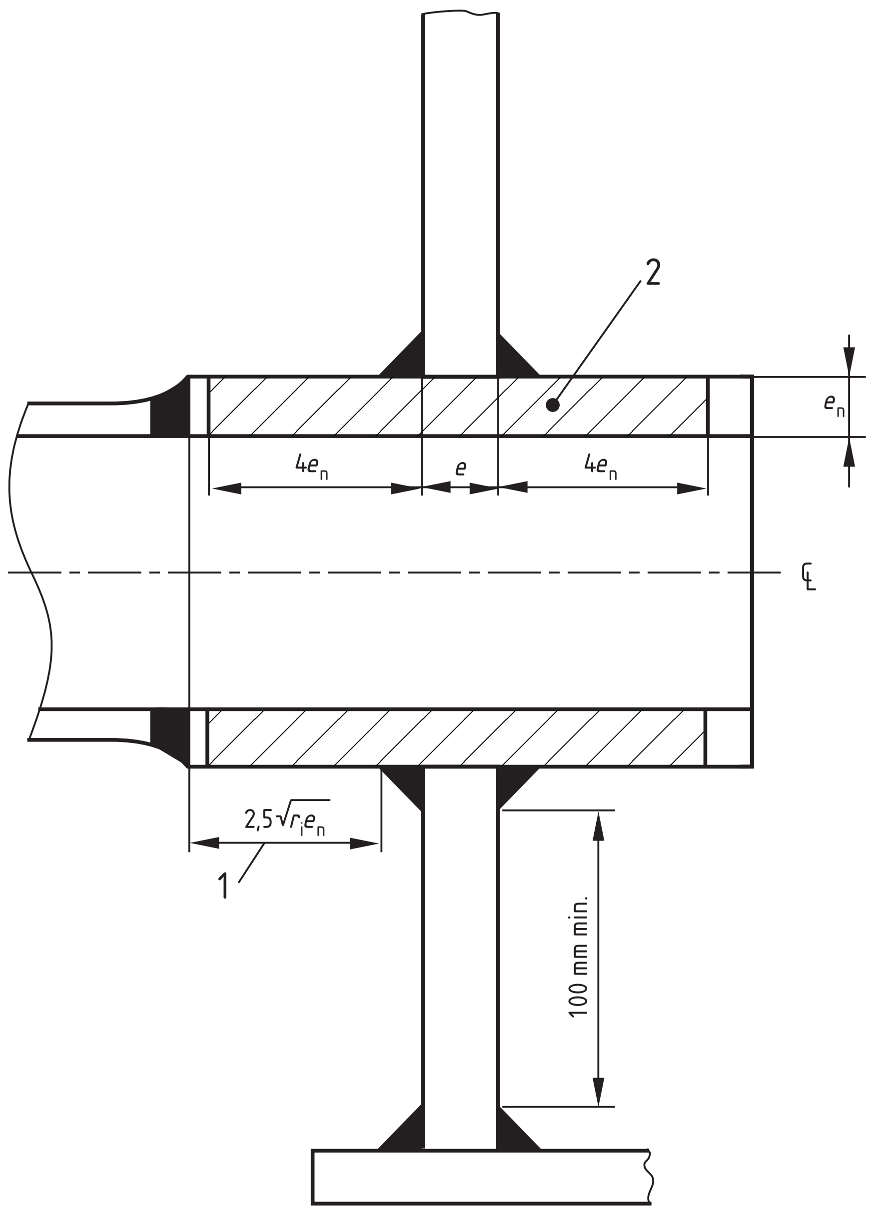
F = the lesser of $e_b/2$ and $e_r/2$

Key

1 Nozzle
2 1:4 Transition
3 Shop weld
4 Site weld
5 Shop weld ground flush

Figure 11 — Reinforcement details for low type nozzles

Dimension in millimetres



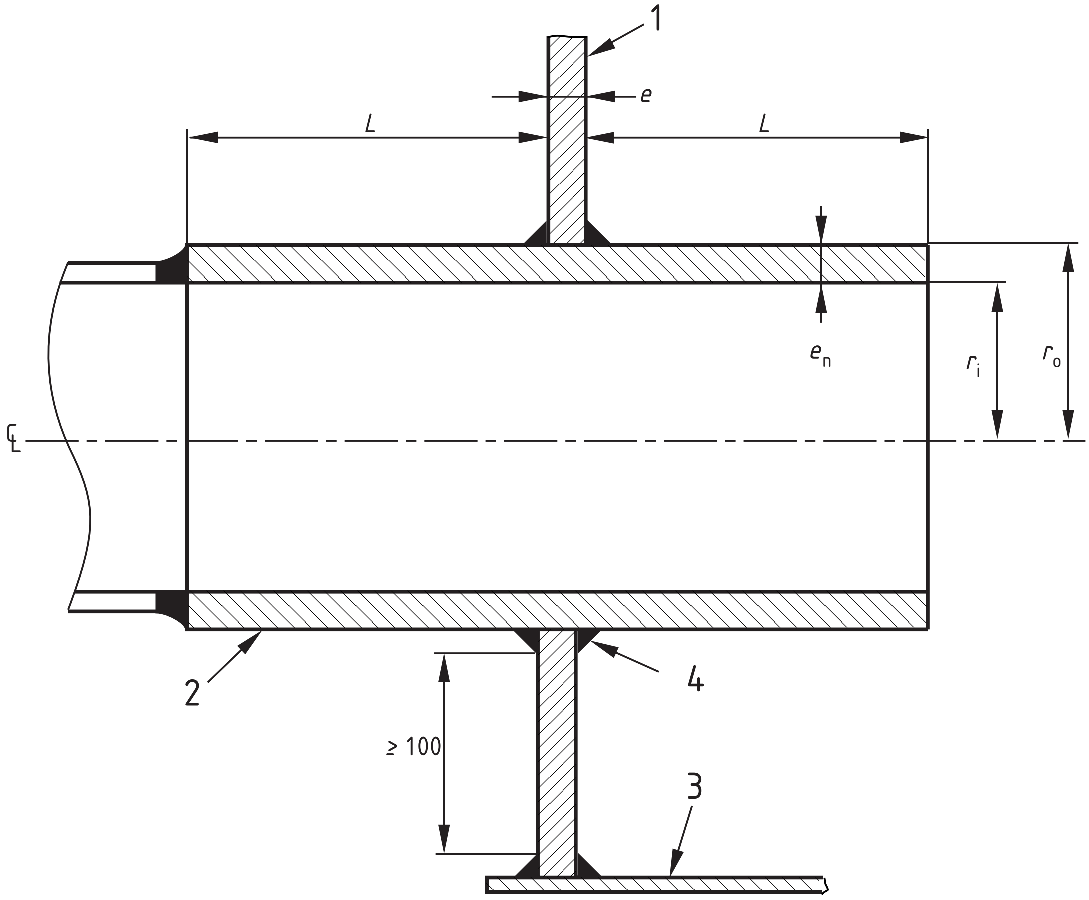
Key

1 Shell plate

2 Nozzle

Figure 12 — Thickened nozzle shell reinforcement

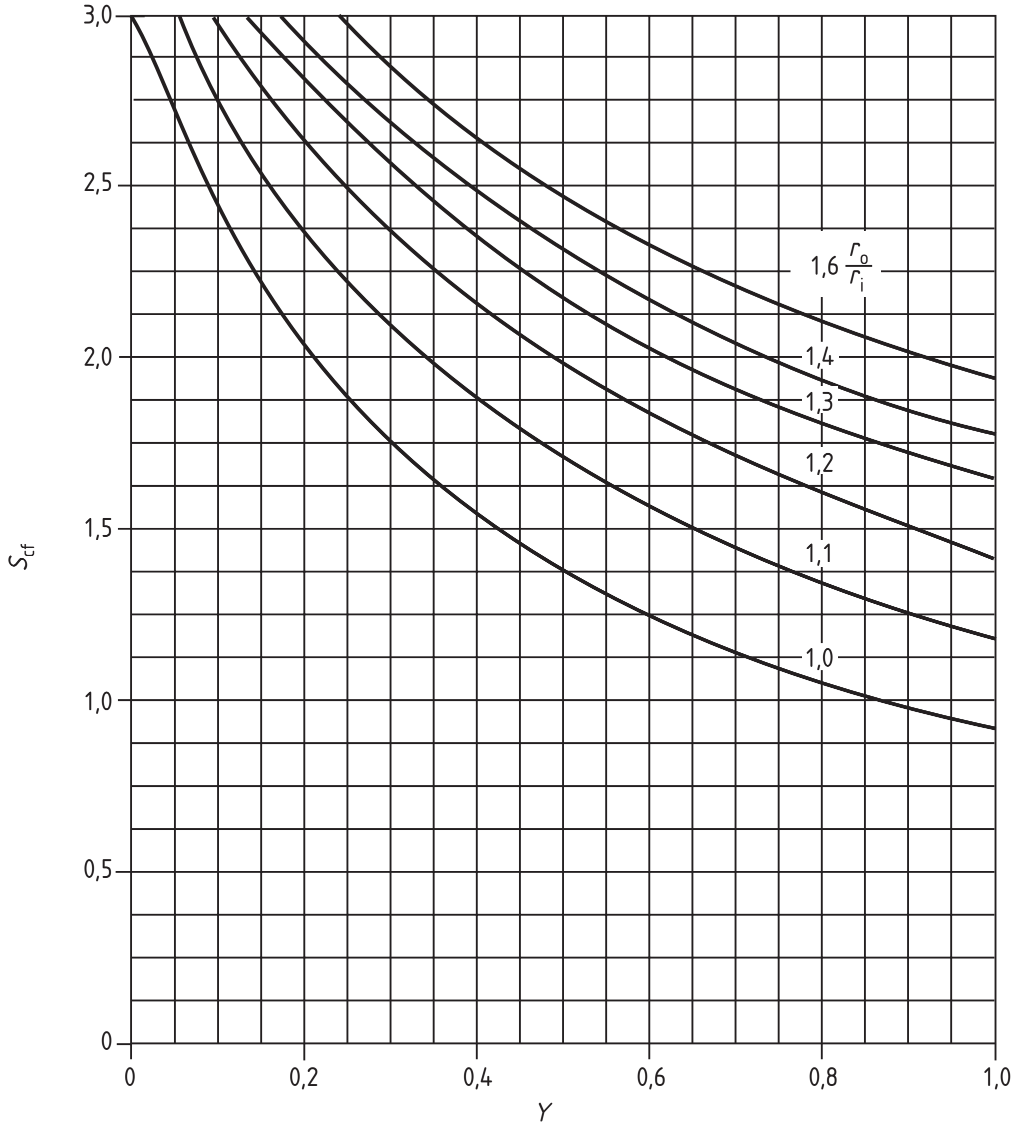
Dimension in millimetres



Key

1	Shell plate	3	Bottom plate
2	Nozzle	4	For weld details see **13.7**

Figure 13 — Alternative barrel type nozzle reinforcement (see 13.1.5)



S_{cf} Stress concentration factor

Y Replacement factor

NOTE Reference should be made to R.T. Rose, Strength of rim reinforcement for manholes in welded storage tanks. [1]

Figure 14 — Graph for the determination of the thickness of barrel-type nozzle reinforcement (see 13.1.5)

13.2 Shell nozzles less than O/D 80 mm

No additional reinforcement shall be required for nozzles less than O/D 80 mm, provided that the thickness of the nozzle wall is not less than that given in Table 20.

NOTE Set-on nozzles may be used.

Table 20 — Minimum shell nozzle body thickness

Outside diameter of nozzle d_n	**Minimum shell nozzle body thickness** e_n	
	Carbon and carbon manganese steel	**Stainless steel**
mm	mm	mm
$d_n \leq 50$	5,0	3,5
$50 < d_n < 80$	5,5	5,0

13.3 Roof nozzles

13.3.1 Roof manholes shall have a minimum inside diameter of 500 mm. They shall be suitable for attachment by welding to the tank roof plates. The manhole covers shall be either as specified (see A.1) or of the multiple bolt, fixed or hinged type.

NOTE See Table 21 and Figure 15 for details of bolted manholes.

Rescue holes, if required, shall have a minimum inside diameter of 600 mm.

Table 21 — Manhole dimensions

Dimensions in millimetres

Type of hole	**I/D**	**Cover plate dia.**	**Pitch circle diameter**	**Number of bolts**	**Gasket diameter**		**Diameter of hole in roof plate**	**O/D of reinforcing plate**
	d_i	d_c	**PCD**		**inside**	**outside**	d_h	d_r
Man	500	660	600	16	500	660	520	1060
Rescue	600	760	700	20	600	760	625	1170

13.3.2 Flanged nozzles for fixed roof tanks with design pressures up to and including 60 mbar shall be as shown in Figure 16 and Table 22. Other designs and details can be used and shall be subject to agreement (see A.2).

NOTE For nozzle diameters > 80 mm, the thickness includes a 3 mm corrosion allowance.

13.3.3 For very high-pressure tanks (pressures greater than 60 mbar), the roof nozzles shall be designed in accordance with the requirements of 13.1 and the nozzles and flanges shall be designed to withstand the design pressure.

Dimensions in millimetres

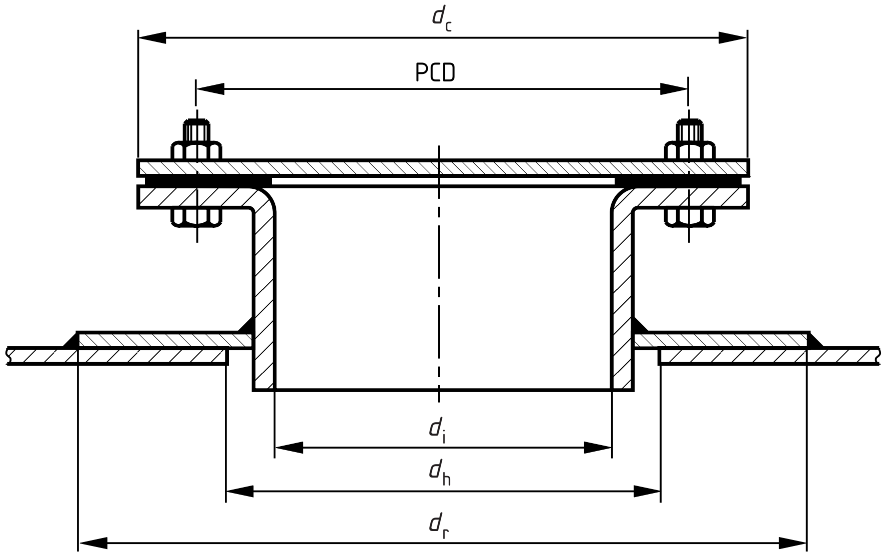
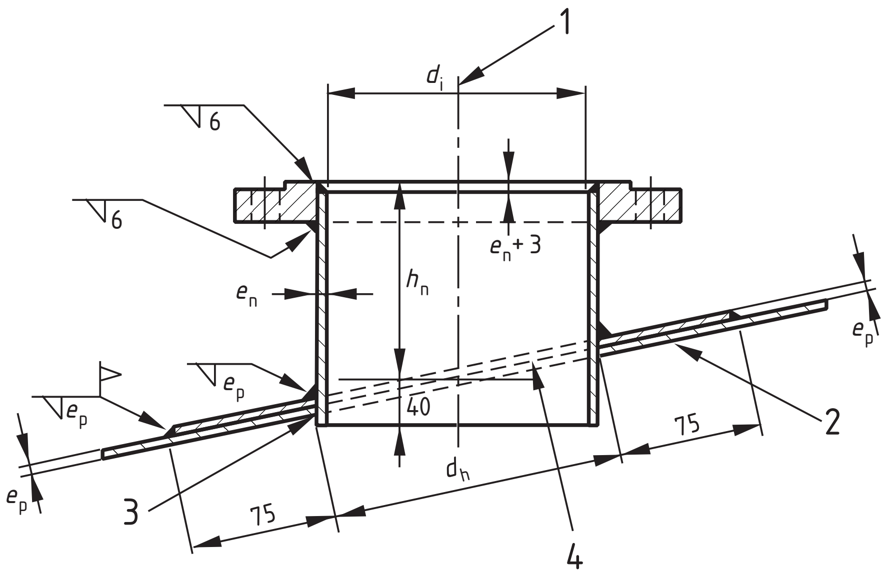


Figure 15 — Bolted manholes



Key

1 Axis always vertical

2 Roof plate

3 Depending on the tank contents, it may be necessary to seal weld

4 When roof nozzle is used for venting purposes the neck may be trimmed flush with the reinforcing plate or roof line.

Fillet weld sizes refer to throat thickness

Figure 16 — Flanged roof nozzles (see Table 22)

Table 22 — Roof nozzle dimensions

Dimensions in millimetres

Nominal diameter of nozzle	Outside diameter of nozzle d_n	Diameter of hole in roof plate d_h	Minimum height of nozzle h_n	Minimum nozzle wall thickness e_n	
				Carbon and carbon manganese steel	Stainless steel
25	34	40	150	3,4	2,7
50	60	66	150	3,9	2,7
80	89	95	150	5,5	3,0
100	114	120	150	6,0	3,0
150	168	174	150	7,1	3,4
200	219	230	150	8,2	3,7
250	273	284	200	9,3	4,0
300	324	336	200	9,5	4,5
NOTE 1 Flanges should conform to class 150 of prEN 1759-1: 2000, or PN 25 of EN 1092-1: 1994. NOTE 2 See Figure 16.					

13.4 Studded pad connections

Studded pad connections for the attachment of inspection windows, instruments, etc., shall be butt welded or fillet welded to the tank shell or roof as detailed in Figure N.3. Adequate reinforcement shall be provided when the hole in the shell or roof plate exceeds 80 mm diameter. Where reinforcement is required, this shall be in accordance with 13.1.4 or 13.1.5 and the whole cross-sectional area of the pad can be considered as reinforcement.

13.5 Nozzle loads

Nozzles shall be designed to withstand the loads resulting from connected piping and attachments (see 7.2.12).

13.6 Flush type clean-out doors and water draw-off sumps

13.6.1 General

In view of the complicated stress patterns, the use of flush type doors and sumps shall be kept to a minimum. The design shall be agreed (see A.2).

NOTE Examples of suitable designs are given in Annex O.

13.6.2 Flush type clean-out doors

When it is proposed to embody flush type clean-out doors in the bottom course of shell plating, the vertical opening shall not exceed 915 mm or half the shell plate width, whichever is the lesser. The assembly shall be prefabricated and post-weld heat treated in accordance with 18.10.

Typical details are shown in Figures O.1, O.2, O.3 and O.4.

13.6.3 Water draw-off sumps

13.6.3.1 Water draw-off sumps shall be fully supported by the foundation. Suitable local excavations of the foundation shall be prepared in accordance with the approved foundation design drawings.

13.6.3.2 The fillet weld to the underside of the bottom sketch plate or annular plate shall be deposited in the flat position, the bottom plate being reversed for this purpose, before final positioning on the tank foundation.

Typical details are shown in Figure O.5.

13.6.4 Combined water draw-off and clean-out sump

Combined water draw-off and clean-out sumps shall not be used in tanks where the shell plate thickness exceeds 20 mm.

Typical details are shown in Figure O.6.

13.7 Nozzle welding details

13.7.1 Partial penetration welds shall only be used when the shell thickness is not more than 12,5 mm and the allowable design stress is less than 185 N/mm^2.

NOTE Nozzle welding details are given in Annex N.

13.7.2 The toes of fillet welds connecting the nozzle or reinforcing plates to the shell, or the centre line of butt welds connecting insert plates to the shell, shall be not closer than 100 mm to the centre line of any other shell butt joint, the toe of the shell to bottom fillet weld, or the toe of fillet welds of adjacent attachments.

NOTE The reinforcing plate or insert plate may be extended to the shell to bottom junction provided the plate intersects the bottom at 90° (see Figure 11).

Subject to agreement (see A.2), when it is impractical for all the nozzles to avoid crossing the shell welds of small diameter tanks with a wall thickness up to 10 mm, the tangent to the cut-out in the shell at the centre line of the shell butt weld shall be at an angle between 45° and 90° to the centre line (see Figure 17). The shell weld at the cut out shall be subjected to 100 % MPI or DPI.

Any shell butt weld which then underlies a reinforcing plate shall be ground smooth and subject to 100 % radiographic inspection.

13.7.3 The dimensions of the welds connecting set-through nozzles to the shell shall be as shown in Figures N.1.

NOTE These weld dimensions are not required to be greater than twice the wall thickness of the mounting.

When the thickness of nozzle bodies manufactured from rolled carbon and carbon manganese steel plate exceeds 20 mm, either material with specified through thickness properties shall be used, or a minimum layer of 3 mm of weld metal shall be applied to the surface of the body, prior to welding the nozzle to the shell (see Figure 18).

13.7.4 Butt joints connecting insert plates to the shell plates shall have full penetration and complete fusion.

13.7.5 The throat thickness of fillet welds around the periphery of reinforcing plates shall be 70 % of the thickness of the reinforcing plate or 14 mm, whichever is less.

13.8 Flange drilling

Unless otherwise specified (see A.1), the flanges of all mountings except shell and roof manholes shall be made and drilled in accordance with prEN 1759-1:2000, class 150 or EN 1092-1, PN 25. The orientation of mating flanges shall be checked for compatibility.

13.9 Post-weld heat treatment of nozzles

The manufacturer shall arrange for post-weld heat treatment (PWHT), in accordance with 18.10 for all nozzles included in Table 28, according to the shell thickness or the nozzle diameter.

13.10 Heating and/or cooling systems

Heating or cooling of the product shall be achieved by the use of a heat transfer fluid in a heating or cooling device (see Annex P) or heated by electrical means. The method shall be subject to agreement (see A.2).

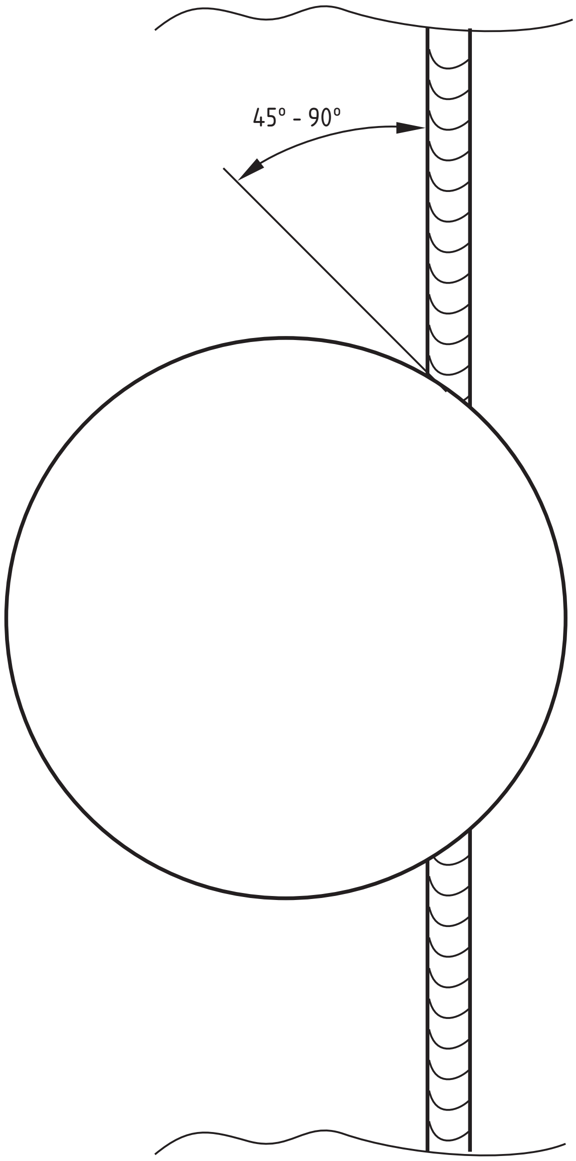
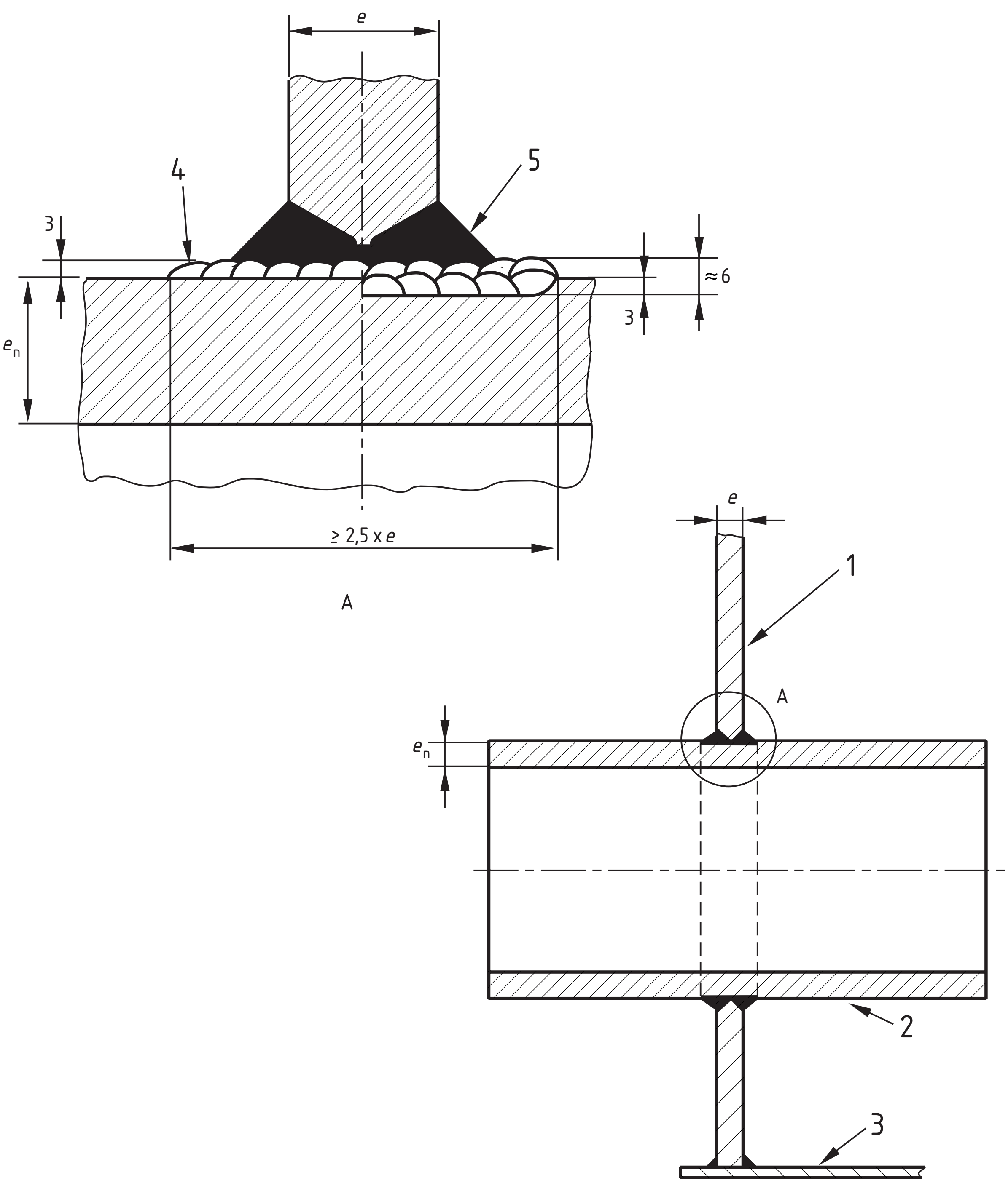


Figure 17 — Openings for nozzles that intersect shell welds

Dimensions in millimetres



Key

1	Shell plate	3	Bottom plate	5	For weld details see Annex N
2	Nozzle	4	Weld overlay		

NOTE For nozzle attachment, an alternative is to remove 3 mm from the nozzle and replace with at least two layers of weld overlay.

Figure 18 — Details of weld overlay for nozzles

13.11 Stairways and walkways

13.11.1 Stairways and walkways shall be in accordance with EN ISO 14122, together with the specific requirements in 13.11.2 to 13.11.6, 13.12 and 13.13.

13.11.2 Stairways and walkways shall be of metallic construction and the minimum clear walking space shall be 600 mm.

NOTE 1 It is recommended that the angle of stairways to the horizontal plane should not exceed 45°.

NOTE 2 For stairways on insulated tanks, see Annex Q.

13.11.3 The stairway treads shall be of the non slip type.

NOTE 1 The rise should normally be 200 mm, and the tread should have a minimum width of 200 mm measured at the mid length of tread. The rise may be adjusted to within ± 5 mm to make treads level with landings or platforms.

NOTE 2 Attention is drawn to possible local or National Regulations.

13.11.4 Spiral type stairways incorporating stair treads welded directly to the shell, or by means of local pads, shall only be permissible where:

a) the minimum specified yield strength of the shell material does not exceed or equal 275 N/mm^2; or

b) the minimum specified yield strength of the shell material exceeds 275 N/mm^2 and the shell thickness does not exceed 12,5 mm.

Where the minimum specified yield strength of the shell material exceeds 275 N/mm^2 and the shell thickness exceeds 12,5 mm, stairways shall be independently supported or affixed by horizontally oriented continuous welds (see 13.15).

13.11.5 Stairways and walkways shall be capable of supporting a minimum superimposed load of 2,4 kN/m^2, a concentrated load of 5 kN at any location, together with the wind loads specified for the design of the shell.

NOTE It is recommended that where the vertical rise of stairways is more than 6 m, intermediate landing or landings should be provided.

13.11.6 Tank walkways which extend from one part of a tank to any part of an adjacent tank, or to the ground, or any other structure, shall be so supported as to permit free relative movement of the structures joined by the walkway.

13.12 Handrailing

13.12.1 Handrailing to tank roofs, stairways and walkways shall be solid steel bar or sections, and shall be designed to protect personnel and prevent objects from falling.

NOTE It is recommended that the handrail should be capable of withstanding a point load of 1 kN applied at any point and in any direction.

13.12.2 Handrails shall be provided on both sides of walkways and stairways, except on spiral stairways where the distance between the tank shell and the inner stringer is less than or equal to 200 mm when no inner handrail is required. At breaks in the handrail, any space between the tank and the platform which exceeds 150 mm in width shall be floored.

13.12.3 For tanks over 12,5 m diameter, where access is required to fittings at or near to the centre of the roof, handrailing and treads shall be provided.

13.12.4 The full strength of the members shall be maintained at the joints.

13.13 Ladders

Fixed steel ladders shall be provided with safety cages and intermediate platforms.

NOTE Attention is drawn to local or National regulations.

13.14 Earthing connections

All tanks shall be fitted with earthing connections.

13.15 Permanent attachments

13.15.1 Permanent attachments welded to tank shells thicker than 12,5 mm shall be kept to a minimum and shall preferably be disposed in a horizontal direction.

NOTE If vertical fillet welds are necessary, these should be made with special care, having due regard to their stress-intensifying effect.

13.15.2 Vertical attachment welds shall not be located within 150 mm of any main vertical seam and horizontal attachment welds shall not be made on top of any main horizontal seam.

Stud welded and similar attachments shall not be permitted on plates exceeding 13 mm in thickness.

13.16 Temporary attachments

The requirements governing the location, orientation and procedure for the provision of temporary attachments other than the location of temporary key plate erection attachments shall be the same as for permanent attachments (see 13.15).

14 Insulation

The permanent attachments associated with the requirements for the insulation of a storage tank shall conform to 13.15.

NOTE Tanks designed to conform to this document may require to be insulated for various reasons, e.g. maintaining product temperature. Although the design of this insulation is not specified in this document, the recommendations of Annex Q should be taken into consideration.

15 Shop fabrication of tank components

15.1 General

During the development of the fabrication procedures of the tank, the manufacturer shall take account of the product to be stored.

15.2 Reception and identification of materials

When the materials and equipment to be used in the fabrication of a tank are received, they shall conform to the requirements set out in the order to the supplier (in terms of quality, quantity, dimensions, surface finish, appearance, inspection documents etc.), and shall be suitable for their intended use.

All flats, rolled sections and forged parts to be used shall bear the identifying marks specified in the order and at the very least those specified in the product standards. Materials used in construction of ladders, stairways supports and other similar attachments need not contain such marking.

It shall be verified that the packaging of welding consumables is in good order and their markings conform to the requirements of the purchase order and of the product standard.

15.3 Handling and storage of materials

Stainless steel plates shall be stored and handled with equipment incorporating protection to avoid surface contamination.

Machined parts such as flanges and machined surfaces shall be protected against corrosion and mechanical damage during transport and storage.

Welding consumables shall be protected and stored in accordance with the conditions laid down by the welding consumable standard and/or the supplier's recommendations. Consumables for issue to site shall be stored in their original packaging.

15.4 Material markings

The method of marking shall be subject to agreement (see A.2). The preferred method of marking shall be die-stamping using low stress stamps with a minimum radius of 0,25 mm. However, this method is not suitable for plates less than 6 mm thick, and paint or ink marking shall be used instead. The manufacturer shall ensure that the paint or ink is compatible with the material to which it is applied and will not cause damage to the plate surface, and is also compatible with the product to be stored.

Markings on material ordered with inspection documents in accordance with EN 10204-2004, Cert. 2.3 and higher, shall remain visible after erection of the tank. In case the marking becomes obliterated during fabrication, at least one marking shall be transferred to a location visible after completion of the tank.

Reinforcing plates, pipes, flanges and similar items requiring material inspection documents, as mentioned above, and specified in Tables 5 to 8, shall be marked.

Prior to cutting, the identification marks on materials to be used in the subsequent construction of the shell or any other structural part of the tank shall be transferred to the different component parts. Unless otherwise specified, marking shall be visible on the inside of the tank.

Transfer of mill identification markings shall only be executed by an authorised person.

Markings shall remain legible at least until the hydrostatic test of the tank.

If the material specification does not permit marking or identification on the plate, etc, the identification marks shall be noted on a drawing or an identification list.

NOTE Non-welded components not subject to pressure loads need not be marked for material identification.

15.5 Plate preparation and tolerances

Preparation tolerances of plates shall be adapted to suit the assembly tolerances (see Clause 16).

Plates to be used in construction of lap welded bottoms and roofs shall meet the normal mill tolerances specified in the steel standard.

The method of cutting shall be appropriate to the materials. Shearing of plates above 10 mm thickness shall be subject to agreement (see A.2).

When trimming edges, special attention shall be paid to their uniformity and the angle of chamfers.

Thermal cut edges shall be free from oxide and cutting scale and cleaned before welding. All plate edges shall be straight with no irregularities exceeding 2 mm. The tolerance on plate length and width (course height) shall be ± 2 mm. Grinding shall be allowed if necessary.

The plates constituting the shell shall be rectangular and the lengths of the diagonals shall not differ by more than 3 mm.

The layout of plates in the shell shall be in accordance with 9.4.

Cut-outs for openings and nozzles shall be produced by machining or thermal cutting and ground smooth. Sharp corners shall be avoided. The distance between the opening and the nearest plate edge shall conform to 13.7.2 unless otherwise agreed (see A.2).

The minimum circumferential dimensions of a shell plate shall be 1 m (see Figure 4).

15.6 Preparation of nozzle components

Component parts of nozzles (pipes, flanges etc.) shall be prepared by machining, mechanical or thermal cutting. Thermal cutting shall only be permitted for pipe ends not requiring subsequent welding, unless otherwise agreed (see A.2).

15.7 Plate forming and tolerances

When required, shell plates shall have their ends preset before forming.

After forming, the plates shall be inspected for geometry and surface imperfections.

Local thinning of the plates shall be permitted such that the final thickness of the plate shall not be less than 95 % of the plate thickness, determined in accordance with 9.2, over an area of $6e$ by $6e$.

Special precautions shall be taken for stainless steels to avoid contamination of plate surfaces during the forming process.

15.8 Openings

15.8.1 Nozzles

Two types of nozzles shall be considered according to their location (see Clause 13):

— those positioned on the tank roof;

— those positioned anywhere on the shell or bottom.

Flanges shall be manufactured from forgings or from plates. Where plates are used, they shall be guaranteed free from laminations.

The weld preparation for the butt welds shall be such as to ensure total penetration and shall be examined.

On all flanges, bolt holes shall be offset from the vertical and horizontal axes (see 13.8).

The manufacturer shall arrange for PWHT if the nozzle falls within the requirements of Table 28.

The PWHT shall be in accordance with 18.10.

15.8.2 Inspection windows

The welding of the window body to the tank shall be carried out in such a manner as to keep deformation of the machined surface to which the glass is to be fitted to a minimum.

15.8.3 Nozzles for mixers

The method of assembly, the quality of welds and their geometry shall be selected to avoid any stress concentration or crack initiation features.

15.8.4 Clean-out doors

The manufacturer shall arrange for PWHT as specified in 18.10.

The preparation of the assemblies where these are welded to the shell, shall allow for full penetration welds, and, as for mixers, the method of assembly, the quality of welds and their geometry shall be selected to avoid any stress concentration or crack initiation features.

15.8.5 Reinforcement plates

Nozzle reinforcement plates (see Figure 11) shall be of the same quality as the shell plates (see 6.1.7.2) to which the nozzle is fitted.

The reinforcement plates shall be formed so that, when assembled, they possess the same curvature as the shell course plate on which they are welded.

All nozzle reinforcement plates shall have at least one tapped hole for inspection purposes.

15.8.6 Insert plates

Nozzle insert plates (see Figure 10) shall be of the same quality as the shell plates (see 6.1.7.2) to which the nozzle is fitted.

The edges of insert plates, shall be tapered 1:4 to match the tank shell plates.

15.9 Welding

All welding of shop fabricated components shall be carried out in accordance with appropriately approved welding procedures and by appropriately approved welders as specified in Clause 17. All welding of shop fabricated components shall be carried out in accordance with Clause 18.

Temporary welds used for the assembly of parts of shop fabricated components shall be removed by mechanical grinding, chipping or gouging so that no weld material is left proud of the surface. For carbon steels with specified minimum yield strength ≥ 355 N/mm^2, these locations shall be examined for cracks in accordance with Table 29.

Slip-on flanges shall be welded from both sides.

All weld-neck flanges shall have full penetration butt welds.

Nozzles made from rolled plate over 20 mm thick which have not been manufactured from Z guaranteed plates (through thickness tension tested) shall be overlaid with weld metal on the shell side in the weld area (see 13.7.3 and Figure 18).

The minimum distance between nozzle welds and the nearest plate edge shall be in accordance with 13.7.2.

The manufacturer shall arrange for PWHT in accordance with 18.10 when required.

15.10 Surface condition

All welds shall be cleaned and brushed, and traces of slag removed.

Appropriate equipment shall be used for the fabrication of stainless steel tanks.

Welds on stainless steels shall be passivated and all traces of rust removed from the plates.

All surfaces shall conform to the requirements of Annex R.

15.11 Marking for erection purposes

All plates, sections and accessories shall be marked for identification purposes using paint, ink or labels as appropriate to the item.

When a number of identical items are to be despatched together, at least one item shall be marked so that assembly errors are avoided.

Identification marks shall be recorded on a drawing to facilitate assembly on site.

15.12 Packing, handling and transport to site

Packing shall be such as to avoid any damage of the components being transported.

When necessary, plates shall be placed on blocks to avoid permanent deformation.

When handling plates, the manufacturer shall employ lifting equipment capable of working in complete safety without damaging the materials. The use of grabs with an automatic clamping action shall not leave unacceptable imperfections on the plates.

Stainless steel plates shall be handled using equipment incorporating suitable protection.

Blocks, shims, etc. for stainless steel plates and prepainted plates shall be made of suitable materials and the manufacturer shall ensure that appropriate protection is used.

Machined surfaces shall be protected against corrosion and mechanical damage

NOTE 1 Small, finish-machined parts such as flanges should be placed in boxes or on pallets.

NOTE 2 Larger items may be transported in bulk so long as their machined surfaces are protected.

Gaskets shall be protected against damage in transport and storage.

Welding consumables shall be delivered in their original packaging which should give protection against damage and moisture pick-up during transport and storage.

16 Site erection and tolerances

16.1 General

16.1.1 All information necessary for the site erection of the tank shall be made available. This shall include at least the following information:

- erection specification including erection sequences;
- construction drawings;
- identification plans as required by 15.11;
- required construction tolerances;
- detailed welding procedures;
- documentation relating to examinations and inspections already performed;
- material inspection documents;
- surface finish, insulation and painting specifications, where appropriate.

16.1.2 All components delivered to site shall be checked to ensure that they conform to the specification, and that they have not been damaged during transportation.

16.1.3 The method of assembly shall not produce constraints or permanent deformation inconsistent with the normal mechanical loads and outside the specified tolerances of the finished tank, empty or full.

16.1.4 Floating covers or floating roofs where specified, shall be installed and assembled in accordance with C.4 or D.6.

16.1.5 If required, the methods to be employed in the assembly of the tank including the methods to be used to hold plates in position for welding, the sequences of assembly and welding, means of access for welding, and the methods to be used to avoid wind damage during erection shall be specified (see A.3).

16.1.6 Erection tolerances shall be in accordance with Clause 16 for design negative pressures not greater than 8.5 mbar.

16.1.7 For design internal negative pressures greater than 8.5 mbar, the design methodology and associated fabrication tolerances shall be subject to agreement (see A.2).

16.2 Foundations

16.2.1 General

The design and construction of the foundations for a tank are important to the integrity of the tank, but are not part of this document (see Annex I). Before the erection of the tank, it shall be ensured that the location, height, shape, geometry, horizontal plane or slope, surface finish and cleanliness of the supporting foundation conform to 16.2.2 and 16.2.3.

16.2.2 Peripheral tolerance

The datum height for the foundation and its permissible variation shall be specified (see A.1).

The difference in level between any two points around the foundation shall be not more than 24 mm.

The difference in level between any two points 5 m apart around the periphery of the tank shall be not greater than 5 mm.

The tolerance of the inclination or slope of the foundation shall be such as to enable the final vertical tolerances of the tank to be achieved.

16.2.3 Foundation surface tolerance

The surface tolerance, other than the area under the shell plate shall be as follows:

— the sag in the as-built surface measured with a 3 m long template shall not exceed 10 mm;

— the difference between the design level and as-built level shall not exceed the values given in Table 23.

Table 23 — Foundation surface tolerances

Diameter of tank D m	**Tolerances** mm
$D \le 10$	10
$10 < D \le 50$	D / 1000
$50 < D$	50

16.3 Anchor points

When the tank is to be anchored to the foundation, details of the design of the anchorage system shall be provided (see A.3), to ensure that the foundation design incorporates provision for the anchor points and their associated loads (see Clause 12).

At the time of taking over the foundation, the position and dimensions of anchor bolts or straps shall be checked to ensure that they are in accordance with the drawings.

The erector/manufacturer shall be responsible for the setting in place of the anchor rods, preferably after completion of erection of the tank to avoid damage. However, if the anchors have been precast into the foundation, the erector/manufacturer shall take due care to avoid damage to the anchors during erection of the tank.

The anchor points shall not restrict the relative movements due to expansion of the tank.

The threads of anchor rods shall be protected until the nuts are tightened to ‘finger tight’ after the tank has been filled with water and stabilized. Welding shall not be permitted on the anchor rods.

Anchor straps shall be welded after the tank has been filled with water and stabilized, unless they incorporate a means of retightening.

16.4 Handling and storage

The requirements of 15.3 and 15.12 shall be met in respect of handling and storage.

Lifting and handling operations shall not lead to any permanent deformation.

NOTE During handling operations, all necessary precautions in the event of significant winds should be taken.

After reception of materials on the site, the plates shall be stored in such a manner that they will not suffer undue corrosion or damage.

Precautions shall be taken to avoid contamination of stainless steel plates by carbon steels.

Small items of equipment, accessories and welding materials shall be protected against the weather.

16.5 Rectification of parts damaged during transportation and handling

All parts damaged during transport or handling shall be subjected to a thorough examination.

A repair procedure shall be agreed (see A.2).

16.6 Bottom plates

Bottom plates shall be positioned on the foundation in such a manner as to avoid damaging the finished surface of the foundation.

Underside protection of the plates shall be as specified (see A.1).

Fillet welded bottom plates shall be assembled and welded with laps not less than those specified in 8.4.1. No three-thickness plate overlap shall be within 300 mm of any other three-thickness plate overlap or of the inner surface of the shell course. The other plates constituting the bottom shall be overlapped according to the drawing and the plate markings.

A check shall be made to ensure that the overlap of the bottom sketch plates to the annular plates is ≥ 60 mm.

A check shall be made to ensure that the overlap between plates is ≥ 5 times the thickness of these plates.

When a butt welded bottom is specified, the plates shall be assembled and butt welded so as to maintain the tolerances specified for the welded joint.

Localized uplift of the bottom plates from the surface of the foundation shall be minimised by controlling the welding sequences, but in any case, it shall not exceed 0,25 % of the diameter of the tank, with a maximum of 100 mm. The uplift shall be measured at ambient temperature, excluding solar effects.

If an annular ring is to be fitted, its plates shall be assembled end to end and full penetration butt welded before the adjoining bottom and/or sketch plates are welded to it.

16.7 Shell to bottom, and shell

16.7.1 Assembly tolerances of first shell course on flat bottom

Where annular plates are specified, all annular butt welds shall be welded and inspected before welding the shell to the annular plates.

Where annular plates are not specified, welding of the shell plates to the bottom plates shall not commence until all welding of the bottom sketch plates has been completed.

The erector shall ensure that the assembly methods used meet the tolerances specified in this document.

The maximum gap between the bottom course and the annular ring or bottom plates shall not exceed 3 mm.

After assembly and welding of the first shell course to the bottom,

a) centre shall be determined from 3 diameters measured at 120° to each other;

b) inside radius measured horizontally at a height of 200 mm above the bottom of the shell shall be within the limits given in Table 24.

Table 24 — Tolerance limits on inside tank radius

Radius R m	**Tolerance** mm	**Measurement points** minimum number
$R \leq 5$	± 5	6
$5 < R \leq 20$	± 0.1 % of radius	8
$20 < R$	± 20	Each plate
NOTE Measurements should be remote from any fitting or opening.		

The distance between the outside of the bottom shell plate and the outer edge of the annular plate or bottom plate shall be in accordance with the value given in 8.3.4.

16.7.2 Tolerance on shell geometry

Local deformation in the full plate in the vertical direction shall be checked with a 1 m straightedge and in the horizontal direction with a 1 m long template matching the design radius of the tank.

The maximum difference between the design profile and the as built profile shall be as given in Table 25.

Table 25 — Maximum differences between the design and the as built profile

Plate thickness e mm	**Difference** mm
$e \leq 12{,}5$	16
$12{,}5 < e \leq 25$	13
$25 < e$	10

16.7.3 Vertical tolerance

The maximum out of verticality of the top of the shell relative to the bottom of the shell shall not exceed 1/200 of the total height, or 50 mm, whichever is the lesser. The 1/200 tolerance shall apply to individual shell course heights.

Any settling of the tank noted during construction shall be recorded. Repairs of the foundation shall be carried out if uneven settling exceeds the values given in 16.2.

16.7.4 Tolerances on alignment of plates

16.7.4.1 Vertical joints

The misalignment of shell plates at vertical joints shall not exceed the values given in Table 26.

Table 26 — Misalignment at vertical joints

Shell plate thickness e mm	**Misalignment** mm
$e \leq 8$	18 % of e
$8 < e \leq 15$	1,5
$15 < e \leq 30$	10 % of e
$30 < e$	3

16.7.4.2 Horizontal joints

When alignment between the neutral axes of plates is specified on the drawing, the deviation between the axes shall not exceed 20 % of the thickness of the upper plate, with a maximum of 3 mm.

In all cases, the internal diameter of the upper course shall be greater than, or equal to, the internal diameter of the lower course.

When alignment between the internal surface of the plates is specified on the drawing, the deviation between the surface of plates shall not exceed 20 % of the thickness of the upper plate, with a maximum of 3 mm.

16.7.5 Tolerances on shape of welded joints

A template shall be used to check the profile of welded joints.

Local deformation at the horizontal joints shall be checked using a 1 m straightedge with a cut-out for the weld.

Local deformation at vertical joints shall be checked using a 1 m long template shaped to the design profile of the tank with a cut-out for the weld.

The maximum tolerance between the design profile and the as-built profile shall be as given in Table 27.

Table 27 —Tolerances on shape of welded joints

Plate thickness e mm	Tolerance mm
$e \leq 12,5$	10
$12,5 < e \leq 25$	8
$25 < e$	6

16.7.6 Primary and secondary stiffening rings (wind girders)

The primary and the secondary stiffening rings (wind girders) shall be welded onto the shell in accordance with a **9.3.1.11.**

The components of the primary and the secondary stiffening rings (wind girders) shall be assembled and joined together by full penetration butt welding.

When reinforcing plates or additional members for strengthening openings are used (see Figure 7), these shall be welded with a continuous weld at the corners and along each side.

These components shall be positioned on the shell to avoid the possibility of water retention.

16.8 Fixed roofs

16.8.1 General

Temporary supports, lifting lugs and cleats fitted to the tank crown or the roof and used for the installation of the roof, shall not cause damage or permanent deformation.

Whatever type of roof is to be assembled, the method of construction shall ensure full stability throughout the erection process.

16.8.2 Support framework

In the case of a roof containing a support framework, all necessary precautions to avoid the twisting of the support beams and the rotation of the structure as a whole by the use of anti-rotation stiffening shall be taken.

Welding of support framework elements, when required, shall be carried out by approved welders.

In the case of bolted assemblies, the bolted faces shall be smooth and clean. Tightening of bolts shall be carefully controlled.

16.8.3 Roof plates

When installing plates in lapped welded roofs, the welding faces shall be cleaned to remove all rust and paint, except in the case of prepainted plates where the protection was taken into account and included in the welding procedure qualification.

In order to avoid entrapment of condensation, the correct order of plate lapping shall be achieved ensuring that the lower plate is placed on top of the upper plate, unless otherwise specified (see A.1).

The fitting of plates shall be carried out in such a manner as to distribute the weights equally in order to avoid imbalance of the roof. Any temporary supports shall be left in place until the completion of the assembly.

When installing plates on butt welded roofs, the plates shall have their edges prepared to conform to the welding procedure to be used.

The roof to shell connections of conical roofs without corner ring (see Figure 6a)) shall be made by a butt welding procedure, and shall be examined in the same manner as the shell welds.

The roof to shell connections of conical roofs with corner ring (see Figure 6b)) shall be reinforced in accordance with the drawing, and the weld joints shall be lapped or angle type preparation.

16.8.4 Roof plating and roof structure

Roof plating shall not be welded to the roof structure (see 10.3.2) unless specified (see A.1).

16.8.5 Frangible roofs

When frangibility of a fixed roof is required, Annex K shall apply.

16.9 Nozzles

Openings in the shell to accommodate nozzles shall be either machine or thermal cut. All thermal cut edges shall be ground.

The root gap between the nozzle and the edge of the cut plate shall be in accordance with the welding procedure used.

All reinforcing plates shall have at least one tapped hole for inspection purposes.

16.10 External attachments

Stairways, ladders and walkways installed on tanks shall be in accordance with 13.11.

All fillet welds shall be continuous to avoid corrosion areas.

During construction, the free movement of inter-connecting walkways (see 13.11.6) shall be ensured.

16.11 Internal attachments

All internal attachments shall be compatible with the product to be contained in the tank and shall be so designed and constructed as to avoid the possible retention of the product.

Where reinforcing plates are fitted to the bottom, they shall be welded to the bottom plate by continuous fillet welds.

16.12 Temporary attachments

16.12.1 Temporary access facilities where considered necessary shall be fitted.

As few assembly lugs as possible shall be used.

Temporary attachments shall be welded by the same procedure as that used for the materials to which they are attached (see 18.7).

16.12.2 When removing temporary attachments from shell plates, the attachment shall be burned 3 mm to 6 mm proud of the plate surface or, alternatively, the securing weld shall be weakened by grinding, chipping or gouging, taking care not to damage the parent plate, and the attachment shall be knocked-off. For carbon and carbon manganese plates of yield strength ≥ 355 N/mm^2, special precautions shall be taken when removing temporary attachments (see 18.7 and Table 29).

16.12.3 The resultant scar shall then be ground to a smooth profile, ensuring no under-flushing of the plate surface occurs.

NOTE After grinding, the surface should be checked for cracks particularly on plates with specified minimum yield strength greater than 275 N/mm^2 and 20 mm thick and over. Should under-flushing be present, reference should be made to EN 10163 for guidance on possible repair.

17 Approval of welding procedures and welders

17.1 General

All welding, including repair, tack or attachment welding, and all welders, shall be approved by welding and testing appropriate test pieces in accordance with 17.2 to 17.5.

In the case of prepainted protection of the plates which may remain in place during the welding operation, the approval of the welding procedures shall be carried out on plates with this paint.

The following terms shall be as given in EN ISO 15607:2003, Clause 3:

— Preliminary Welding Procedure Specification (pWPS);

— Welding Procedure Specification (WPS);

— Welding Procedure Approval Record (WPAR).

17.2 Welding procedure approval

17.2.1 General

If required by the purchaser, all WPSs and WPARs shall be submitted by the manufacturer and/or erector for acceptance.

Before undertaking the approval tests, the manufacturer and/or erector shall draw up a pWPS, which shall conform to EN 288-2.

The approval test pieces and their dimensions shall be in accordance with EN ISO 15614-1:2004, Clause 6.

17.2.2 Welding of test pieces

Test pieces shall be welded in accordance with EN ISO 15614-1:2004, 6.3.

17.2.3 Examination and testing of test pieces

17.2.3.1 The extent of examinations, location and NDE on the test pieces shall be in accordance with EN ISO 15614-1:2004, 7.1 to 7.3.

17.2.3.2 The destructive tests shall be performed in accordance with EN ISO 15614-1:2004, 7.4 with the following conditions:

a) The joint tensile test shall fail in the plate material;

b) Impact tests are not required for stainless steels;

c) For carbon and carbon manganese steels, impact tests shall be carried out at the temperature determined from 6.1.6.

One set of three specimens shall be taken from the weld, and one set of three specimens from the HAZ. The minimum values of impact energy shall be:

27 J on average, with only one smaller than 27 J, but not less than 19 J.

17.2.3.3 Where specified (depending on the product stored), the hardness in the weld and the HAZ of a carbon or carbon manganese steel test piece, produced in accordance with 17.3.1 shall be < 350 HV 10.

17.3 Welding Procedure Approval Record (WPAR)

17.3.1 Preparation

The WPAR shall be prepared in accordance with EN ISO 15614-1:2004, Clause 9.

NOTE However, WPAR proposed to the purchaser may be accepted if they have been approved in accordance with another standard, and when their scope conforms to 17.2, 17.3 and 17.4 of this document.

17.3.2 Range of approval

The range of approval of the WPAR shall be in accordance with EN ISO 15614-1:2004, Clause 8.

A test piece shall be produced for the welding of the first shell course to the bottom plate, and the range of approval shall be:

$$0{,}8\,e \text{ to } 1{,}1e \qquad (22)$$

where

e is the thickness of the shell course.

17.4 Welders and welding operators approval

Welders shall be approved in accordance with EN 287-1.

Welding operators shall be approved in accordance with EN 1418.

17.5 Production control test plates

17.5.1 Horizontal welds

Test plates shall not be required.

17.5.2 Vertical welds

17.5.2.1 One test plate per tank shall be produced when vertical welds are welded by an automatic or semi-automatic welding process, and the plate thickness exceeds 13 mm.

This test plate shall be produced during the welding of the bottom course V1, shall have a minimum width of 300 mm, and shall be large enough to avoid the effects of heating on its mechanical properties.

If the method of erection is such that the test plate cannot be placed at the end of a vertical weld, it shall be welded on a nearby bracket.

17.5.2.2 The following shall be performed on each test plate:

— NDE to locate the position of internal imperfections;

— the mechanical test specimens shall be taken from an imperfection free area in accordance with EN ISO 15614-1:2004, 7.2, and 17.2.3 of this document, and the values specified in the WPS shall be obtained.

18 Welding

18.1 General

All welding, including repair, tack or attachment welding, shall be carried out in accordance with approved welding procedures, and shall be carried out by approved welders.

In addition to the requirements of Clause 17, the following welding-related rules, pertinant to the special conditions relating to site-built storage tanks, shall be observed.

All welding areas shall be clean and free from grease, paint, scale, etc. unless the paint is a weldable primer.

Welds shall be marked with the welders identification number for all work completed on a daily basis. This information shall be recorded on the master welding plan.

18.2 Welding sequences

The erector shall ensure by appropriate methods of assembly and welding sequences that distortion and shrinkage are kept to a minimum.

18.3 Welding of bottoms

18.3.1 Removal of coatings

Where a coating system is applied to the underside of bottom plates, it shall be removed in the area of the lap joints prior to welding.

18.3.2 Annular ring plates

All joints shall be full penetration butt welds (see 8.2.3).

Where backing strips are used, their removal shall not be necessary.

18.3.3 Bottom plates

Joints shall be lapped and fillet welded, or full penetration butt welded (see 8.2.1 and 16.6).

Manual (111) and semi automatic (114, 131, 135 and 136)(see EN ISO 4063) welding of fillet welds shall be with a minimum of two passes.

Where full penetration butt welded bottoms are used, the joining of backing strips to the bottom plate shall be agreed (see A.2).

18.4 Welding of shell to bottom

The edges of fillet welds shall not contain any unacceptable undercuts and the weld shape shall be in accordance with the requirements given in Table 32. This shall be checked using a template or other means.

18.5 Welding of shell

All vertical and horizontal joints shall be full penetration butt welds.

Excess weld metal of the internal welds shall be minimised in a tank intended to house a floating roof or floating cover.

18.6 Welding of roof

Roof plates shall be fillet or butt welded as specified in 10.3.5 and 10.4.1.

Welds shall be leak tight and shall not have any excess weld metal or undercuts in excess of those specified in Table 32.

NOTE In the specific case where roof frangibility is required, see Annex K.

18.7 Temporary welds

Temporary welds used for the positioning of parts during assembly shall be made in full conformity to an approved welding procedure (see 17.1.2.)

The welding consumables shall be those specified in the approved welding procedures.

The preheating specified and used in the approved welding procedure shall also be applied to temporary welds.

18.8 Atmospheric conditions

When welding in moist weather conditions, the erector shall ensure the areas to be welded are dry. The drying temperature shall not be confused with the preheating temperature requirement.

When the parent metal temperature is below + 5 °C, the material on both sides of the joint shall be warmed.

The welding stations shall be protected against excess ventilation due to wind or to chimney effects.

18.9 Preheating

When preheating is required, it shall encompass the whole thickness of the parts to be welded for a distance of four times the plate thickness or 75 mm, whichever is the greater, in any direction before welding begins.

Each welder or operator shall be capable of measuring the preheating temperature at all times.

18.10 Post-weld heat treatment

18.10.1 When post-weld heat treatment (PWHT) of carbon and carbon manganese steel sub-assemblies is required by 13.6.2 and 13.9 (see Table 28), the procedures specified in 18.10.2 to 18.10.8 shall be applied.

Table 28 — Nozzles to be post-weld heat treated

Material grade	**Shell plate thickness** e mm	*Nozzle diameter* d_i mm
S275	≥ 25	> 300
S355	≥ 25	> 300
S420	≥ 20	All

18.10.2 The temperatures specified shall be the actual temperatures of any part of the assembly and shall be measured by thermocouples attached to the assembly, unless it can be demonstrated that the type of furnace used will always comply with 18.10.

The temperature from a sufficient number of points shall be recorded continuously and automatically to ensure that the whole assembly being heat treated is within the range specified.

18.10.3 The temperature of the furnace shall not exceed 400 °C at the time the assembly is placed in it.

18.10.4 The rate of heating T_h above 400 °C (in degrees Celsius per hour) shall be:

$$T_h \leq \frac{5500}{e} \text{ with a maximum rate of 220 °C /h,} \quad (23)$$

where

e is the greatest shell plate thickness, in mm.

18.10.5 During the heating period, there shall be no variations in temperature throughout the assembly being heated greater than 150 °C within any 4500 mm interval of length, and when at the holding temperature, the temperature throughout the assembly shall be within the range 550 °C to 600 °C.

18.10.6 During the heating and holding periods, the furnace atmosphere shall be so controlled as to avoid excessive oxidation of the surface. There shall be no direct impingement of the flame on the assembly.

18.10.7 When the assembly has attained a uniform temperature as specified in 18.10.5, the temperature shall be held constant for a period in minutes equal to e, the thickness in millimetres of the thickest plate, with a minimum of 30 minutes.

18.10.8 The assembly shall be cooled in the furnace to 400 °C at a rate of cooling T_c (in degrees Celsius per hour)

$$T_c \leq \frac{5500}{e} \text{ with a maximum rate of 220 °C /h,} \qquad (24)$$

where

e is the greatest shell plate thickness, in mm.

NOTE Below 400 °C, the assembly may be cooled in still air.

18.11 Repair welding

All defects in excess of the minimum requirement specified in 19.11 shall be removed by chipping, grinding or gouging one or both sides of the joint, as required, and rewelded using an approved welding procedure. Only sufficient cutting-out of the joints shall be done as is necessary to remove the defects.

All repairs carried out because of non-compliance with 19.11 shall be 100 % radiographically or ultrasonically examined unless the complete seam is removed and rewelded, in which case the original weld inspection percentage shall be followed.

19 Testing and inspection

19.1 General

All Non-Destructive Examinations and Tests (NDE & NDT) required by this document shall be the responsibility of the manufacturer or erector. They shall be carried out by a NDE unit or organization independent of the production departments of the manufacturer or erector as defined in 3.1.

With the exception of the paragraph above, the erector shall have the authority to authorise a trained and experienced member of the erection staff to carry out the visual examination during erection. In this case, written authority shall be provided and attached to the reports.

Free access to the places of manufacture or erection at any stage of construction shall be given to the purchaser's inspectors in order that they can satisfy themselves of the quality of inspection being exercised and that the fabrication and erection instructions are being followed. As far as possible, these interventions shall be planned and carried out so as to avoid delaying or interfering with fabrication or erection.

19.2 Qualification of NDT personnel

NDT personnel shall possess a qualification corresponding at least to the level of work they are required to carry out. This qualification shall be certificated in accordance with EN 473.

The manufacturer/erector, or his chosen sub-contractor, shall prove the validity of the qualification of the NDT personnel.

In the case of sub-contracted NDT, the manufacturer/erector shall remain responsible to the purchaser.

19.3 Test procedures

For each of the test processes implemented, procedure documents describing the methods and techniques chosen for the test shall be supplied (see A.3).

Each procedure document shall indicate:

a) scope of the procedure;

b) operational conditions:

— type of equipment used;

— type and characteristics of consumable products;

— test parameters (duration, temperature, etc.);

— conditions for reading the results (light, etc.);

— safety rules applicable.

19.4 Type of inspections and examinations

19.4.1 Inspection of materials

It shall be the manufacturer's/erector's responsibility to ensure that products have been inspected in accordance with the material standards and any other specified requirements and that the results conform to the requirements of this document.

The material inspection documents shall be supplied before inspection begins on the construction site (see A.3). It shall be possible at all times for the inspector to identify all the materials used.

19.4.2 Examinations of edges to be welded and joint preparations

All edges to be welded, and all joint preparations, shall be visually examined to EN 970.

Visual examinations are intended to detect the presence of any imperfection on the plate edges, and to ensure the quality of assembly. They shall include verification of the geometry of the preparation made (distance between plates, chamfers, alignment or local deformations, etc.) and the cleanliness of the parts to be welded. Areas to be covered include bottom, bottom to shell, shell plates, roof to shell, roof, nozzles, framed roof, stiffening rings (wind girders) and stiffening members.

When shell nozzles are manufactured from carbon and carbon manganese steel plate of thickness ≥ 25 mm, an ultrasonic examination for laminations in the nozzle plate shall be made in the region of the nozzle to shell weld, over an area of width 2,5 times the thickness of the plate into which the nozzle will be welded. This examination shall not be necessary if forgings are used for the nozzles.

19.4.3 Visual examination

A visual examination shall be conducted according to EN 970 to check weld runs, shapes and dimensions, and to detect surface imperfections, both on welds and on the plates, nozzles and all accessories on the tank during its fabrication and erection.

It shall precede any other non-destructive examination or test.

19.4.4 Type and extent of examination and test of welds

The type and extent of examination of welds shall depend on the type of assembly, its location and the materials used, and shall be to Table 29, complimented by Tables 30 and 31.

The positions shall be chosen by the inspector.

Table 29 — Type and extent of weld examinations and tests for carbon, carbon manganese and stainless steel *(continued)*

Part of tank	Type of assembly	Visual examination (19.4) %	Dye penetrant test (19.6) %	Magnetic particle examination (19.7) %	Vacuum box test (19.5) %	Soap bubble examination (19.8) %	Radiography (19.9) or Ultrasonic examination (19.10) %
Bottom plates	Butt weld	100	100	100[a] or	100[a]		
	Fillet weld[b]	100	100	100[a] or	100[a]		
Bottom annular plates	Radial joint butt weld	100	100 or	100 or	100		[c] and [d]
Bottom to shell	Fillet weld	100 [e]	100 [f] or	100 [e] or	100 [e] or	100 [g]	
Shell	Butt weld	100					Tables 30 and 31
Roof to shell	Fillet weld	100		100 [h] or	100 [h] or	100 [h]	
	Butt weld	100		100 [h] or	100 [h] or	100 [h]	
Roof	Fillet weld[b]	100		100 [h] or	100 [h] or	100 [h]	
	Butt weld	100		100 [h] or	100 [h] or	100 [h]	

a Done when vacuum box test impractical.

b Fillet weld includes welds connecting lapped plates.

c Radiographic examination with one 400 mm full length film from the outer edge of the annular plate, or ultrasonic examination over the full length, one joint in four.

d For steel with yield strength ≥ 355 N/mm^2 and thickness > 10 mm, radiographic examination with one 400 mm full length film from the outer edge of the annular plate, or ultrasonic examination over the full length, one joint in two.

e On both sides.

f For steel with yields strength < 355 N/mm^2 and thickness ≤ 30 mm, on inside only.

g For steel with yields strength < 355 N/mm^2 and thickness ≤ 30 mm, on inside only.

h One side.

Table 29 — Type and extent of weld examinations and tests for carbon, carbon manganese and stainless steel *(continued)*

Part of tank	Type of assembly	Visual examination (19.4) %	Vacuum box test (19.5) %	Penetrant test (19.6) %	Magnetic particle examination (19.7) %	Soap bubble examination (19.8) %	Radiography (19.9) or Ultrasonic examination (19.10) %
Nozzles in shell or bottom and nozzles in roof where design pressure > 60 mbar gauge	Longitudinal weld	100[i]					100
	Weld neck flange to pipe $d_n \geq 100$ mm	100[i]					10
	Weld neck flange to pipe $d_n < 100$ m	100[h] [i]		100[h] or	100[h]		
	Slip on flange to pipe fillet weld	100[i]		100 or	100		
Nozzle to shell or insert and nozzle with reinforcing plate	Nozzle to shell or insert weld	100[i]		100 or	100		
	Nozzle to reinforcing plate	100[i]		100 or	100		
	Reinforcing plate to shell	100[i]				100	
	Insert plate to shell	100					100

h One side.

i After post-weld heat treatment of sub-assembly, if required.

Table 29 — Type and extent of weld examinations and tests for carbon, carbon manganese and stainless steel *(concluded)*

Part of tank	Type of assembly	Visual examination (19.4) %	Dye penetrant test (19.5) %	Magnetic particle examination (19.6) %	Vacuum box test (19.7) %	Soap bubble examination (19.8) %	Radiography (19.9) or Ultrasonic examination (19.10) %
Clean out door nozzle flush with bottom plate	Butt weld on bottom	100 [i]					100
	Other than reinforcement	100 [i]	100 [i]	100 [j]			
Nozzle in roof where design pressure ≤ 60 mbar	Longitudinal weld	100				100	
	Weld neck flange to pipe butt weld	100				100	
	Slip on flange to pipe fillet weld	100				100	
	Nozzle to roof fillet weld	100	100	or		100	
Temporary bracket	After removal of the bracket	100	100 [k] or	100 [k]			
Permanent bracket and pad plates	Fillet weld	100	100 [k] or	100 [k]			
Stiffening rings (Wind girders)	Main butt welds in stiffening rings	100					
	Fillet welds to shell	100	100 [k] or	100 [k]			

i After post-weld heat treatment of sub-assembly, if required.

j After first pass.

k For steel with yield strength ≥ 355 N/mm².

Table 30 — Extent of radiographic and ultrasonic examination of welds to carbon and carbon manganese steel shell plates

Plate		Type of examination	Welds			
Yield strength N/mm^2	Thickness *e* mm		V1[1)] %	Vr [2)] %	T-joint % [3)]	Horizontal %
< 355	≤ 13	Radiograpic	5	1	25	1
	> 13 to 30	Radiograpic or Ultrasonic [4)]	10	5	50	2
	> 30	Radiography or Ultrasonic [4)]	20	10	100	2
≥ 355	≤ 13	Radiograpic	10	5	25	1
	> 13 to 30	Radiograpic or Ultrasonic [4)]	20	10	50	2
	> 30	Ultrasonic [4)]	50	20	100	5

[1)] V1 is the vertical weld in the first shell course (bottom course).

[2)] Vr are the vertical welds in the remaining courses.

[3)] 50 % of these percentages taken with a 400 mm film positioned horizontally and 50 % with a film positioned vertically.

[4)] Ultrasonic examination for semi-automatic welding processes is obligatory above 20 mm thickness.

NOTE 1 In addition to these examinations, there shall be at least one examination as follows :

a) For each welding process on the first vertical/horizontal joint ;

b) For each welder or welding operator ;

c) At the changeover from manual to automatic welding (vertical start V1).

NOTE 2 Where radiography is used, a single film may cover more than one of these checks.

Table 31 — Extent of radiographic examination and penetrant testing of welds to stainless steel shell plates

Plate thickness *e* mm	Type of examination or test	Welds			
		V1[1)] %	Vr [2)] %	T-joint % [3)]	Horizontal %
≤ 8	Radiographic	1	1	1	1
> 8 to 13	Radiographic	5	1	5	1
> 13	Radiographic	5	2	10	2
All thickness	Penetrant	10	10	10	10

[1)] V1 is the vertical weld in the first shall course (bottom course).

[2)] Vr are the vertical welds in the remaining courses.

[3)] 50 % of these percentages taken with a 400 mm film positioned horizontally and 50 % with a film positioned vertically.

NOTE 1 In addition to these examinations, there shall be at least one examination as follows :

a) For each welding process on the first vertical/horizontal joint ;

b) For each welder or welding operator ;

c) At the changeover from manual to automatic welding (vertical start V1).

NOTE 2 Where radiography is used, a single film may cover more than one of these checks.

19.4.5 Additional examinations if imperfections are found

19.4.5.1 General

If imperfections outside the acceptable limits are found, additional examinations shall be conducted.

19.4.5.2 Automatic welding

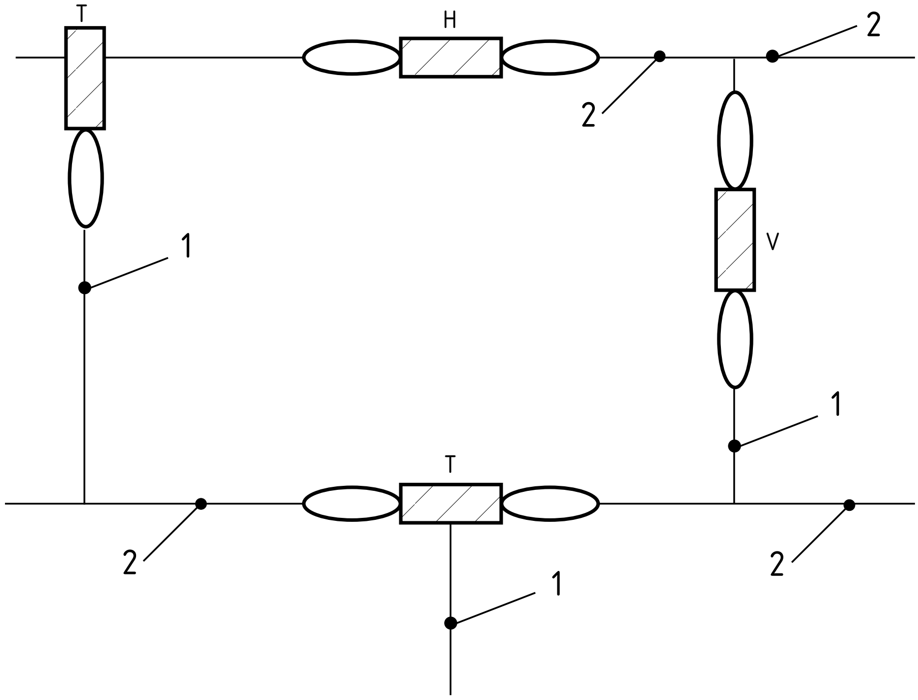
One further film shall be taken, or 1 m of ultrasonic examination shall be carried out, each side of the original area, see Figure 19.

If one of these additional films or ultrasonic examinations is rejected, then there shall be a total examination of the day's production by the machine in question.

19.4.5.3 Manual welding

One further film shall be taken, or 1 m of ultrasonic examination shall be carried out, each side of the original area, see Figure 19.

If one of these additional films or ultrasonic examinations is rejected, then there shall be a total examination of the day’s production by the welder in question.



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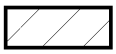
 Weld under examination

 Additional examinations

1 Vertical weld   2 Horizontal weld

Figure 19 — Additional examinations of defective welds

19.5 Vacuum box test

Testing of the welds between the bottom plates shall be carried out using a vacuum box in accordance with EN 1593 and soapy water.

The plates shall be clean and the welds shall be degreased and free of any slag or scale which might affect the quality of the test.

The vacuum box shall be of a size and shape appropriate to the test.

The pumping system used shall guarantee a minimum pressure of – 300 mbar (– 30 kPa) gauge.

The soapy water used shall have:

- high wetting power;
- low viscosity;
- low surface tension;
- high foaming power.

19.6 Penetrant test

A penetrant test shall be conducted in accordance with EN 571-1.

All penetrant products used during a particular test shall be compatible.

The manufacturer/erector shall ensure that there is no risk of the products contaminating the items being tested and products which are to be stored.

The manufacturer/erector shall be in possession of all the necessary elements from the makers of the test products to enable them to establish procedures defining the working methods for the test and detection of any imperfections.

The surface quality required to enable correct interpretations to be made shall be specified.

19.7 Magnetic particle examination

The magnetic particle examination shall be conducted in accordance with EN 1290.

The method of magnetisation used shall not involve feeding current into the part. A movable electromagnet with which the inspected part will form a closed magnetic circuit shall be employed.

The procedure and equipment used in the examination, and the methods used in the search for and elimination of defects shall be specified in a document available to the purchaser or the inspector.

The procedure shall indicate the surface quality required to an enable correct interpretation to be made.

NOTE Dry powder should be avoided on unmachined surfaces.

19.8 Soap bubble examination

19.8.1 Reinforcement plates

After suitable wetting of the reinforcement plate welds with soapy water specified in 19.5, air at a pressure of 300 mbar (30 kPa) gauge shall be introduced through the threaded hole provided for this purpose.

The holding time shall be not less than 30 seconds.

After the examination, the threaded hole shall be sealed.

19.8.2 Fixed roof and roof to shell

During the pneumatic pressure test of the roof, the external fillet welds shall be wetted with soapy water specified in 19.5.

The pressure shall be maintained during the examination.

19.8.3 Shell to bottom with double fillet weld

For shell plates with a thickness greater than 30 mm, welded with double fillet welds to the bottom, air at a pressure of 300 mbar (30 kPa) gauge shall be introduced into the space between the fillet welds, and shall be maintained during the examination.

Soapy water specified in 19.5 shall be applied by brush or spray to the welds.

After the examination, the threaded holes shall be sealed.

19.9 Radiographic examination

19.9.1 General procedure

A radiographic examination shall be conducted in accordance with EN 1435.

The manufacturer/erector and his qualified personnel shall abide by the current safety regulations when conducting radiographic examinations at the works and on the erection site.

The radiation source shall be subject to agreement (see A.2) and/or inspection organization, and shall depend on the thicknesses and areas of material to be examined.

The radiographic technique used for examination of welds in carbon and carbon manganese steels shall be in accordance with EN 444.

For carbon and carbon manganese steels with yield strength < 355 N/mm^2, the radiographic class shall be A.

For carbon and carbon manganese steels with yield strength ≥ 355 N/mm^2, the radiographic class shall be B.

The length of a radiographic film shall be 400 mm. The use of narrow films shall be allowed provided a strip of 10 mm of base metal, free of any film marking inscription, is visible at either side of the weld bead.

The Image Quality Indicator (IQI) shall be in accordance with EN 462-1 or EN 462-2.

The films of the weld shall be marked with care. The identifying marks and positions shall be shown on a drawing, along with the identity of the welders and weld operators involved. Each film shall be marked with the tank reference and its position on the tank.

NOTE For a weld made in several passes by different welders, it is usually acceptable for one radiograph taken at any point to serve as a control for all welders involved.

19.9.2 Storage of films

Films shall be kept in storage for interpretation for a minimum period of 5 years either by the manufacturer/erector or by the purchaser, as specified in the order.

19.10 Ultrasonic examination

The ultrasonic examination shall be conducted in accordance with EN 1714.

19.11 Acceptance criteria

19.11.1 Imperfection acceptance criteria

The imperfection acceptance criteria for various parts of the tank shall be in accordance with Table 32.

The designations of imperfections given in EN ISO 6520-1 shall be used.

Areas found to be outside these limits shall be repaired in accordance with 18.11.

Table 32 — Imperfection acceptance criteria *(continued)*

EN ISO 6520-1 reference number	Imperfection designation	Welds	Limits of imperfections
100	Cracks	All	Not permitted
101	Longitudinal crack		
102	Transverse crack		
104	Crater crack	All	Not permitted
2011	Gas pore	Butt welds in shell Shell to bottom welds Shell and bottom nozzle welds	$\bar{z}$ Porosity area ≤ 1 % Single pore - butt weld $d \leq 0{,}3\ s$ Single pore - fillet weld $d \leq 0{,}3\ a$ With d maximum 3 mm
2012	Uniformly distributed porosity	Roof and roof structure Roof nozzles	$\bar{z}$ Porosity area ≤ 2 % Single pore - butt weld $d \leq 0{,}4\ s$ Single pore - fillet weld $d \leq 0{,}4\ a$ With d maximum 4 mm
2013	Localised (Clustered) porosity	Butt welds in shell Shell to bottom welds Shell and bottom nozzle welds	$\bar{z}$ Porosity area ≤ 4 % Single pore - butt weld $d \leq 0{,}3\ s$ Single pore - fillet weld $d \leq 0{,}3\ a$ With d maximum 2 mm
		Roof and roof structure Roof nozzles	$\bar{z}$ Porosity area ≤ 8 % Single pore - butt weld $d \leq 0{,}4\ s$ Single pore - fillet weld $d \leq 0{,}4\ a$ With d maximum 3 mm

Table 32 — Imperfection acceptance criteria *(continued)*

EN ISO 6520-1 reference number	Imperfection designation	Welds	Limits of imperfections
2015	Elongated cavity	Butt welds in shell Shell to bottom welds Shell and bottom nozzle welds	Long imperfections not permitted Short imperfections - butt weld $h \leq 0{,}3\ s$ Short imperfections - fillet weld $h \leq 0{,}3\ a$ With h maximum 2 mm
2016	Worm-hole	Roof and roof structure Roof nozzles	Long imperfections not permitted Short imperfections - butt weld $h \leq 0.4\ s$ Short imperfections - fillet weld $h \leq 0.4\ a$ With h maximum 3 mm
2017	Surface pore	All	Single pore - butt weld $d \leq 0{,}3\ s$ Single pore - fillet weld $d \leq 0{,}3\ a$ With d maximum 3 mm
2024	Crater pipe	All	Not permitted
300	Solid inclusion	Butt welds in shell Shell to bottom welds Shell and bottom nozzle welds	Long imperfections not permitted Short imperfections - butt weld $h \leq 0{,}3\ s$ Short imperfections - fillet weld $h \leq 0{,}3\ a$ With h maximum 2 mm
		Roof and roof structure Roof nozzles	Long imperfections not permitted Short imperfections - butt weld $h \leq 0{,}4\ s$ Short imperfections - fillet weld $h \leq 0{,}4\ a$ With h maximum 3 mm
3041	Tungsten inclusion	All	Not permitted
3042	Copper inclusion		
401	Lack of fusion	All	Not permitted
402	Lack of penetration (incomplete penetration)	Butt welds in shell Butt welds in stiffening rings	Not permitted
		Shell nozzles	Long imperfections not permitted Short imperfections $h \leq 0{,}1\ s$, max 1,5 mm
——	Bad fit-up, fillet welds	All	$h \leq 0{,}5$ mm + 0,2 a, maximum 3 mm

Table 32 — Imperfection acceptance criteria *(continued)*

EN ISO 6520-1 reference number	Imperfection designation	Welds	Limits of imperfections
5011	Continuous undercut	All	Not permitted
5012 5013	Intermittent undercut Shrinkage groove	All	10 % of e with 0,5 mm max for vertical welds 10 % of e with 1 mm max for horizontal welds. Smooth transition is required.
502	Excess weld metal	Internal weld of shell with floating roof or floating cover	$h \leq 1$ mm + 0,1 b, maximum 5 mm
		Other welds	$h \leq 1$ mm + 0,15 b, maximum 7 mm
503	Excessive convexity	Nozzles on shell	$h \leq 1$ mm + 0,1 b, maximum 3 mm
		Shell on bottom	$h \leq 1$ mm + 0,1 b, maximum 3 mm
		Other welds	$h \leq 1$ mm + 0,15 b, maximum 4 mm
——	Fillet weld having a throat thickness smaller than the nominal value	Nozzles on shell	Not permitted
		Shell on bottom	Not permitted
		Other welds	Long imperfections not permitted Short imperfections $h \leq 0,3$ mm + 0,1 a maximum 1 mm
504	Excessive penetration	All	$h \leq 1$ mm + 0,3 b, maximum 3 mm
506	Overlap	All Shell	Not permitted See 16.1.6 and 16.7
507	Linear misalignment	Butt welds in nozzles	$h \leq 0,5\ e$, maximum 2 mm
		Structural steelwork	$h \leq 0,15\ e$, maximum 4 mm
509 511	Sagging Incompletely filled groove	All	Long imperfections not permitted Short imperfections $h \leq 0,1\ e$ max 1 mm
512	Excessive asymmetry of fillet welds	All	$h \leq 2$ mm + 0,15 a
515	Root concavity	All	10 % of e with 1 mm maximum
516	Root porosity	All	Not permitted
517	Poor restart	All	Not permitted

Table 32 — Imperfection acceptance criteria *(concluded)*

EN ISO 6520-1 reference number	Imperfection designation	Welds	Limits of imperfections
601	Stray flash or arc strike	All	Not permitted on stainless steel or carbon steel with yield strength ≥ 355 N/mm^2
602	Spatter	All	Shall be removed (see Annex R)
603	Torn surface		Not permitted
604	Grinding mark		See 19.11.2
605	Chipping mark		See 19.11.2
606	Underflushing		See 19.11.2

a : nominal fillet weld throat thickness

b : width of weld reinforcement

d : diameter of pore

e : thickness of parent metal

h : dimension (width or height) of imperfection

l : length of imperfection

s : nominal butt weld thickness or, in the case of partial penetration, the prescribed depth of penetration.

$\overline{z}$: summation of projected area

Long imperfections: one or more imperfections of total length greater than 25 mm in any 100 mm length of the weld, or a minimum of 25 % of the weld length for a weld shorter than 100 mm.

Short imperfections: one or more imperfections of total length not greater than 25 mm in any 100 mm length weld, or a minimum of 25 % of the weld length for a weld shorter than 100 mm.

Intermittent undercuts are defined as the sum of the undercuts shall not exceed 200 mm in any 2 m on one edge.

19.11.2 Acceptable thinning after grinding

If grinding is acceptable, the defect shall be removed in its entirety and the surface shall be checked by a further examination or test.

Any reduction in thickness below that defined in 9.2.2 shall not be permitted. However, local thinning relative to the thickness shall be allowed so long as the following two conditions are satisfied:

— final thickness of the plate shall not be less than 95 % of the plate thickness determined in accordance with 9.2.2 over an area of 6*e* by 6*e*, and shall be blended smoothly to the unaffected surface;

— distance between any two areas affected by thinning shall be at least equal to the diameter of the circle circumscribing the largest area.

19.12 Dimensional check

In addition to the checks in the workshop on the internal dimensions of prefabricated parts and the checks requested under 16.6, 16.7 and 16.8, the erector or inspector shall check, as a minimum, the following:

— general orientations of the tank;

— main dimensions of the tank;

— slope of the roof;

— positions of the nozzles (orientation, tilt, etc.);

— seal faces of the flanges;

— verticality of the level tube when fitted;

— location and conformity of accessories for fitting safety devices;

— curvature of the wall and the absence of any flat area.

19.13 Hydrostatic and pneumatic tests

19.13.1 General

All tanks shall undergo a hydrostatic test.

Apart from exceptional cases subject to agreement between the purchaser and the erector (see A.2), water shall be used for the hydrostatic test.

The hydrostatic test shall not be carried out until all welding has been completed and all welded accessories to the shell and the bottom of the tank are in place.

Unless otherwise agreed (see A.2), testing shall be carried out prior to painting.

19.13.2 Hydrostatic test liquid level

For all tanks, the hydrostatic test liquid level shall be equal to the design liquid levels specified in 9.1.3 and 9.2.1.

19.13.3 Pneumatic test pressure

For fixed roof tanks, the pneumatic test pressure applied to the vapour space during the hydrostatic test shall be

p_t as given in 9.2.2.

This shall not apply to tanks with free vents.

19.13.4 Conditions of implementation

Before the start of the test, the tank shall be cleaned, any spatter and slag removed from the welds, and all materials, objects or temporary installations used during its construction shall be removed.

For the tests, the erector shall install, on the roof or on one of the roof nozzles, a safety system of sufficient capacity in order that the excess pressures and negative pressures do not exceed those calculated and used in the design of the tank. A water column gauge shall be installed on the tank roof.

Clean water shall be used to perform the test.

Where it is impractical to use clean water, alternative water shall only be used with the agreement of the purchaser (see A.2).

NOTE A corrosion inhibitor may be used.

In all cases, the use of brackish or sea water shall be kept to a minimum and arrangements shall be made for rinsing with clean water after the test.

In the case of a stainless steel tank, or a tank with stainless steel components (e.g. floating cover), the quality of the water shall be checked and the chloride ion content (Cl-) shall not exceed 0,0025 %.

If the ambient temperature is equal to or less than 0 °C, the erector shall ensure that the necessary measures are taken to avoid freezing.

19.13.5 Examination during filling

19.13.5.1 Peripheral level check

Before filling, in order to check for any settlement or movement of the foundation during the test, the erector shall place the following markers on the outer surface of the tank:

- four markers for tanks with a diameter ≤ 10 m;
- eight markers for tanks with a larger diameter.

Where the settlement of the foundation is not known, the erector shall use markers which remain visible after the tank is painted.

The heights of these markers relative to a fixed datum shall be noted before filling begins and, thereafter, as often as necessary, but not less than when the tank is half full, three quarters full, and full.

19.13.5.2 Bottom surface level survey

Before filling, the erector shall survey and record the contour of the tank bottom in order to determine any deformation that might occur due to the weight of the water. The dimensions shall be obtained either by a surface survey taking for a reference a fixed exterior point, or by dimensions taken with respect to nozzles on the roof used to that effect.

In addition, in order to check for any settlement or movement of the foundation during the test, the erector shall survey the level of the bottom before the hydrostatic test at the following locations:

- for tanks with diameter ≤ 10 m, on 3 radii at 0°, 120° and 240°, the level survey shall be carried out at the one third and two thirds of the way along each radius and at the centre;
- for tanks with diameter > 10 m, on 6 radii at 0°, 60°, 120°, 180°, 240° and 300°, the level survey shall be carried out at the one third and two thirds of the way along each radius and at the centre.

19.13.6 Filling

The rate of filling shall be subject to agreement (see A.2) between the erector and the purchaser and shall take into consideration the tank dimensions, the ground conditions, the geotechnical survey and the availability of water.

The full water load shall be maintained for at least 24 hours, and during the test the erector shall carry out a visual inspection of the welds and verify the shape of the tank.

Should a leak be discovered, the water level shall be lowered to approximately 300 mm below the location of the imperfection before repairs are carried out.

After repairing and testing to the original requirements, the water level shall be returned to the original test level.

While the load is maintained, level checks shall be carried out at least every 12 hours, and for tanks with an anchorage system, these shall be adjusted.

There shall be no significant subsidence of the foundation, nor of the shell, beyond those predicted in the designs.

19.13.7 Checking and testing of roof (over pressure)

The following shall be carried out during the hydrostatic test of the tank.

All seams in the shell and roof above the test water level shall be inspected.

All the openings shall be closed and, for this test only, the safety valves shall be set up to the maximum over pressure permitted by the calculation.

NOTE It may be necessary to supply appropriate safety valves for the test.

The air pressure shall be increased to the test pressure given in 19.13.3, and for column supported roofs, the test pressure shall be limited to a pressure equivalent to the roof plate weight.

The over pressure shall be maintained for the duration of the soapy water test which shall not commence for at least 30 minutes after the over pressure is achieved.

For tanks with a design pressure greater than 10 mbar, the test pressure shall be held for 15 minutes, and then reduced to the design pressure before personnel go on the roof to conduct the soapy water test. The design pressure shall be maintained for the duration of this test. The pressure gauge shall be readable from ground level.

Soapy water of the type used for vacuum box examination (see 19.5) shall be applied by brush or spray to all welds.

Any welds where leakage is detected shall be repaired.

Weld repairs shall not be carried out while the roof is under pressure.

The repairs shall be examined by a vacuum box examination in accordance with 19.5.

Where tanks cannot be pressurized to detect leaks, the soundness of the welds shall be determined by the use of a vacuum box leak examination in accordance with 19.5.

NOTE Attention is drawn to the need for careful control and monitoring of pressures during this testing. Climatic changes can cause sharp fluctuations in test pressure and provision should be made for the safe relief of pressure or vacuum in the event of such fluctuations.

19.13.8 Test for tank stability under negative pressure

After the liquid level in the tank has been lowered to one meter above the top of the draw-off nozzle, the tank stability under negative pressure (depressurization) shall be tested.

All the openings shall be sealed off except for the negative pressure safety valve (pressure/vacuum) and the water level shall be reduced until the value required by 5.1 is obtained.

19.14 Empty checks

When all the tests have been concluded, the tank shall be emptied, cleaned and may be dried.

The erector shall check the level of the bottom, and compare these levels with those noted before filling began. (see 19.13.5.2)

In the case of a drain pipe fitted under the bottom, after the tank has been dried, the erector shall examine the drain pipe nozzle weld to the bottom plates by 100 % visual inspection plus 100 % penetrant test or magnetic particle examination.

19.15 Accessories

19.15.1 External accessories

The examinations of the accessories (see 13.10 to 13.15) shall be concerned with the quality of the welds.

Welded supports shall be examined, to ensure all welds are continuous.

The quality and tightness of the bolted assemblies shall be examined to ensure that the walkways between adjacent tanks can move freely.

The earth connections shall be examined to ensure correct tightening and protection.

19.15.2 Internal accessories

In addition to the verification of the positions of the accessories (piping, supports, reinforcements, etc.), the quality of the welds (absence of undercuts, of underthickness, etc.) shall be examined.

No spaces which could constitute a seat for product retention shall be left by the installation and welding of the accessories.

20 Documentation and name-plate

20.1 Documentation

Using the list in Table 33, the purchaser shall indicate the documents required, or those to be examined.

NOTE The term "documentation" refers to all documents generated by the:

- purchaser;
- manufacturer;
- erector;
- inspection organization.

The documents shall be identified in such a way that they make it possible to trace all products and operations back to the order for which they were issued.

Table 33 — List of documents *(continued)*

Documents	Required	Examined	Observations
Design calculations.			
Drawings as built: Layout drawing; General site drawing; Detail drawings. Roof, Shell, Bottom: nozzles and accessories. Fixed roof: framework. Floating roof: nozzles, corner plates, walkways stairways and guard rails. Floating cover. Seal.			
Suppliers inspection documents, including material certificates: plates; tubes; flanges; welding consumables; etc.			

Table 33 — List of documents *(concluded)*

Documents	Required	Examined	Observations
Welding documents: pWPS; WPAR; Approval of welding personnel; PWHT; Welding and welders reference drawing.			
Examination and testing documents: Approval of NDT personnel; Examination and/or test procedures; Visual examination and dimensional report: diameter verticality Dye penetrant test report; Magnetic particle examination report; Radiographic examination report, location plan; Ultrasonic examination report, location plan; Bottom weld tightness examination report; Report on pneumatic testing of the reinforcements; Bottom level reading report; Shell level reading report; Water quality analysis report (for stainless steel tank); Tank hydrostatic test report; Geometrical foundation report.			
Heating or cooling system: Design calculations; Drawings; Material certificates; Hydrostatic test report.			
Safety systems.			

20.2 Name-plate

A name-plate giving the following information shall be affixed to each tank on the name-plate support provided for this purpose:

- manufacturer's company's name and address;
- serial No;
- design standard (EN 14015: 2004);
- year of manufacture;
- tank identification mark;
- diameter, in m;
- design density, in kg/l;
- design pressure, in mbar;
- internal negative pressure, in mbar;
- design temperature, in °C;
- maximum design liquid level, in m;
- storage capacity, in m^3.

On tanks fitted with a fixed heating or cooling circuit (see Annex P), an additional name-plate shall be fitted to the inlet or outlet connection of the circuit giving as a minimum:

- manufacturer's company's name and address;
- serial No;
- design standard;
- heat exchange area, in m^2;
- volume, in m^3;
- type of heat transfer medium;
- design pressure, in bar;
- design temperature, in °C.

Annex A
(normative)

Information and requirements to be documented

A.1 Information to be supplied by the purchaser

The following information to be supplied by the purchaser shall be fully documented, where applicable:

- design pressure and the design internal negative pressure (see 5.1 and Table 3);
- stainless steel grade, (see 6.2.1.2);
- requirements for the surface finish of stainless steel (6.2.1.4);
- when required, the value of the seismic load including the vertical and horizontal accelerations to be used in the design (see 7.2.11);
- bottom type if not single (see 8.1.1);
- gradient of the bottom (see 8.1.1);
- bottom, if not lap welded, is to be butt welded (see 8.4.1);
- whether the underside welds of stiffening rings is to be continuous or intermittent (see 9.3.1.11);
- roof slope of a self-supporting cone roof, the radius of curvature of a dome roof and the roof slope of a column supported roof, if different to that specified in 10.2.2;
- side of the roof that is welded and the size of the overlap (see 10.3.5);
- venting requirements (see 10.6.1);
- emergency pressure relief is not to be included (see 10.6.2);
- provision of floating covers (see 10.7);
- provision of floating roofs and floating roof seals (see 11);
- amount of product to be always present in the tank (see 12.1);
- roof manhole cover (see 13.3.1);
- drilling of flanges (see 13.8);
- datum height for the foundation and it's permissible variation (see 16.2.2);
- underside protection of bottom plates (see 16.6);
- order of plate lapping (see 16.8.3);

- if the roof plates are to be welded to the roof structure (see 16.8.4);
- liquid to be contained, and any special properties, in tanks with floating covers (see C.3.2.1);
- maximum filling and emptying rates (see C.3.3.3);
- if mesh is not required (see C.3.4.1);
- position of the inlet diffuser (see C.3.4.3);
- position of floating roof (see D.3.1);
- floating roof design and type (see D.3.4);
- additional roof manholes (see D.3.6);
- roof main drain if not a hose or articulated pipe type (see D.3.8.1);
- whether double deck roofs shall be equipped with open type roof drains (see D.3.8.1);
- maximum liquid filling and withdrawal rates and any special venting requirements (see D.3.11);
- support leg operating and cleaning positions (see D.3.13);
- gauging device (see D.3.14);
- if a rolling ladder is not required (see D.3.15);
- if a trial erection and inspection of a floating roof is required (see D.4);
- if floating roof rim seals are required (see E.1);
- if weather shields are not required (see E.4);
- venting system flash back prevention (see L.2.6);
- evaporation rate (see L.3.2.1 c));
- maximum gas flow under malfunction conditions of the gas blanket (see L.4.3);
- emergency flow capacity for other possible causes (see L.4.4);
- emergency vacuum flow capacity (see L.5);
- range of operating temperature (see Q.2.4);
- procedure, qualification and acceptance tests for adhesive (see Q.3.3.1);
- insulation thickness or heat loss requirements (see Q.6.1);
- condition of the internal surface of the tank (see R.1.3.1);
- tank's external appearance and finish (see R.2.1).
- painting system used (see R.2.2)

A.2 Information agreed between the purchaser and the manufacturer

The following information to be agreed between the purchaser and the manufacturer shall be documented:

- additional requirements for roof plating and nozzle reinforcement (see Table 3);
- design methodology and fabrication tolerances for design internal negative pressures > 8.5 mbar (see Table 3);
- steel to be used if not from Tables 5 to 7 (see 6.1.1.1);
- mounting materials, when different, to the shell plates (see 6.1.7.1);
- live loads (see 7.2.6);
- concentrated live load (see 7.2.7);
- value of the wind load if the 3 second wind gust velocity is more than 45 m/s (see 7.2.10);
- anticipated settlement loads (see 7.2.13);
- emergency loads (see 7.2.14);
- bottom gradient, if more than 1;100 (see 8.1.1);
- guaranteed residual liquid level to resist uplift (see 8.2.3);
- option to be used if the maximum density of the contained liquid exceeds 1,0 kg/l (see 9.1.3);
- shell thickness for stainless steel tanks of diameters greater than 45 mm (see Table 16,);
- design methodology for load combinations (see 9.3.3.9);
- joint efficiency if different to specified values (see 10.3.6);
- minimum size of manholes (see 13.1.1);
- details of non-standard nozzles (see 13.3.2);
- crossing of shell welds by nozzles (13.7.2);
- method of heating or cooling the fluid (see 13.10);
- method of material marking (see 15.4);
- shearing of plates above 10 mm thickness (see 15.5);
- non-standard distances between an opening and a plate edge (see 15.5);
- thermal cutting of pipe ends (see 15.6);
- design methodology and fabrication tolerances for design internal negative pressures greater than 8,5 mbar (see 16.1.7);
- repair procedure for damaged parts (see 16.5);

- joining of backing strips to the bottom plates (see 18.33);
- radiation source (see 19.9.1);
- use of any liquid other than water in the hydrostatic test (see 19.13.1);
- tank is to be painted prior to testing (see 19.13.1);
- use of alternative water (see 19.13.4);
- rate of filling of the tank (see 19.13.6);
- non-standard types of floating roofs (see D.2);
- non-standard floating roofs (see D.3.1);
- specific requirement for a floating roof (see D.3.2.4);
- alternative values for live load when resting on its support legs (see D.3.3 b));
- use of alternative materials (see F.1);
- negative pressure and time to be used (see H.4);
- method of assessing frangibility (see K.2);
- safety coefficient for frangible roofs (see K.4);
- details of the tank anchorage (see M.1);
- proprietary system of insulation (see Q.1);
- basis for the wind load calculations (see Q.2.3);

A.3 Information to be supplied by the manufacturer

The following information to be supplied by the manufacturer shall be fully documented:

- if required, the methods to be used in the assembly of the tank including the methods to be used to hold plates in position for welding, the sequences of assembly and welding, means of access for welding and the methods to be used to avoid wind damage during erection (see 16.1.5);
- details of the design of the anchorage system to ensure that the foundation design incorporates provision for the anchor points and their associated loads (see 16.3);
- for each of the test processes implemented, a description of methods and techniques chosen for the test (see 19.3);
- material inspection documents (see 19.4.1);

A.4 Information to be supplied by the steel manufacturer

The following information to be supplied by the steel manufacturer shall be fully documented:

- for design metal temperatures in excess of 100 °C, and for steels not conforming to Table 8, the elevated temperature yield stress values of the steels (see 6.1.1.2);

A.5 Information to be agreed between the steel manufacturer and the tank manufacturer

The following information to be agreed between the steel manufacturer and the tank manufacturer shall be fully documented:

- method of proof for steels proven to be unaffected by ageing, when the maximum design metal temperature exceeds 250 °C (see 6.1.1.3);
- material marking (see 6.2.2);
- method of proof for the effects of ageing (see F.4.3).

A.6 Information to be agreed between the purchaser and the cover supplier

The following information to be agreed between the purchaser and the cover supplier shall be fully documented:

- equipment for testing electrical resistance (see C.4.3.3);
- type of seal, if different from that specified in C.3.2.3 and Annex E.

A.7 Information to be agreed between the tank manufacturer and the cover supplier

The following information to be agreed between the tank manufacturer and the cover supplier shall be fully documented:

- provision for adequate clearance, tank tolerances, position of shell manways, installation of floating suction, fixed roof vents and inlet diffuser (see C.3.1.1).

A.8 Information to be supplied by the cover supplier

The following information to be agreed between the tank manufacturer and the cover supplier shall be fully documented:

- evidence that the cover and seal will conform to specified pollution control requirements (see C.3.1.5);
- complete material specification (see C.3.2.1);
- operating instructions (see C.5).

Annex B
(informative)

Operational and safety considerations for storage tanks and storage installations

B.1 General

The intention of this Annex is to provide some outline guidance to purchasers of storage tanks about some of these wider issues which need to be considered and to indicate some references which might assist in providing detailed requirements.

NOTE Attention is drawn to possible local/National legislation/regulations.

B.2 Tank type

B.2.1 Stored product

The type and nature of the product to be stored are the most important criteria in selecting the type of tank to use - fixed or floating roof or fixed roof with floating cover. For hydrocarbon liquids, Codes of Practice such as the IP Refinery Safety Code [2] the European Model Code of Safe Practice [3] and NFPA 30 use systems of classification based upon the closed flash point of individual products to determine appropriate requirements. These classification systems are different and it is important to define which applies when considering, for example, a Class I or Class II product.

NOTE Attention is drawn to possible local/National legislation/regulations.

B.2.2 Local climatic and geological conditions

High snow loads or very strong wind conditions can influence design choice. Extreme conditions might preclude the use of floating roof tanks and fixed roof tanks with or without internal floating covers might be necessary.

Foundation conditions and the levels of seismic activity are also significant factors in the selection of both type and size of tank. Generally column supported fixed roofs can be difficult to design for sites where significant foundation settlement is envisaged although provision can be made for limited settlement. Tanks without column supported roofs are less sensitive to uniform foundation settlement but uneven settlement can lead to significant problems of shell distortion and can lead to tank bottom failure.

Fatigue cracking of pontoon type single deck floating roofs has been experienced under certain wind conditions and stiffened or even double deck roofs might have to be used.

B.3 Health, safety and environmental considerations

B.3.1 Containment

Many of the products stored in tanks are highly inflammable, others may be corrosive or hazardous to health. Such products could create pollution of the ground, ground water, sea, rivers or the atmosphere if they escaped. There could be a threat to the health of employees and the general public, and a serious risk of explosion or fire. Consideration needs to be given to the level of precautions to be included in the design of the overall system to minimise the risk of such leakages and to confine their spread if leakage does occur.

Requirements for bunding and spacing as well as basic designs to address these issues are covered by a number of codes of practice appropriate to the product stored. The IP Refinery Safety Code and NFPA 30 are widely used to establish the proximity of oil storage tanks to the site perimeter; the spacing between tanks; the number of tanks which can be protected by a single bund; etc.

B.3.2 Fire protection

Whilst basic design considerations and plant layout aim to eliminate the risk of storage tanks catching fire, tank fires do occur and the installation of water cooling systems or other aids for fire fighting need to be considered in the initial design. On floating roof tanks there is a risk of rim fires occurring, e.g. from lightning strikes, and automatic extinguishing systems using vaporizing liquids or special foams can be installed. However, such liquids are usually toxic and care is needed in their use. It is essential that experts in firefighting are involved in evaluating the techniques to be utilized in tackling such fires. Often dry risers and ring mains around tanks are provided. Ready access to the windgirder should be provided, which can be used as a firefighting platform, provided appropriate escape routes are also incorporated. If such fires are to be fought from ground level, then appropriate access to the area around the tank is essential which permits the stand off distances appropriate to the firefighting equipment to be deployed.

The protection of adjacent tanks, process plant or the external environment in the event of a tank fire also needs to be addressed in the initial design as this will have an influence upon spacing and bunding.

B.4 Attachments to tanks for safety or firefighting facilities

The design and manufacture of safety equipment or facilities for firefighting are often undertaken by organisations other than the tank designer or manufacturer and purchased under separate contracts. Where such equipment or facilities require to be attached to or supported by the tank itself then such attachments or supports should be bolted connections. Where direct attachment to the tank structure by welding is necessary then this should only be made onto pre-installed pads or supports welded to the tank structure by the tank erector before the tank hydrostatic test is undertaken. The detailed design, welding and inspection of these pre-installed pads or supports should comply with the appropriate requirements of this document.

Annex C
(normative)

Requirements for floating covers

C.1 General

This annex specifies minimum requirements for the materials, design, construction, testing, and operation of floating covers for use in storage tanks containing volatile products. It also specifies the design of related tank fittings. It is applicable to floating covers fitted to new tanks, and those fitted to existing tanks.

This annex specifies requirements for a number of different types of covers, details of which are given below, which can be divided into two basic designs, floating covers with full contact of membrane surface (full contact designs) and floating covers with gas between the liquid and the membrane (non-contact designs).

Floating covers are also known as floating decks, and should not be confused with external floating roofs (see Annex D).

Floating covers operate inside a fixed roof tank and are protected from the weather.

Floating covers can be installed for any of the following reasons:

a) To reduce evaporative emissions e.g. breathing and filling losses and hence air pollution;

b) To reduce ingress of airborne contaminants e.g. rainwater, sand and other solids into the product;

c) To minimise nuisance from odours;

d) To reduce hazards of static ignition associated with highly charged liquids;

e) To provide thermal insulation in fuel oil storage as an alternative to roof lagging.

NOTE 1 Special design considerations are involved for this application and they are not covered in this annex.

Floating covers are also used in storage tanks containing other types of product such as chemicals, de-mineralized water, drinking water and effluent. Again special requirements apply which are not covered in this annex and prospective users are advised to consult suppliers before undertaking such installations.

NOTE 2 Floating covers are not normally installed in tanks smaller than 6 m diameter because of the difficulty of fitting peripheral (rim) seals satisfactorily in tight tank shell curvatures i.e. tanks having an area/circumference ratio of less than 1.5. There are no upper limits on tank diameter for the installation of a floating cover. This annex therefore specifies requirements for floating cover installations in tanks of 6 m diameter and above.

NOTE 3 If work involving the application of heat is carried out in an existing tank precautions should be taken to ensure that the tank is gas free.

C.2 Types of floating covers

The clearance between the periphery of the cover and the tank wall shall be filled with a flexible seal, mounted on the cover, which provides a good close fit to the tank shell surface.

NOTE Figure C.1 shows a typical floating cover installed in a fixed roof tank.

The floating cover shall be one of the following types:

a) **Type 1** Lightweight all metal (non-contact design)

This type shall consist of a thin metal sheet, normally aluminium alloy, which is fixed on a grid framework of the same material. It shall be supported by tubular buoyancy chambers.

NOTE When the cover floats on the product, it creates a vapour space between the liquid and the underside of the cover.

b) **Type 2** Metal/foam sandwich (full contact design)

This type shall consist of panels of expanded material (e.g. polyurethane) as a core with thin metal, normally aluminium sheet, bonded to the top and bottom. The panels shall slot into a channel lattice.

NOTE 1 The cover floats in contact with the product, there is no vapour space underneath the cover, and additional buoyancy chambers are not required.

NOTE 2 A limited degree of product absorption into the panels can occur depending on the cover design, the materials chosen and the product being stored and could lead to delamination between the foam and cover sheet.

c) **Type 3** Metal/honeycomb sandwich (full contact design)

This type shall be the same as Type 2, except that the panels shall consist of an aluminium honeycomb structure sandwiched between layers of thin aluminium sheet.

d) **Type 4** Interlocking Glass Reinforced Plastic GRP panels (full contact design)

This type shall consist of resin coated glass-fibre reinforced polyester (or similar) panels, encapsulating foam, which shall be interlocked or bolted together to form a continuous covering which floats on the liquid surface.

e) **Type 5** Unsupported metal pan (full contact design)

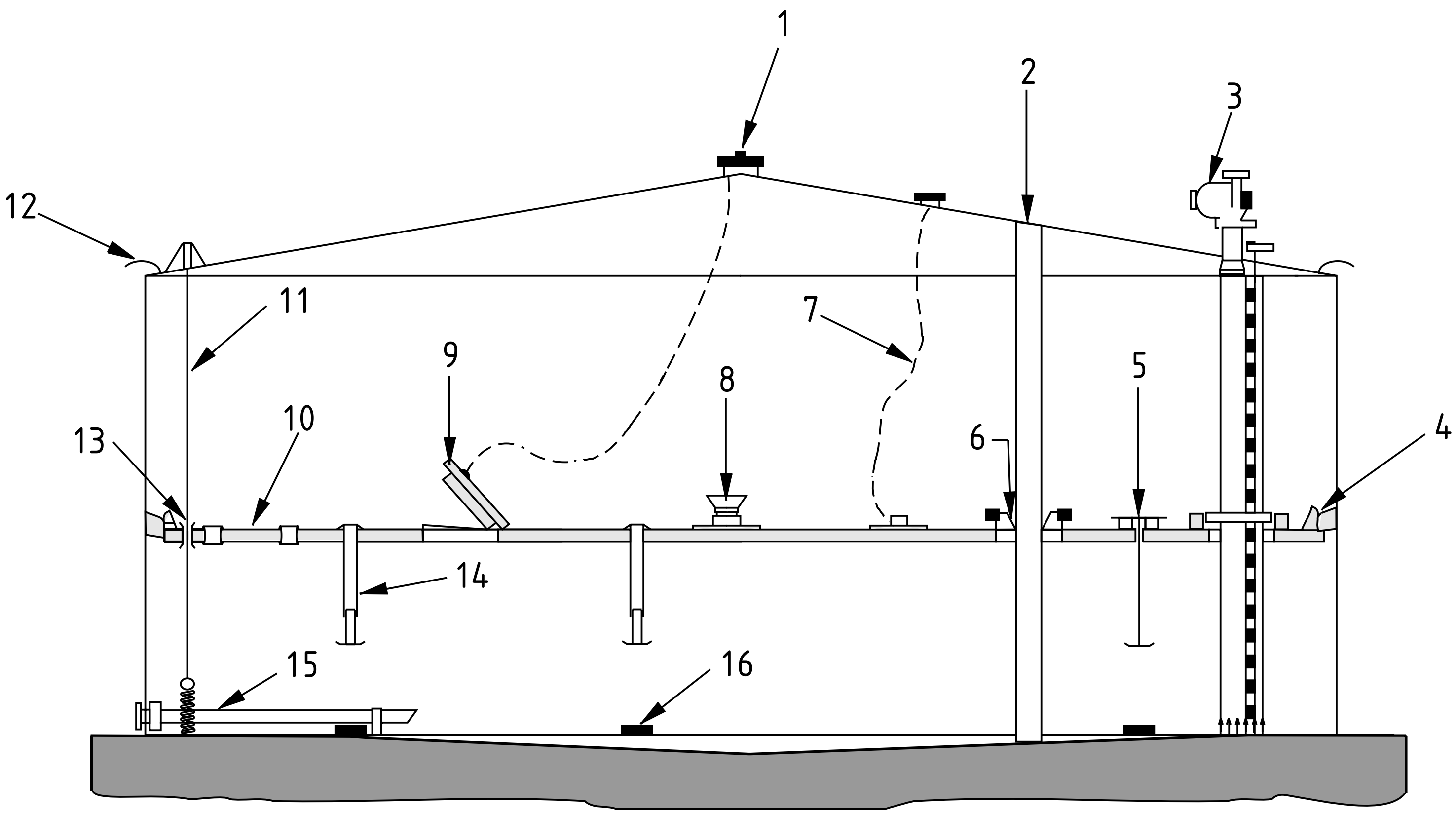
This type shall consist of a shallow central pan with an outer rim plate which shall float on the liquid.

NOTE It may be made from either steel or aluminium and is normally welded.

f) **Type 6** Supported metal pan (full contact design)

This type shall be the same as Type 5 with the addition of an outer ring of pontoons or buoyancy chambers, at the periphery and is normally welded.

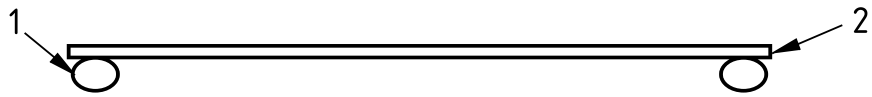
NOTE Examples of various types are given in Figure 18.



Key

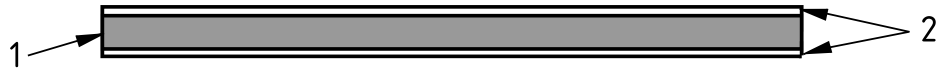
1	Manhole with dip hatch	5	Bleeder vent	9	Manhole	13	Guide tube
2	Roof column	6	Roof column seal	10	Cover	14	Support legs
3	Tank gauge	7	Anti-static cable	11	Anti-rotation cable	15	Inlet pipe/diffuser
4	Peripheral seal	8	Dip funnel	12	Tank vent	16	Bottom reinforcing pads

Figure C.1 — Example of the installation of a typical floating cover in a fixed roof storage tank



1 Buoyancy chamber 2 Thin sheet

a) Type 1 - Lightweight all metal

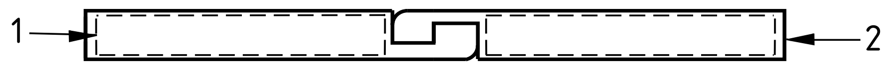


1 Polyurethane 2 Metal

b) Type 2 - Metal/foam sandwich

1 Metal honeycomb 2 Metal

c) Type 3 - Metal/honeycomb sandwich



1 Foam inner 2 GRP outer

d) Type 4 - Interlocking GRP

e) Type 5 - Unsupported metal pan

1 Buoyancy chambers

f) Type 6 - Supported metal pan

Figure C.2 — Examples of different types of floating covers

C.3 Design and construction requirements

C.3.1 Design

C.3.1.1 General

The cover shall be designed so that it is compatible with the storage tank in which it is to be used, the products that may be stored and the frequency of filling and emptying.

The cover shall be designed and constructed to float horizontally, and the design shall ensure that in normal operation, stored product cannot be displaced on the top surface of the cover.

The operating height shall be set to ensure that no part of a floating cover is allowed to come into contact with the tank roof or it's internal structure or to obstruct vents or overflow slots at the upper part of the travel of the floating cover.

The cover shall be designed to support without permanent deformation or damage at least a load of 1 kN/m^2 or 3 kN over an area of 3 m^2 anywhere over its surface, either when floating on water or when resting on its support legs.

The maximum load that the cover can take shall be stated in the design calculation as a safety factor on the load of 3 kN over an area of 3 m^2.

The following details shall be subject to agreement (see A.7):

a) provision for adequate clearance between the cover high position and the roof structure and any overflow slots;

b) tank tolerances relative to anticipated foundation settlement, rim gap, and type of seal;

c) position of shell manways and any internal fittings;

d) installation of floating suction if specified;

e) installation of fixed roof vents;

f) installation of an inlet diffuser.

C.3.1.2 Buoyancy

C.3.1.2.1 Lightweight all metal covers (Type 1)

A minimum of 100 % excess buoyancy shall be provided, i.e. there shall be sufficient buoyancy to support at least 2,0 times the installed weight of the cover. The cover shall be capable of floating in a liquid having a minimum specific gravity of 0,7, even when there is a loss in buoyancy equivalent to 15 % of the total.

A skirt dipping into the product by at least 150 mm shall be provided around the rim of the cover and around all columns, and other openings with the exception of bleeder vents.

Aluminium and its alloys shall not be used where there is a risk of the product stored being alkaline i.e. where the *pH* could exceed 8, unless the surfaces are specifically protected.

Buoyancy tubes shall be leak tested prior to final assembly using either air and soapy water or air under water. They shall be permanently sealed after test, and retested after sealing.

C.3.1.2.2 Metal/foam sandwich, metal/honeycomb, and GRP floating covers (Types 2, 3 & 4)

A minimum of 100 % excess buoyancy as specified in C.3.1.2.1 shall be provided.

Any adhesive used in the construction shall be fully resistant to vapour/liquid penetration. The properties of the adhesive and mechanical soundness of joints shall remain unaffected by contact with the product.

C.3.1.2.3 Unsupported and supported metal pan covers (Types 5 & 6)

A minimum of 100 % excess buoyancy as specified in C.3.1.2.1 shall be provided for Type 6 supported pan covers.

Fabrication and erection of mild steel pan covers shall be in accordance with Clauses 6, 16, 17, 18 and 19.

C.3.1.3 Assembled clearances

The cover shall be designed, constructed and installed so that it can rise to, and descend from its design operating height, without damage to itself, the tank or any fittings.

NOTE The maximum operating level may require to be reduced in tanks with fixed truss roof supports.

The cover shall not impede or strike any tank fittings, mixers, pipework, gauge thermowells or nozzles at any position over its design operating range.

C.3.1.4 Material compatibility

Materials of all components, including adhesives if used, shall be suitable for the product specified.

NOTE 1 Consideration should be given to using materials which provide adequate resistance against the following:

a) iron oxide corrosion - caused by flakes of tank scale or rust falling on to the cover surface;

b) electrolytic corrosion - caused by surface moisture;

c) salt water corrosion - caused by salt water entrained in the product.

NOTE 2 Special consideration should be given to the design and application when attack by micro-organisms is likely to be encountered.

NOTE 3 When using light metals or light metals alloys, special precautions to avoid a thermic reaction (i.e. exothermic reaction between iron oxide and aluminium) should be applied.

NOTE 4 Particular attention should be paid when storing fuels used for transport to ensure that all materials used are compatible with oxygenates.

Any non-metallic components shall be selected and fabricated to prevent excessive absorption by the product liquid or vapour. Data shall be provided by cover suppliers to indicate that if absorption occurs, material quality and construction and cover buoyancy remain unaffected.

All seams and other joints in the floating covers Types 1, 5 and 6 that are required to be liquid or vapour tight shall be tested for leaks using a method and acceptance criteria agreed between the purchaser and cover supplier.

C.3.1.5 Vapour retention

Evidence that the cover and its seal system will conform to any air pollution control requirements specified in the order shall be supplied (see A.8).

C.3.1.6 Electrical resistance

The electrical resistance between the tank shell and any part of the cover shall not be greater than 100 MΩ when measured by an approved method.

C.3.1.7 Fire protection

The type of fire protection to be adopted shall be selected on the basis of the type of cover installed in a tank and its contents.

C.3.2 Materials of construction

C.3.2.1 General

The liquid to be contained shall be specified, indicating any special properties which may affect materials (see A.1). All cover materials shall be compatible with the product to be stored. Where dissimilar materials are used for the cover, the possibility of corrosion due to cathodic-reaction shall be considered.

A complete material specification for the cover, for approval by the user, shall be supplied (see A.8).

C.3.2.2 Metal sheet for cover

C.3.2.2.1 Steel

Steel shall conform to the requirements of EN 10025.

C.3.2.2.2 Aluminium

Aluminium shall conform to the requirements of EN 485, EN 754 or EN 755.

C.3.2.2.3 Stainless steel

Stainless steel shall conform to the requirements of EN 10088.

C.3.2.3 Peripheral (rim) seals

One of the following three types of seal, or a seal from Annex E, shall be used, unless otherwise agreed (see A.6).

a) Wiper seal (see Figure C.3 a))

This shall be made from plastic sheet e.g. polyurethane, which is riveted or bolted to the cover. The seal shall reverse direction as the cover rises and falls.

NOTE 1 Where improved efficiency is required, either a wiper seal on top of another type of seal, or double wiper seals may be used.

The position of the wiper seal and its attachment to the cover shall be such that the seal is always above the liquid surface at all times of cover operation.

b) **Tubular seal (see Figure C.3 b))**

This shall be made from polyurethane or nylon sheet which is formed into a circular shape and bolted to the cover.

NOTE 2 It is not usually filled internally.

c) **Buffer seal (see Figure C.3 c))**

This shall consist of flexible foam contained in a liquid tight sheath e.g. polyurethane foam covered with urethane-coated nylon. The shape shall be circular, square or pentagonal.

NOTE 3 This seal design provides a large area of contact which can be beneficial where tanks are badly deformed.

NOTE 4 For special applications, other seal materials may be used e.g. PTFE or carbon impregnated plastics.

The seal shall be constructed of material that resists absorption and is compatible with the product to be stored.

The seal material (or outer sheathing) shall have demonstrable abrasion resistance and durability under all operating conditions

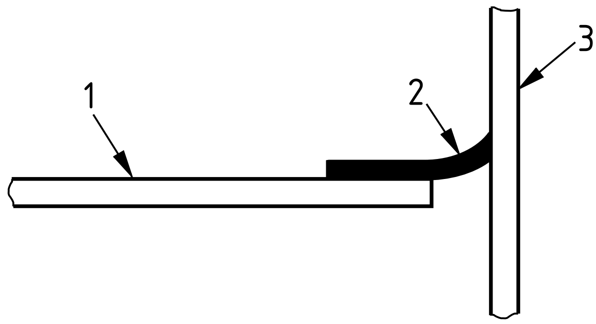
The peripheral seal shall be designed to cater for any tank out-of-roundness which may exist and to provide efficient sealing.

At installation, the width of the gap between the cover and the tank shall be checked to ensure that during operation positive contact is always made between the seal and the tank shell irrespective of irregularities (see C.4).

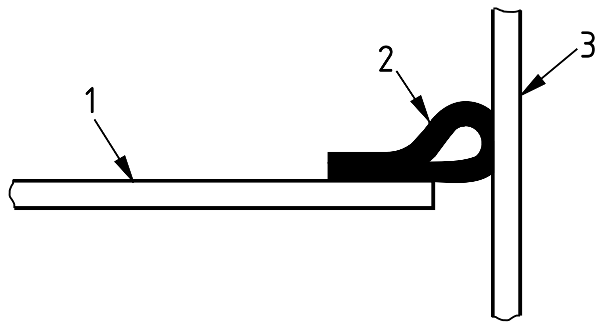
The seal mounting shall be firm to ensure good seal contact with the tank shell and to prevent vapour leakage at the seal mounting. Positive wiping action by the seal shall be provided at all points on the tank inner shell for the complete vertical movement of the cover. The position of the seal mounting shall be kept as low as possible above the cover surface in order to maximise usable storage capacity of the tank.

Circumferential joints on tubular and buffer seals shall be liquid tight. When the joints are made at the time of installation, there shall be an overlap of at least 75 mm.

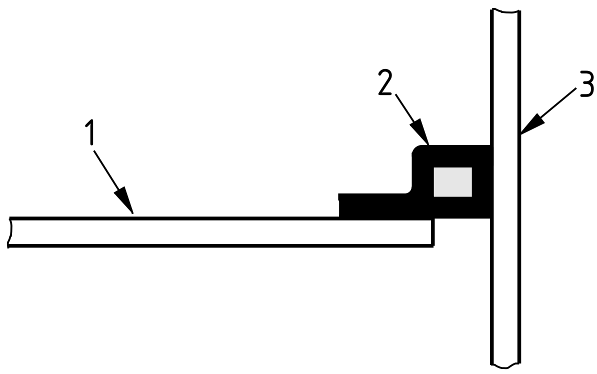
The seal design and initial assembly shall provide free movement of the cover over its complete design range.



a) Wiper seal



b) Tubular seal



c) Buffer seal

Key

1	Floating cover	2	Seal	3	Tank shell

Figure C.3 — Examples of peripheral (rim) seal configurations

C.3.2.4 Joints

Single welded butt joints without backing shall be permitted for buoyancy and flotation units where one side is inaccessible.

Fillet welds on material less than 5 mm thick shall have a thickness at least equivalent to the thinnest member of the joint.

Bolted, threaded and riveted joints may be used provided their use has been agreed by the user.

Joints between non-metallic (plastic/GRP) members, including adhesive joints, shall be compatible with the materials joined, have an acceptable service life, and be of a size and strength that will support the cover design loads without failure or leakage. The joining procedure, along with test results demonstrating the above features shall be fully documented and available to the user.

All seams exposed directly to product vapour or liquid shall be welded, bolted, screwed, riveted, clamped, or sealed, and checked for vapour and liquid tightness by means of an approved method acceptable to the user. Any joint sealing compound shall be compatible with the product stored and the materials joined.

C.3.2.5 Corrosion allowance

Where necessary, an allowance for corrosion shall be included in the thickness of the materials used for construction of the cover.

C.3.3 Cover fittings

C.3.3.1 Manholes

For covers up to and including 15 m diameter, at least one manhole shall be provided for access and ventilation purposes when the cover is sitting on its support legs and the tank is empty. The manhole shall be designed to be opened from the underside of the cover. For covers above 15 m diameter, additional manholes spaced to give good ventilation, shall be provided if specified by the purchaser.

Circular manholes shall permit free access by maintenance personnel and shall have a minimum diameter of 600 mm.

NOTE Rectangular manholes may be fitted, with minimum dimensions of 600 mm × 400 mm.

C.3.3.2 Support legs

The cover shall be fitted with support legs which support it after product has been withdrawn from the tank (see Figure C.4.a)).

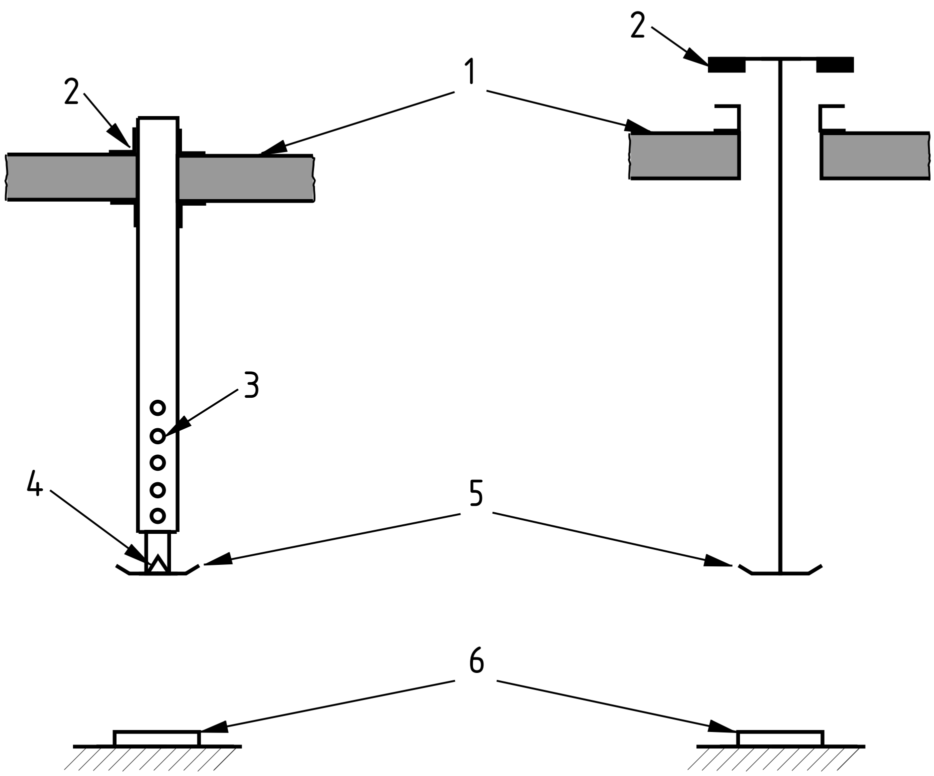
The height of the cover when resting on its legs shall be as specified by the user. There shall be no obstruction of the tank shell manholes by the cover. Provision shall be made to permit inspection and working under the cover. Adequate clearance shall also be made so that fittings such as side entry mixers, internal piping and inlet and outlet nozzles are clear of the cover when it is standing on its legs on the tank base.

During cover installation, the support legs shall be adjusted to accommodate any unevenness in the tank floor so that the cover is installed horizontally. The height of the cover shall be fixed, although a facility for altering the height of the legs at a later date may be incorporated.

In order to distribute the induced loads of the support legs over the tank bottom, measures such as the fitting of steel pads, shall be introduced. These pads shall be continuously welded to the bottom plates. When pads overlap bottom plate fillet welds in a lap joint, completely welded shim plates shall be installed in order to compensate for the difference in bottom level.

When support legs are hollow, they shall include a hole at their base for drainage purposes.

Support legs fixed to the cover are preferred to those fitted to the tank bottom. The supports, attachments and tank bottom shall be designed to withstand the weight of the cover (see 8.3.4) plus a uniformly distributed load of 1 kN/m^2. Particular attention shall be given to providing strong leg support attachment to the cover in order to prevent failures occurring at this point when in operation.



a) Support leg (fixed)

b) Bleeder vent (open position)

Key

1	Floating cover	4	Drain hole
2	Seal	5	Protective foot
3	Adjustment holes	6	Reinforcing pad

Figure C.4 — Typical design of support leg and bleeder vent

C.3.3.3 Bleeder vents

Venting shall be provided in the cover. The purpose is to release air from under the cover during initial tank filling and to allow air and vapour to pass through the cover when draining product whilst the cover is stationary and resting on its support legs. For this second situation it is most important to ensure that the vent shall be fully open when the cover settles on its legs.

NOTE An effective method of doing this is to mechanically open the vent by means of its own leg arrangement. (see Figure C.4.b)). Alternatively they could be a simple trap door design.

The maximum filling and emptying rates shall be specified (see A.1) so that venting of the correct capacity can be provided. Calculations shall confirm that the vent area for both cases is adequate for the intended duty and that venting overstressing cannot occur to either the cover or its seal.

C.3.3.4 Drains

Although the cover shall be designed to prevent product from being forced past the peripheral (rim) seal and cover (see C.3.1), liquid can accumulate on the upper surface of the cover due to condensation, spillage or other reasons. Sufficient drains or drainage paths shall be incorporated to enable this liquid to be quickly dispersed into the product below the cover. The design of these drains shall have a minimum effect on the vapour sealing efficiency of the cover.

Pan design types 5 and 6 cannot be drained in this manner. Alternative permanently installed means shall be considered in the design stage, or an operational procedure developed to remove accumulated liquids. Care shall be taken to ensure that a breach of any permanent drainage system does not compromise the flotation of these types of covers.

C.3.3.5 Dissipation of static electricity

All covers shall be electrically conductive and meet the requirements of C.3.1.6. In addition multi-strand anti-static cables shall be installed between the cover and the tank shell to provide an electrical bond (see Figure C.1).

A minimum of two anti-static cables shall be provided for tanks having a diameter less than or equal to 20 m and a minimum of four cables shall be provided for larger diameter tanks.

NOTE The anti-static cable should have a minimum cross-section of 3 mm^2.

The cables shall be attached to the upper surface of the cover and the storage tank roof and shall be fastened in such a way that they do not obstruct other equipment.

There shall be no obstruction above the cover surface which could interfere with these anti-static cables during up and down movement of the cover. Alternatively, spring loaded cable reels shall be used to keep the cables taut at all times.

C.3.3.6 Anti-rotation and centralization

The floating cover shall be prevented from rotating.

NOTE 1 A guide pole or a vertical, non-centred, anti-rotation cable, which passes through the cover and is fitted between the tank roof and the floor may be used for this purpose.

NOTE 2 The cable should be spring loaded to maintain tension. A guide tube through the cover of compatible design and material should be provided.

NOTE 3 In large diameter tanks without supporting roof columns it may be necessary to install several anti-rotation cables in order to provide the desired cover stability.

NOTE 4 Alternatively, non-central roof columns may be used for this purpose.

C.3.3.7 Tank gauging and sampling

Unless otherwise specified, the design shall ensure that tank gauges are unimpeded and remain fully operational over the complete travel of the cover. Alternatively, the cover shall be used to accommodate an in-built gauging system designed to conform to with the requirements of the purchaser.

The cover shall be provided with sampling points which are in line with dip hatches on the tank roof, thus enabling normal tank dipping and sampling to take plate without obstruction (see Figure C.1).

NOTE Sampling points may be covered with a suitable device e.g. split seal which reduces vapour loss but still permits dipping and sampling to take place.

C.3.3.8 Cover penetrations

Where columns or other fittings pass through the cover, seals shall be fitted to ensure minimum vapour leakage during all horizontal and vertical movements of the cover. They shall be a close fit and designed to accommodate a local horizontal deviation of ± 125 mm. Seals shall not be fitted on internal roof drains or bleeder vents.

Penetrations for sampling and gauging shall be belled (tapered) to provide a guide for the sampling tube or gauge.

With the exception of bleeder vents, penetrations through lightweight all metal non-contact type covers (Type 1) shall be fitted with a skirt which is immersed in the product to at least a depth of 150 mm.

C.3.3.9 Level alarms

Unless otherwise specified, a high level alarm shall be fitted to warn the operator automatically if the liquid rises above a predetermined level.

C.3.3.10 Floating suction devices

In some tanks, especially where product cleanliness is important e.g. aviation fuel, de-mineralized water etc, floating suction devices are a standard fitting. Covers can be installed in such tanks but shall be modified to accommodate the floating suction devices.

NOTE This can require the addition of a guide channel to the underside of the cover. The fitting of such a channel can alter the buoyancy of the cover and could affect its stability.

The supplier shall ensure that when a floating suction device is fitted, the buoyancy of the cover is not reduced below the levels specified in C.3.1 and that the stability of the cover is not impaired.

The floating suction devices shall be compensated for excess buoyancy during hydrostatic testing of the system.

It shall be demonstrated that a cover equipped with floating suction channels can be raised and lowered over its full operating range within the tank in combination with the floating suction device without mechanical problems occurring.

C.3.4 Tank fittings

C.3.4.1 Roof vents

C.3.4.1.1 General

When a floating cover is fitted in a tank containing certain products, e.g. gasoline, vapour could build up above the cover to such an extent that a potentially flammable atmosphere shall be present. To avoid this, roof vents designed in accordance with C.3.4.1.2 or C.3.4.1.3 shall be installed.

Free vents shall not be used:

a) where the vapour space is purged or inert gas blanketed;

b) where there is a likelihood of excessive winds which would cause significant vapour losses with conventional open vents;

c) where open vents are prohibited by local regulations

The operating height of the floating cover shall not result in the seal obstructing the vents.

NOTE Unless otherwise specified (see A.1) all vents should be provided with mesh in accordance with 10.6.3 Notes 1 and 2.

C.3.4.1.2 Free vents

These permit free ventilation of the vapour space and a typical design is shown in Figure C.5.

Open vents, one at the centre of the tank, and others at the periphery of the tank roof, shall be fitted. The Centre roof vent shall be provided as near as possible to the highest point of the tank roof. It shall have a minimum open area of 0.03 m^2.

The peripheral roof vents shall be of the scoop type (see Figure C.5) and shall be positioned as close to the edge of the tank as practicable. There shall be at least one vent for every 10 m of tank circumference, but in no case shall there be less than four equally spaced vents. The effective total open area of these vents shall not be less than 0.06 m^2 per meter of tank diameter.

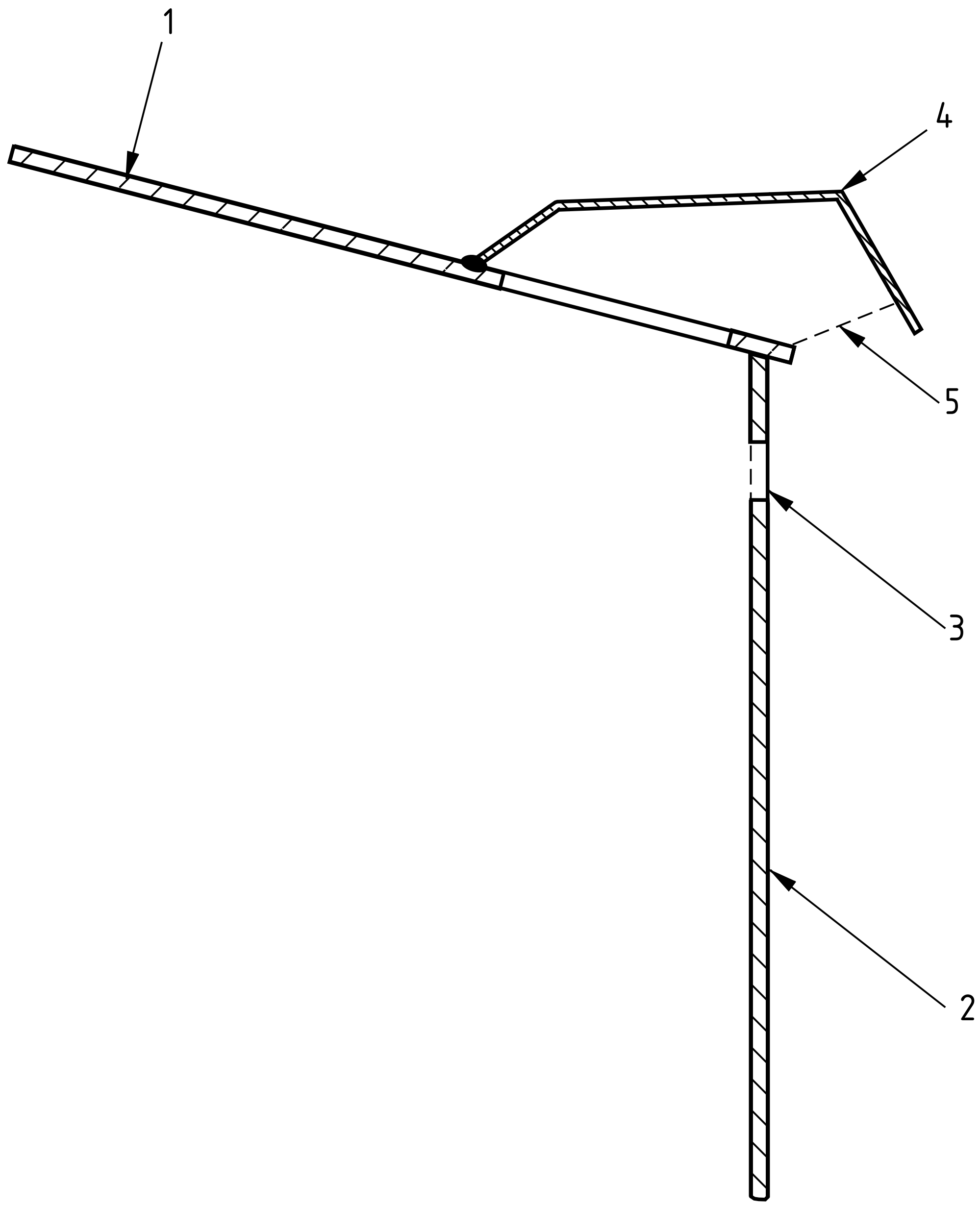
NOTE These are minimum dimensions and depending on the product volatility, a larger area than this may be specified by the purchaser.

C.3.4.1.3 Control vents

Pressure/vacuum vents shall be fitted to tanks which are not free vented.

Suitable pressure and/or vacuum relief valves shall be installed for tanks which have inert gas blanketing or where product vapours are not permitted to be emitted to atmosphere.

Pressure/vacuum vents shall be in accordance with Annex L.



Key

1	Tank roof	4	Peripheral roof vent
2	Tank shell	5	Protective mesh
3	Emergency overflow slot with mesh		

Figure C.5 — Typical design of roof vent

C.3.4.2 Overflow slots

When emergency overflow slots are provided in a tank, the peripheral (rim) seal shall not obstruct the slots when at normal maximum cover operating height.

C.3.4.3 Inlet diffuser

When specified, (see A.1) an inlet diffuser shall be positioned to move the inlet point close to the tank centre and away from the peripheral (rim) seal (see Figure C.1).

C.3.4.4 Manholes and inspection access

At least one roof manhole (see 13.3.1) shall be provided in the fixed roof for access to the tank interior.

C.4 Installation

C.4.1 Tank examination

Before the floating cover is installed, the cover manufacturer and tank erector shall make an internal and external examination of the tank. As a minimum, the examinations listed below shall be made:

a) the verticality of the tank shell;

b) the out-of-roundness of the shell using an appropriate and proven method (as much of the tank as is accessible to be checked);

c) the size and location of the tank shell manhole;

d) if a floating suction device is installed;

e) elevation of the lowest part of the roof structure, including clearance of overflow slots where provided, in order to determine the permissible height of travel for the cover;

f) the minimum clearances between the cover and any internal fittings over the complete range of operation of the cover;

g) size, position and verticality of any roof support columns;

h) access available for insertion of cover components;

i) any areas of unacceptable roughness in the tank shell welds or plate surface;

j) details of internal fitments such as mixers or heating/cooling coils (see Annex P).

C.4.2 Examination and installation of the cover

An examination of the delivered cover components shall be made at the installation site by the cover supplier to ensure there has been neither damage during transport nor deterioration during storage. Any damaged items shall be rectified by the cover supplier prior to erection to the satisfaction of the purchaser.

The method of erection for the cover shall be submitted by the cover supplier or contractor for the approval of the purchaser, if such approval has not already been given in writing.

The cover supplier shall be responsible for ensuring that all cover components can enter the tank without creating assembly problems.

The cover shall be installed horizontally. Every care shall be taken to minimize distortion or lack of circularity due to welding or other reasons. The clearance between the periphery of the cover and the tank shell shall be uniform and conform to the dimensional requirements specified for the peripheral (rim) seal (see C.3.2.3).

NOTE The sheeting of lightweight all metal covers should be laid without excessive rippling.

Access for in-service inspection/maintenance shall be by way of the tank shell manholes and cover access manholes.

C.4.3 Tests

C.4.3.1 Inspection of tank bottom after installation of the floating cover

A visual examination of the tank bottom shall be performed after installation of the floating cover.

C.4.3.2 Flotation test

A flotation test over the full travel of the cover shall be carried out after installation.

NOTE This may be done in combination with the hydrostatic test (see 19.13).

The tank shall be filled to check that the cover and seals travel freely without sticking, hold ups or obstruction over the design range of the cover and that the cover is visibly free from leaks. All leaks detected during such testing shall be rectified to the satisfaction of the purchaser.

Consideration shall be taken of the possible corrosion effects between the cover material, the flotation test liquid and the tank shell.

C.4.3.3 Electrical resistance test

A measurement of the electrical resistance between the tank and the cover shall be made in accordance with C.3.1.6. The equipment used for testing shall be subject to agreement (see A.6).

C.5 Documentation

Written operating instructions and limitations of use shall be supplied by the floating cover supplier (see A.8).

Annex D
(normative)

Requirements for floating roofs

D.1 General

A floating roof is a structure designed to float on the surface of the liquid in an open top tank and shall be in complete contact with this surface.

D.2 Roof types

This following three types of floating roofs shall be considered:

a) **single deck floating roof** shall comprise of a single deck diaphragm in contact with the liquid and a continuous annular pontoon separated by bulkheads into liquid tight compartments;

b) **double deck floating roof** shall comprise of an upper and lower deck. The whole of the lower deck shall be in contact with the liquid surface and is separated from the upper deck by rim plates and bulkheads forming liquid tight pontoon compartments;

c) **single deck floating roof with central deck buoyancy compartments** shall comprise of a single deck diaphragm, in contact with the liquid, on which additional buoyancy compartments are placed locally, and a continuous annular pontoon separated by bulkheads into liquid tight pontoon compartments.

NOTE Typical examples are shown in Figure D.1.

Requirements for any other types shall be subject to agreement (see A.2).

D.3 Design

D.3.1 General

The design of the floating roof shall take the following points into account:

— climatic conditions: temperature, rainfall, snowfall, wind etc.;

— tank dimensions;

— tank tolerances relative to the envisaged foundation settlement, rim gap, and type of seal;

— nature and characteristics of the liquid to be stored (density, temperature, etc.);

— material of construction;

— filling and emptying velocities and maximum flow rates;

— lowest level to which the roof can descend;

— presence of mixers;

— presence of heaters;

— use of gauging and sampling devices and of alarms;

— type of mobile ladder;

— antistatic cables.

Unless otherwise specified (see A.1), the roof shall be designed to remain floating in normal operation. It shall only rest on its support legs during maintenance and inspection operations.

Unless otherwise agreed (see A.2), the roof and accessories shall be designed and constructed so as to allow the liquid contained in the tank to overflow without the roof structure sustaining any damage, and subsequently to return to a normal level of operation. This agreed requirement shall be applicable both under operating and hydrostatic test conditions.

When a windskirt or tank shell top extension aimed at maintaining the roof seals at the highest point of travel is used, overflow and drainage openings shall be provided in the upper part of the tank shell above the level corresponding to the nominal capacity of the tank.

The specified thickness of all floating roof plating shall be not less than 5 mm.

D.3.2 Buoyancy

D.3.2.1 Single deck floating roof

The minimum pontoon volume shall be sufficient to keep the roof floating on a liquid having a specific gravity of 0,7, if:

a) any two adjacent compartments of the pontoon and the central diaphragm are punctured and the main roof drain is considered to be inoperative; or

b) it carries a load of 250 mm of rain water, calculated on the total roof area, which is concentrated on the central diaphragm, all the pontoon compartments and the central diaphragm are intact and the main roof drain is considered to be inoperative.

D.3.2.2 Double deck floating roof

The minimum pontoon volume shall be sufficient to keep the roof floating on a liquid having a specific gravity of 0,7, if:

a) any two adjacent compartments are punctured and the main drain is considered to be inoperative;

b) it carries a load of 250 mm of rain water present on the total roof area and the main roof drain is considered to be inoperative.

c) As an alternative, it shall be permissible to design the roof to support a lower load than required by b), provided that emergency drains are installed (see D.3.9) in order to evacuate the excess rain water directly into the product.

a) Single deck

b) Double deck

c) Single deck with central deck buoyancy compartments

Figure D.1 — Typical examples of floating roofs

D.3.2.3 Single deck floating roof with central deck buoyancy compartments

The minimum combined pontoon volume (i.e. sum of the volumes of the annular pontoon and of the additional buoyancy compartments) shall be sufficient to keep the roof floating on a liquid having a specific gravity of 0,7, if:

a) the diaphragm is punctured and

— either any two adjacent buoyancy compartments are punctured;

— two adjacent compartments of the annular pontoon are punctured;

— one single compartment of the annular pontoon and one single adjacent buoyancy compartment are punctured,

and the main roof drain is considered to be inoperative.

b) it carries a load of 250 mm of rain water calculated on the total roof area and concentrated on the central diaphragm, all the annular pontoon compartments and the central buoyancy compartments are intact and the main roof drain is considered to be inoperative.

D.3.2.4 Alternative loading condition

If the roof is to be designed for a fixed specific gravity, a particular product, or a specified amount of rainfall deviating from the requirements of D.3.2.1 to D.3.2.3, this shall be subject to agreement (see A.2).

D.3.3 Structural design

The roof shall be designed to be structurally sound under the following loading conditions:

a) all buoyancy conditions specified in D.3.2;

b) when the roof is resting on its support legs and with a live load equal to 1,2 kN/m^2 or another value subject to agreement (see A.2).

The live load shall not include the load due to rain water, but it may be increased to include foreseeable higher loads.

D.3.4 Roof stability under wind load

When tanks are to be erected in a region where wind conditions can give rise to fatigue in the roof centre deck welds, the roof design and type to be used shall be as specified by the purchaser (see A.1) for tanks 50 m diameter and above. In other cases, no account shall be taken of wind generated fatigue loads.

D.3.5 Pontoon manholes

All pontoons and compartments shall be equipped with a manhole fitted with a water-tight cover. The manhole covers shall be designed to return to their closed position if they are raised by a gust of wind and not to be torn off under the design wind conditions.

The top edge of manhole necks shall be at a height such that water cannot enter the compartments under the conditions specified in D.3.2.

D.3.6 Roof manhole

At least one roof manhole shall be provided for gaining access to the tank interior and for ventilation when the tank is empty. Any additional roof manholes shall be as specified (see A.1). Roof manholes shall have an inside diameter of at least 600 mm and shall be fitted with a tight seal and bolted cover.

D.3.7 Centering and anti-rotation devices

Centering and anti-rotation devices shall be installed in order to maintain the roof central in the tank and to prevent its rotation.

These devices shall be designed to withstand the lateral forces imposed on them by the roof ladder, unequal snow loads, wind loads, etc.

D.3.8 Main roof drains

D.3.8.1 General

Unless otherwise specified (see A.1), the main roof drains shall be of the hose or articulated pipe type. They shall be capable of operating under all roof working conditions. Siphon drains for single deck roofs shall not be permitted.

The discharge rate of the main roof drains shall be calculated as a function of the specified maximum rainfall and with the roof floating at its lowest level.

The minimum diameter of the main drain for all types of roof shall be equivalent to the following:

— 75 mm diameter for roof diameters less than 30 m;

— 100 mm diameter for roof diameters between 30 m and 60 m inclusive;

— 150 mm for roof diameters greater than 60 m.

Hose or articulated pipe drains on single deck roofs shall have a non-return valve fitted close to the roof end of the drain in order to prevent any backflow of the product on to the roof, in the event of leakage of the hose or articulated pipe.

The installation of either type of drain shall include the fitting of the necessary shell accessories required for their operation and, if need be, their replacement.

Where specified, double deck roofs shall be equipped with open type roof drains (see A.1).

D.3.8.2 Hose drains

Precautions shall be taken in order to avoid kinking or pinching of the flexible hose under the roof support legs.

NOTE It is recommended that hose drains should be designed so as to allow their replacement without it being necessary to enter the tank.

D.3.8.3 Articulated pipe drains

The swivel joints of the articulated pipe drains shall be designed so as to prevent any leakage of water into the product, or of the product into the water.

D.3.9 Emergency drains

Because the level of product in the tank is always higher than the level of rain water on the centre deck, emergency drains shall not be installed on a single deck floating roof.

Emergency drains shall be installed at the lowest point of the top deck of a double deck roof in order to discharge rain water directly into the product (see D.3.2.2). This type of emergency drain shall be designed to prevent the product from flowing onto the roof.

D.3.10 Drain plugs

In order to allow any accumulation of rain water to drain into the tank when the roof is resting on its support legs, a drain plug shall be located in the vicinity of the centre of the roof. This device shall be capable of draining the specified rainfall (see D.3.1).

Before the roof goes into operation, this drain plug shall be closed and measures taken to prevent its inadvertent opening.

D.3.11 Vents

The maximum liquid filling and withdrawal rates shall be specified as well as any special venting requirements (see A.1).

Where overloading of the roof deck or of the floating roof sealing joint is envisaged, provision shall be made for the fitting of vents on the floating roof membrane and, if necessary, in the rim seal.

These vents or bleed valves shall allow the evacuation of the air and gases trapped beneath the roof and the rim gap during initial filling, and allow the entrance of air during withdrawal of the product when the roof is resting on its support legs and, should the occasion arise, the evacuation of any vapours present in the rim space during operation.

The vent opening mechanism shall be adjustable so as to align with the different vertical settings of the roof support legs.

D.3.12 Seals

Seals for floating roofs shall conform to Annex E.

D.3.13 Support legs

Floating roofs shall be equipped with support legs.

The support legs and their attachments shall be designed in order to support the roof and any additional load such as indicated in D.3.3 b).

NOTE These loads do not take into account any action of the products contained in the tank, nor the possible effects of frequent landing of the roof (see D.3.1).

The design of the support legs shall not allow the product to flow onto the roof when the latter is loaded with the maximum volume of rain water, nor permit vapour emission (if applicable) when the central diaphragm of a single deck roof is lifted off the liquid surface by vapour pressure.

Where bulkheads or reinforcing plates are provided, the roof loads shall be transmitted to the support legs via these bulkheads or reinforcing plates.

In order to distribute the induced loads of the support legs over the tank bottom, measures such as the fitting of steel pads, shall be introduced. These pads shall be continuously welded to the bottom plates. When pads overlap bottom plate fillet welds in a lap joint, completely welded shim plates shall be installed in order to compensate for the difference in bottom level.

When support legs are hollow, they shall include a hole at their base for drainage purposes.

Where different static roof levels are required, the legs shall be vertically adjustable from the top of the roof.

The support leg operating and cleaning position levels shall be as specified (see A.1).

The manufacturer shall ensure that no accessory (e.g. mixers, interior piping, filling nozzles) interferes with the roof in the low position.

D.3.14 Gauging device

Each roof shall be equipped with a tight closing gauge hatch or gauge well with a tight cap conforming either to the purchaser's specifications (see A.1) or to the manufacturer's own standard.

D.3.15 Rolling ladder

Unless otherwise specified (see A.1), the roof shall be equipped with a rolling ladder having self-levelling steps which automatically adjust to any roof position, or rungs, and is equipped with guard rails on both sides, so that access to the roof is always possible.

The minimum loading strength of the steps or rungs shall conform to EN ISO 14122.

The ladder shall be designed for full roof travel. It therefore cannot be used for tanks of which the height/diameter ratio is greater than or equal to 1,0.

The ladder shall be designed for both a vertical mid-point load of 5 kN (500 kg) minimum with the ladder in any operating position, combined with the maximum wind load acting on the ladder from any direction. Attention shall be paid to the torsional rigidity of long ladders and vibrational wind effects which are likely to cause them to become derailed.

The track on which the ladder travels shall be positioned at a sufficient height above the deck, to avoid derailment of the ladder by snow or ice.

NOTE For long, heavy ladders, particular attention should be paid to the load bearing width of the rails and the resistance of the wheels.

D.3.16 Earthing cables

The floating roof shall be systematically equipped with earthing cables. At least two cables shall be provided for tanks having a diameter less than or equal to 20 m and a minimum of four cables shall be provided for larger diameter tanks.

NOTE The earthing cable should have a minimum cross section of 50 mm^2.

D.3.17 Foam dam

A circular foam dam of vertical stiffened plates shall be constructed on the ring pontoons at about 1,0 m distance from the tank shell to aid the containment and distribution of foam into the seal space. It shall be designed and constructed so that the top of the foam dam is nominally 200 mm higher than the top of the seal. Openings at the bottom of the foam dam shall be provided to permit the drainage of water to the main roof drains.

NOTE In the area of the foam pourer, the vertical height of the foam dam may be increased to prevent

D.4 Prefabrication in the workshop

The tolerances of all pre-fabricated floating roof components shall be such as to ensure a precise and tight final assembly. A trial erection and workshop inspection should be carried out if specified (see A.1).

D.5 Marking, packing, handling, transport

D.5.1 General

The requirements of 15.11 and 15.12 shall be applied.

D.5.2 Repair after damage during handling operations

The requirements of Clause 16.5 shall be applied.

D.6 Assembly

Assembly shall be carried out in accordance with 16.1.

NOTE On account of its fragility and instability, particular care should be taken during assembly, erection and welding of the floating roof, which can be carried out either on the tank bottom or on temporary supports.

The final roof dimensions shall be adjusted to suit the tank shell manufacturing tolerances (see 16.7) and seal tolerances as specified by the seal manufacturer (see Annex E).

D.7 Welding

D.7.1 General

Welding shall be carried out by approved welders in accordance with the procedures drawn up by the floating roof manufacturer.

The erector shall ensure that, by appropriate methods of assembly and welding sequences, distortion and shrinkage of the floating roof are kept to a minimum.

Roof plates shall be overlapped with a minimum lap of 25 mm, and welding shall be carried out with the weld seam on the top side only, except where the roof is to be internally coated, when both sides shall be welded.

D.7.2 Support legs

Lap joints in the central diaphragm of single deck roofs within an area of 200 mm radius of a roof support leg shall be welded on both sides.

D.7.3 Bulkheads

All internal bulkhead plates shall be at least single fillet welded along their bottom and vertical edges for liquid tightness, and the top edge of alternate bulkheads shall also be provided with a continuous single fillet weld for liquid tightness.

Bulkhead plate corners trimmed for clearance of longitudinal fillet welds shall be filled by welding to obtain liquid tightness.

D.8 Inspection and testing

D.8.1 Welds

All welds on the floating roof, openings and pontoons shall be inspected using either penetrant testing (see 19.6) or a soap bubble examination (see 19.8). All defects shall be repaired and the weld shall be re-inspected.

D.8.2 Pontoons

The pontoon compartments and the buoyancy compartments shall be pressure checked where their design allows. A minimum overpressure of 7 mbar (0,0007 MPa) gauge shall be maintained in each of the compartments during the test. Soapy water of the same type as that used for the vacuum box test (see 19.5) shall be applied on all welds.

Where the design does not permit an air pressure test, all welds shall be inspected using a penetrant test (see 19.6).

D.8.3 Checks

The following checks shall be carried out by the roof manufacturer:

a) correct positioning and completion of welding of the steel bottom reinforcing plates;

b) that the height and location of the legs, in the low position, are compatible with the accessories installed on the bottom and shell;

c) that the clearance between the roof edge and tank shell is compatible with D.3.1, D.3.12 and D.6. These checks shall be carried out during filling of the tank with water and shall be at the lowest level, mid-height, and maximum liquid level. A minimum of eight points on the circumference, with a maximum distance of 10 m between adjacent points, shall be checked;

d) that the position of the flexible or rigid connection of the roof drain does not interfere with the other accessories or roof legs;

e) that holes for the outflow of water have been provided when a foam containment device has been installed;

f) setting of the leg height, the leak tightness of pontoons and deck, tightness and freedom of movement of the floating roof, when the roof is floating on water;

g) installation and clamping of the earthing devices.

D.8.4 Drains

The floating roof manufacturer shall conduct a hydrostatic test of the drain after installation, in order to make certain of its tightness. This shall be checked by the inspector. The test pressure shall be specified by the drain manufacturer.

D.9 Documentation

Written operating instructions and limitations of use shall be supplied by the floating roof manufacturer.

Annex E
(normative)

Requirements for rim seals for floating roofs

E.1 General

Tanks equipped with a floating roof shall be fitted with rim seals to minimise the loss of vapours. Where specified (see A.1), rim seals from Annex E may be used for floating covers (see C.3.2.3).

NOTE 1 Attention is drawn to the European Council Directive No 94/63/EC of 20 December 1994.

E.2 Design

The clearance between the floating roof and tank wall shall allow the floating roof to slide up and down the tank wall. The seal design shall prevent the vapours of the product contained therein from escaping. The rim seal shall also prevent the penetration of rain water into the tank.

The seals shall take account of the nature, characteristics and the temperature of the liquid to be stored.

Seals shall be designed to:

— withstand friction against the tank shell;

— be resistant to the products contained in the tank;

— tolerate the construction tolerances in the tank shell and the floating roof;

— tolerate within limits, the lateral movements of the floating roof;

— tolerate deformations caused by changes in the climatic conditions.

In order to achieve the best possible sealing, a lower element of the seal shall project into the stored liquid, close to the tank shell.

NOTE Metallic seal elements completely covering the rim space between floating roof and tank shell should be equipped with foam ports to allow the entry of fire-fighting foam under fire conditions.

All metallic parts of the seals shall be earthed, and all non-metallic parts shall be of anti-static quality. Low sparking and low corrosion metals shall be preferred.

Magnesium alloys, copper and copper alloys shall not be used.

E.3 Seal types

The most common seal types shall be classified as follows:

a) Independent primary seals:

— mechanical shoe seals;

— spring forced lip seals;

— liquid-filled resilient seals;

— foam-filled resilient seals.

b) Independent secondary seals:

— spring forced pad, lip seals with rubber lip, foam filled resilient pad, or water absorbent felt pad;

— compression plate seals with rubber lip or foam filled resilient pad.

c) Wiper seals with rubber or foam wipers.

d) Integrated primary/secondary seals

— working elements of independent primary and secondary seals are integrated into one construction with one or two sealing curtains connected to the floating roof.

E.4 Weather shields

Overlapping weather shields shall be installed to cover and protect the non-metallic parts of floating roof seals against sunlight, weathering, and falling objects, and to deflect rain water onto the floating roof unless otherwise specified (see A.1).

E.5 Application and technical details of rim seals

E.5.1 Mechanical shoe seals

Mechanical shoe seals shall be used either independently or in combination with a secondary seal.

NOTE 1 Mechanical shoe seals may be used in tanks storing crude oil, products or chemically aggressive liquids.

NOTE 2 In crude oil tanks, the application of a wax scraper system acting at the bottom end of the shoes is possible.

NOTE 3 The metal shoes are normally of similar height as the floating roof. Low height shoes can be used in combination with independent secondary seals.

NOTE 4 A typical example is shown in Figure E.1 a).

The metallic shoes shall be earthed through the floating roof.

E.5.2 Spring-forced lip primary seals

Spring-forced lip primary seals shall be used in combination with independent secondary seals.

NOTE 1 Sealing efficiency is only achieved when the seal is fitted with a submerged skirt.

NOTE 2 A typical example is shown in Figure E.1 b).

The maximum operating height of the floating roof shall be such as to provided safe operation of the seal.

E.5.3 Liquid-filled primary seals

Liquid-filled primary seals shall consist of a circular abrasion resistant hose, filled with a non-freezing liquid (if appropriate), kerosene or the stored liquid.

To give good sealing efficiency, the lower part of the seal shall project into the stored liquid.

NOTE 1 Liquid-filled seals require good roundness of tank shell and smooth weld seams.

NOTE 2 They give little centering forces and need frequent control of the filling liquid.

NOTE 3 For hot work during maintenance in an emptied tank, it may be necessary to drain the filling liquid from the seal.

NOTE 4 A typical example is shown in Figure E.1 c).

E.5.4 Foam-filled primary seals

Foam-filled primary seals shall consist of an abrasion resistant sealing curtain, forming a circular hose, with resilient foam elements, and rigid holding down elements.

To achieve good sealing efficiency, the holding down elements shall provide continuous contact of the seal with the stored liquid.

NOTE 1 When the floating roof is moving, and there is a strong friction force between the seal and the tank shell, contact between the seal and the liquid cannot always be maintained due to the vertical displacement of the seal.

NOTE 2 Foam-filled seals have strong centering forces and high friction.

NOTE 3 In the case of damage of the sealing curtain, stored liquid may penetrate into the foam elements.

NOTE 4 For hot work during maintenance in an emptied tank, it may be necessary to detach the foam element from the seal.

NOTE 5 A typical example is shown in Figure E.1 d).

E.5.5 Spring-forced pad or lip secondary seals

Depending on the maximum expected rim space, a minimum spring height shall be provided for satisfactory operation.

NOTE 1 Spring-forced pad or lip secondary seals normally have good flexibility and centering forces.

NOTE 2 The height of the required foam wall and the maximum lifting height of the floating roof are determined by the maximum contact point between the secondary seal and the tank wall.

E.5.6 Compression plate secondary seals

Depending on the maximum expected rim space, a minimum compression plate height shall be provided for satisfactory operation.

NOTE 1 The compression plates should incorporate foam ports to allow fire fighting foam to enter the rim space.

NOTE 2 Compression plate secondary seals have good centering forces and protect the sealing curtain against sun light and weathering.

NOTE 3 The height of the required foam wall and the maximum lifting height of the floating roof are determined by the maximum contact point between the secondary seal and the tank wall.

E.5.7 Wiper seals

Wiper seals shall consist of a continuous ring of rubber sheet or a semi-rigid polyurethane foam lip, pressed bow-shaped against the tank wall.

NOTE Rubber wipers are usually augmented by integrated or external spring blades.

E.5.8 Integrated primary/secondary seals

For integrated primary/secondary seals, several effective elements shall be combined into one unit. The primary part of the sealing system shall normally be a mechanical shoe seal (see E.5.1)

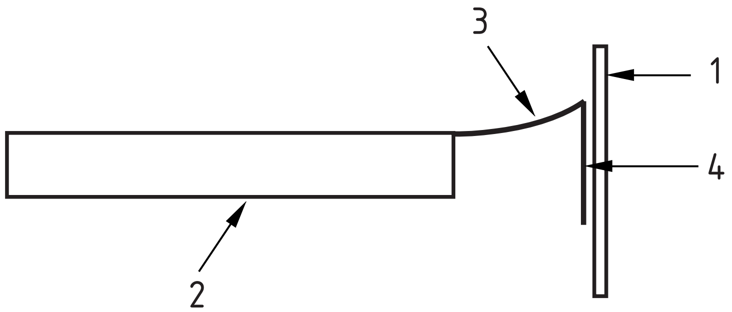
NOTE 1 The operating height above the floating roof rim may be low.

NOTE 2 The vapour volume in the rim space may be effectively sealed by a submerged sealing element.

NOTE 3 A typical example is shown in Figure E.1 e).

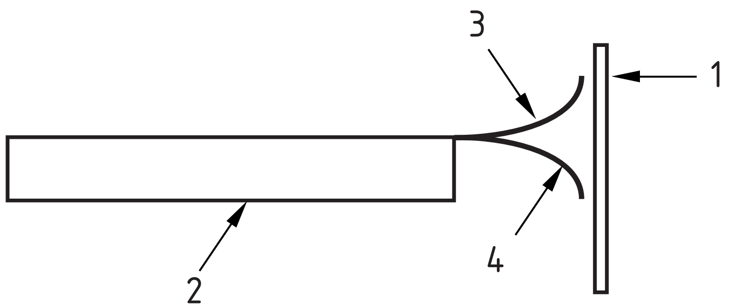
E.6 Installation

Proper installation of seals is vital for their function and service life, and installation shall be carried out by specialized personnel only.



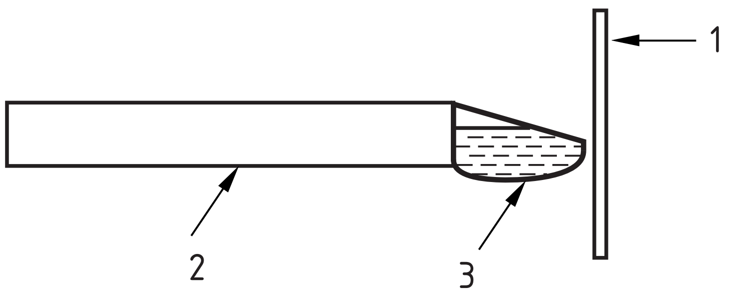
3 Primary membrane seal 4 Shoe

a) Mechanical shoe seal



3 Wiper seal or secondary seal 4 Wiper seal

b) Spring forced lip seal and wiper seal

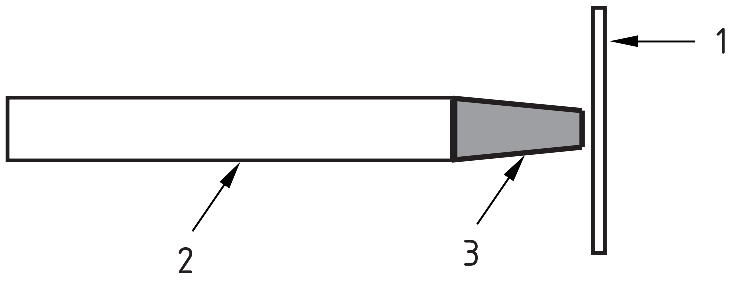


3 Liquid filled seal

c) Liquid filled resilient seal

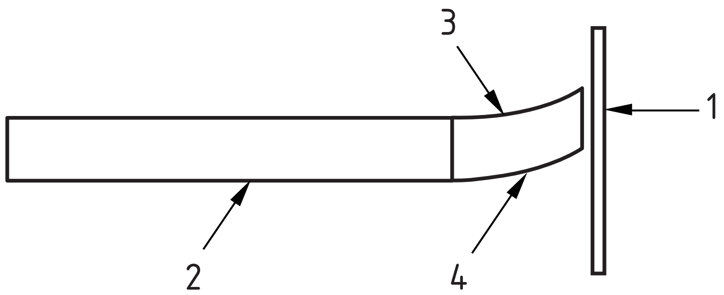
1 Tank shell 2 Floating roof

Figure E.1 — Examples of rim seals for floating roofs (continued)



3 Foam filled seal

d) Foam filled resilient seal



3 Integrated secondary seal

4 Integrated primary seal

e) Integrated primary/secondary seal

1 Tank shell

2 Floating roof

Figure E.1 — Examples of rim seals for floating roofs (concluded)

Annex F
(normative)

Selection of carbon and carbon manganese steel plate to alternative specifications to those in 6.1

F.1 Alternative national standards

All carbon and carbon-manganese steel plate materials used in the manufacture of tanks complying with this document shall be in accordance with 6.1. unless otherwise agreed (see A.2). When so agreed, it shall be permitted to select carbon and carbon-manganese steel plates conforming to a recognised National Standard, provided that they also meet the requirements of this annex. Selection of a suitable material conforming to these requirements shall be the responsibility of the tank manufacturer.

F.2 General

F.2.1 Definitions shall be in accordance with EN 10025:1992, Clause 3.

F.2.2 The basic oxygen, electric arc or open hearth steel making processes shall be permitted. Rimming steels shall not be permitted.

F.2.3 Tolerances, surface finish and internal soundness shall be as specified in EN 10025:1992, Clause 5, 7.6 and 8.9 respectively.

F.2.4 The testing method, number of samples, position of samples and selection and preparation of test pieces for mechanical testing shall be in accordance with EN 10025:1992, 8.6 and 8.7. Tensile testing shall be transverse to the direction of rolling and impact testing parallel to the direction of rolling.

F.2.5 Inspection documents shall be in accordance with 6.1.1 of this document.

Marking shall be in accordance with EN 10025:1992, 9.1.

F.3 Chemical composition

F.3.1 The chemical composition as measured by the ladle analyses shall be in accordance with Table F.1. The ladle analysis shall be reported, together with values of all elements specified in F.3.2 and any deliberate additions, e.g. aluminium, boron, niobium or vanadium.

F.3.2 The carbon equivalent from the ladle analysis, calculated using the following formula, shall not exceed 0,42 % for plates thicker than 20 mm.

$$C+\frac{Mn}{6}+\frac{(Cr+Mo+V)}{5}+\frac{(Ni+Cu)}{15} \quad \text{(F.1)}$$

Table F.1 — Chemical composition (Ladle analysis)

Yield strength N/mm²	Chemical composition Weight % maximum															Notes
	C	Mn	Si	P	S	Nb	V	Al	Cr	Ni	Mo	Cu	N	Cr+Ni Cu+Mo	Nb+V	CEV	
≤ 275	0,21	1,5		0,040	0,040	0,06	0,1	0,07	0,25	0,30	0,20	0,35	0,01	0,80	0,10	0,42	1
> 275 to 355	0,20	1,6	0,55	0,035	0,035	0,06	0,1	0,07	0,25	0,30	0,20	0,35	0,01	0,80	0,10	0,42	1
> 355	0,20	1,6	0,55	0,030	0,030	0,10	0,2						0,01			0,42	2

NOTE 1 The nitrogen content may be increased to 0,02 % max if the ratio of Al/N>2.

NOTE 2 Other alloys such as Cr, Ni, Mo, Cu, if not deliberately added, shall be specified for > 275 to 355, and if deliberately added, the levels shall be agreed between the steel between the steel manufacturer and the tank manufacturer.

F.4 Mechanical properties

F.4.1 The mechanical properties shall be determined in accordance with F.2.4 and shall meet the requirements of F.4.2 to F.4.6.

F.4.2 For design metal temperatures in excess of 100 °C, steels with elevated temperature yield strength values shall be in accordance with the equivalent of Table 8.

Other steel grades for which elevated temperature yield strength values are not specified in the material standard may also be used, provided the actual value of each cast of the material delivered shall be verified by the steel manufacturer in accordance with EN 10002-5.

The test results shall be reported in an inspection document in accordance with EN 10204:2004, Cert. 3. 1B.

F.4.3 When the maximum design metal temperature exceeds 250 °C, steels which are proven to be unaffected by ageing shall be used. The method of proof shall be subject to agreement (see A.5).

F.4.4 For steels with a specified minimum yield strength of less than or equal to 275 N/mm^2:

a) specified minimum tensile strength shall not exceed 430 N/mm^2;

b) elongation on 80 mm gauge length shall not be less than 20 %;

c) Charpy V - notch impact tests, when required, shall meet the requirements of F.5.2.1.

F.4.5 For steels with a specified minimum yield strength greater than 275 N/mm^2 and less than or equal to 355 N/mm^2:

a) specified minimum tensile strength shall not exceed 510 N/mm^2 ;

b) elongation on 80 mm gauge length shall not be less than 20 %;

c) Charpy V - notch impact tests, when required, shall meet the requirements of F.5.2.2.

F.4.6 For steels with a specified minimum yield strength greater than 355 N/mm^2:

a) specified minimum tensile strength shall not exceed 600 N/mm^2 ;

b) elongation on 80 mm gauge length shall not be less than 19 %;

c) Charpy V - notch impact tests, when required, shall meet the requirements of F.5.2.3.

F.5 Impact testing

F.5.1 General

When necessary to meet the requirements of this document, Charpy V-notch impact testing in accordance with EN 10045-1 shall be undertaken in accordance with the appropriate material standard for the plate.

The specified Charpy V-notch impact test values for plates from the three test pieces are based on three longitudinal test pieces, the value taken shall be the average of the three results. The minimum individual value of only one test piece shall be not less than 70 % of the specified average value. Where reduced section test pieces are required, 10 mm × 5 mm test pieces shall be used and they shall demonstrate 50 % of the values specified for full size test pieces. Wherever the section thickness of the test plate permits, 10 mm × 10 mm test pieces shall be used.

F.5.2 Impact properties

F.5.2.1 Materials shall be impact tested in accordance with the requirements of the specified steel standard. When impact testing is required, the impact test temperatures and levels of impact energy shall conform to Clauses F.5.2.2 to F.5.2.4, as appropriate.

Impact testing shall not be required for bottom plates other than annular plates, and roof plates.

Impact testing of bottom annular plates shall not be required when the shell plates attaching to them are not required to be impact tested.

Impact testing shall not be required for shell plates, or materials attached to shell plates, when the minimum design metal temperature and the thickness are within the limits given in Table F.2.

NOTE Roof plates do not normally require impact testing, but it may be required for roofs for very high pressure tanks where the plate thickness exceeds 6 mm (see Figure 1).

Table F.2 — Conditions for waiving impact testing

Minimum design metal temperature °C	**Thickness** mm
≥ + 10	≤ 20
≥ 0	≤ 13
≥ - 10	≤ 10
< - 10	≤ 6

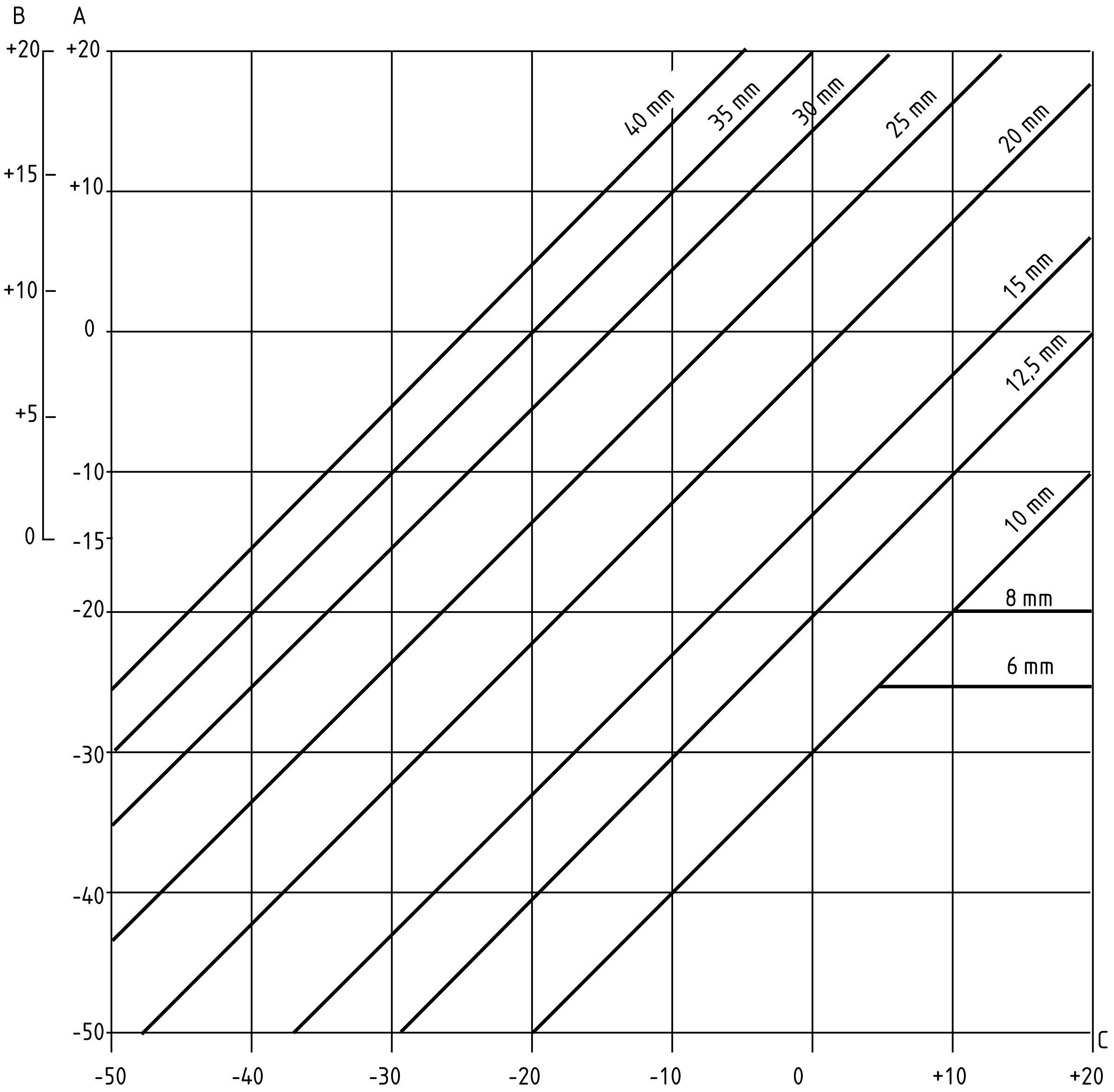
F.5.2.2 When required to be impact tested, steels with a specified minimum yield strength less than or equal to 275 N/mm^2, shall show not less than 27 J at + 20 °C or at the test temperature indicated in Figure F.1, whichever is the lower.

F.5.2.3 When required to be impact tested, steels with a specified minimum yield strength greater than 275 N/mm^2 and up to and including 355 N/mm^2, shall show not less than 40 J at -5 °C or at the test temperature indicated in Figure F.1, whichever is the lower.

NOTE Conversion of the specified impact value from 27 J to 40 J may be made on the basis of 1,3 J/°C. Such extrapolation is limited to a maximum range of ± 10 °C.

F.5.2.4 When required to be impact tested, steels with a specified minimum yield strength greater than 355 N/mm^2, shall show not less than 55 J at -15 °C or at the test temperature indicated in Figure F.1, whichever is the lower.

Dimensions in millimetres



Key

A Minimum design metal temperature °C

B Minimum water test temperature °C

C Impact test temperature °C

NOTE 1 Intermediate values may be determined by interpolation.

NOTE 2 Scale A temperature on the ordinate is to be used in determining minimum Charpy V-notch impact test temperature requirements for the thickness and minimum design temperature concerned. The requirements derived from Scale A take into account an improvement in safety which may be anticipated as a result of the hydrostatic test. During the first hydrostatic test the degree of security against brittle fracture may be rather less than on subsequent loading and consideration should be given to utilising the more conservative requirements of scale B if this would result in more onerous Charpy V-notch impact test temperature requirements having to be specified.

Figure F.1 — Minimum Charpy V-notch impact test requirements

Annex G
(informative)

Recommendations for seismic provisions for storage tanks

G.1 General

This annex gives recommendations for the seismic design of storage tanks and is based on the requirements of Annex E of API 650. The zone coefficients used in API 650 have been modified to lateral force coefficients expressed as a ratio of the acceleration due to gravity. This allows application of these calculations to geographical locations outside the USA.

It is recognized that other procedures e.g.. ENV 1998-1-1 or additional requirements may be called for by the purchaser or the local authorities in highly active seismic areas. In this case, specialized local knowledge should be used in agreement between the purchaser, the local authority and the manufacturer which takes into account local requirements, the necessary integrity, soil conditions, etc.

Consideration should be given to design for an operating basis earthquake (OBE) condition, where the allowable stresses should not be exceeded, and a safe shutdown earthquake (SSE) condition, where the ultimate strength should not be exceeded, when establishing site safety requirements.

G.2 Design loads

G.2.1 Overturning moment

The overturning moment due to seismic forces applied to the bottom of the tank shell should be calculated as follows:

$$M = \frac{G_1 (T_t X_s + T_r H_L + T_1 X_1) + G_2 T_2 X_2}{102} \quad (G.1)$$

where

G_1 is the lateral force coefficient given as a ratio of the acceleration due to gravity (see G.2.3.1);

G_2 is the lateral force coefficient given as a ratio of the acceleration due to gravity and determined in accordance with G.2.3.2;

H_L is the total height of tank shell, in m;

M is the overturning moment applied to bottom of tank shell, in kN.m;

T_1 is the weight of effective mass of tank contents which moves in unison with tank shell and which is determined in accordance with G.2.2.1, in kg;

T_2 is the weight of effective mass of the tank contents which move in the first sloshing mode and which is determined in accordance with G.2.2.1, in kg;

T_r is the total weight of tank roof (fixed or floating) plus portion of snow load, if any, as specified by the purchaser, in kg;

T_t is the total weight of tank shell, in kg;

X_1 is the height from bottom of tank shell to centroid of lateral seismic force applied to T_1 and which is determined in accordance with G.2.2.2, in m;

X_2 is the height from bottom of tank shell to centroid of lateral seismic force applied to T_2 and which is determined in accordance with G.2.2.2, in m;

X_s is the height from bottom of tank shell to centre of gravity of shell, in m.

G.2.2 Effective mass of tank contents

G.2.2.1 The effective mass T_1 and the effective mass T_2 (as given in G.2.1), may be determined by multiplying T_T by the ratios T_1/T_T and T_2/T_T respectively, obtained from Figure G.1 for the ratio D/H_T,

where:

D is the diameter of tank, in m;

H_T is the maximum filling height of tank from bottom of shell to top of curb angle or overflow which limits filling height, in m.

T_T is the total weight of tank contents (based on a specific gravity not less than 1,0), in kg;

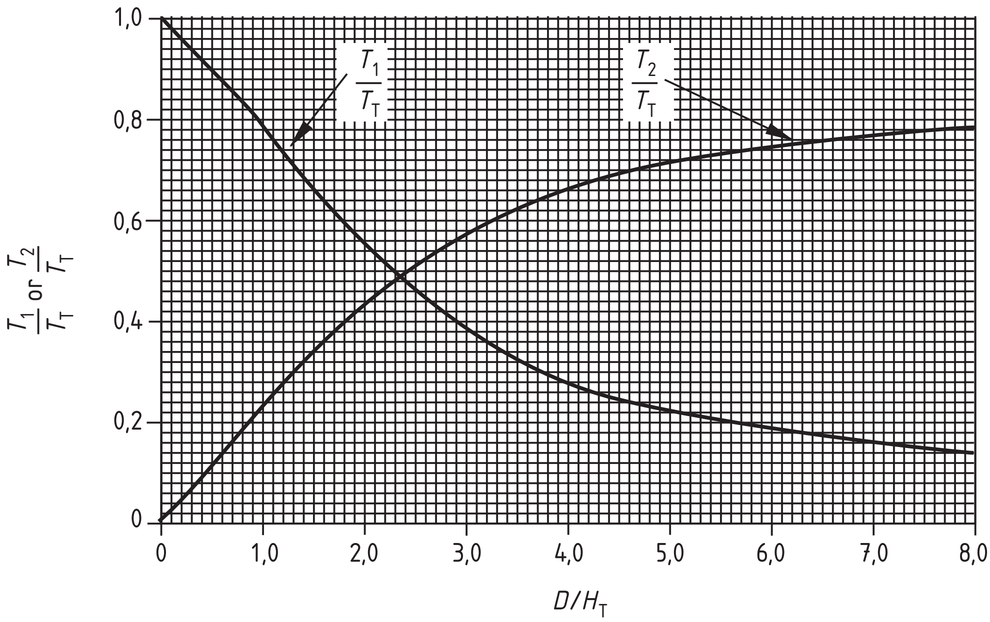


Figure G.1 — Effective masses

G.2.2.2 The heights from the bottom of the tank shell to the centroids of the lateral seismic forces applied to T_1, T_2, X_1 and X_2 may be determined by multiplying H_T by the ratios X_1/H_T and X_2/H_T, respectively, obtained from Figure G.2 for the ratio of D/H_T.

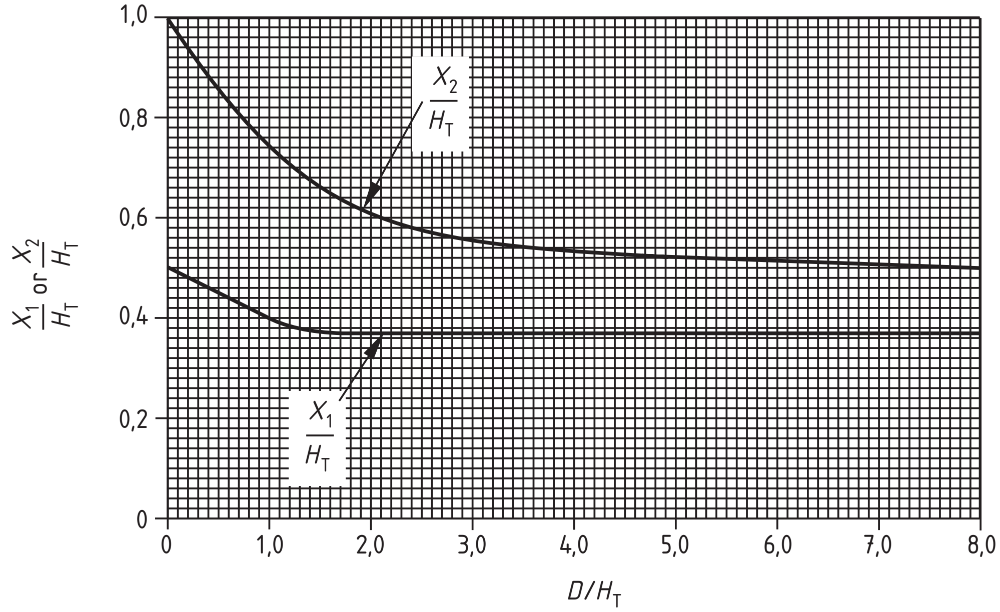


Figure G.2 — Centroids of seismic forces

G.2.2.3 The curves in Figures G.1 and G.2 are based on a modification of the equations presented in ERDA Technical Information Document 7024.[4]

G.2.3 Lateral force coefficients

G.2.3.1 The lateral force coefficient G_1 is to be specified by the purchaser on the basis of seismology records available for the proposed tank site and should be given as a ratio of the acceleration due to gravity.

G.2.3.2 The lateral force coefficient G_2 is to be determined as a function of G_1 of the natural period of the first mode sloshing T_s and the soil conditions at the tank site (unless otherwise determined by the method given in G.2.3.3) as follows:

a) when T_s is the less than or equal to 4,5

$$G_2 = \frac{1{,}25 G_1 j}{T_s} \qquad \text{(G.2)}$$

b) when T_s is greater than 4,5

$$G_2 = \frac{5{,}625 G_1 j}{T_s^2} \qquad \text{(G.3)}$$

where

j is the site amplification factor from Table G.1;

T_s is the natural period in seconds of first mode sloshing;

T_s may be determined from the following expression:

$T_s = 1{,}8\ K_s D^{½}$.

where

K_s is a factor obtained from Figure G.3 for the ratio D/H_T;

Table G.1 — Soil profile coefficient

Site amplification factor	Soil profile type		
	A[1)]	**B**[2)]	**C**[3)]
j	**1,0**	**1,2**	**1,5**

[1)] Soil profile type A is either of two profiles as follows.

a) Rock of any characteristic, either shale-like or crystalline in nature. Such material may be characterized by a shear wave velocity greater than 760 m/s

or

b) Stiff soil conditions where the soil depth is less than 60 m and the soil types overlying rock are stable deposits of sands, gravels, or stiff clays.

[2)] Soil profile type B is a profile with deep cohesionless or stiff clay conditions, including sites where the soil depth exceeds 60 m and the soil types overlying rock are stable deposits of sands, gravels, or stiff clays.

[3)] Soil profile type C is a profile with soft-to-medium-stiff clays and sands, characterized by 10 m or more of soft-to-medium-stiff clay with or without intervening layers of sand or other cohesionless soils.

NOTE In locations where the soil profile is not known in sufficient detail to determine the site amplification factor, *j*, the soil profile, C, should be assumed.

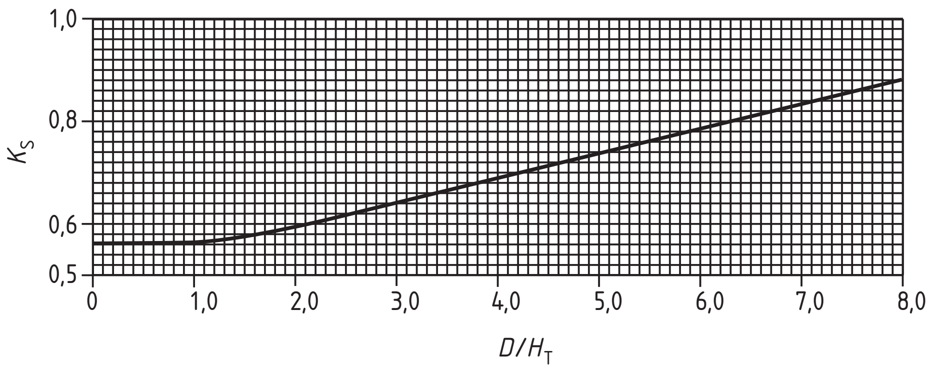


Figure G.3 — Factor K_s

G.2.3.3 As an alternative to the method described in G.2.3.1 and G.2.3.2 and by agreement between purchaser and manufacturer, G_1 and G_2 may be determined from response spectra established for the specific site of the tank and which may also take into account the dynamic characteristics of the tank. The spectrum for G_1 should be established for a damping coefficient of 2 % of critical. The spectrum for G_2 should correspond to the spectrum for G_1 except modified for a damping coefficient of 0,5 % of critical.

NOTE In no case should the values of G_1 and G_2 be less than those obtained from G.2.3.1 and G.2.3.2.

G.3 Resistance to overturning

G.3.1 The tank contents

Resistance to the overturning moment at the bottom of the shell may be provided by the weight of the tank shell and by the anchorage of the tank shell or, for unanchored tanks, the weight of a portion of the tank contents adjacent to the shell. For unanchored tanks the portion of the contents which may be utilized to resist overturning is dependent on the width of the bottom plate under the shell which lifts off the foundation and may be determined as follows:

$$W_{\mathrm{L}} = 0{,}1\, t_{\mathrm{ba}} \sqrt{R_{\mathrm{eb}} W_{\mathrm{s}} H_{\mathrm{T}}} \tag{G.4}$$

except that W_{L} should not exceed 0,2 $W_{\mathrm{s}} H_{\mathrm{T}} D$;

where

R_{eb} is the minimum specified yield strength of bottom plate under the shell, in N/mm^2;

W_{L} is the maximum force of tank contents which may be utilized to resist the shell overturning moment, in kN per metre of shell circumference;

W_{s} is the maximum density of the contained liquid under storage conditions, to be not less than 1,0 kg/l.

t_{ba} is the thickness of bottom plate under the shell, in mm;

G.3.2 The thickness of the bottom plate

The thickness of the bottom plate under the shell, t_{ba}, should not exceed the thickness of the bottom shell course. Where the bottom plate under the shell is thicker than the remainder of the bottom, the width of the thicker plate under the shell in metres, measured radially inward from the shell, should be equal to or greater than:

$$0{,}1744 \frac{W_{\mathrm{L}}}{W_{\mathrm{s}} H_{\mathrm{T}}} \tag{G.5}$$

NOTE A narrower width of annular plate than that required by the above expression is acceptable provided the resultant reduced W_{L} resistance load is adopted in the shell compression computations of G.4.

G.4 Shell compression

G.4.1 Unanchored tanks

The maximum longitudinal compression force at the bottom of the shell, W_b, may be determined as follows:

a) when $\frac{M}{D^2(W_L + W_t)} \leq 0{,}785$ (G.6)

$$W_b = W_t + \frac{1{,}273\ M}{D^2}$$

b) when $\frac{M}{D^2(W_L + W_t)} > 0{,}785$ and $\leq 1{,}5$, (G.7)

W_b may be computed from the value of the parameter $\frac{W_b + W_L}{W_t + W_L}$ obtained from Figure G.4

where

W_b is the maximum longitudinal shell compression force, in kN per metre of shell circumference;

W_t is the maximum force exerted by tank shell and portion of roof supported by shell, in kN per metre of shell circumference.

c) when $\frac{M}{D^2(W_t + W_L)} > 1{,}5$ or when $W_b/t_{bs} > F_a$ (when calculated using the method described in G.4.3), the tank is structurally unstable. In such cases, it is necessary to make the tank stable by one of the following methods:

i) Increase the thickness of the bottom plate under the shell, t_{ba} to increase W_L, providing that the limitations of G.3.1 and G.3.2 are not exceeded.

ii) Increase shell thickness, t_{bs}.

iii) Change the proportions of the tank to increase the diameter and reduce the height.

iv) Anchor the tank in accordance with G.5.

G.4.2 Anchored tanks

The maximum compression force at the bottom of the shell, W_b, in kN per metre of shell circumference, may be determined as follows:

$$W_b = W_t + \frac{1{,}273M}{D^2} \quad \text{(G.8)}$$

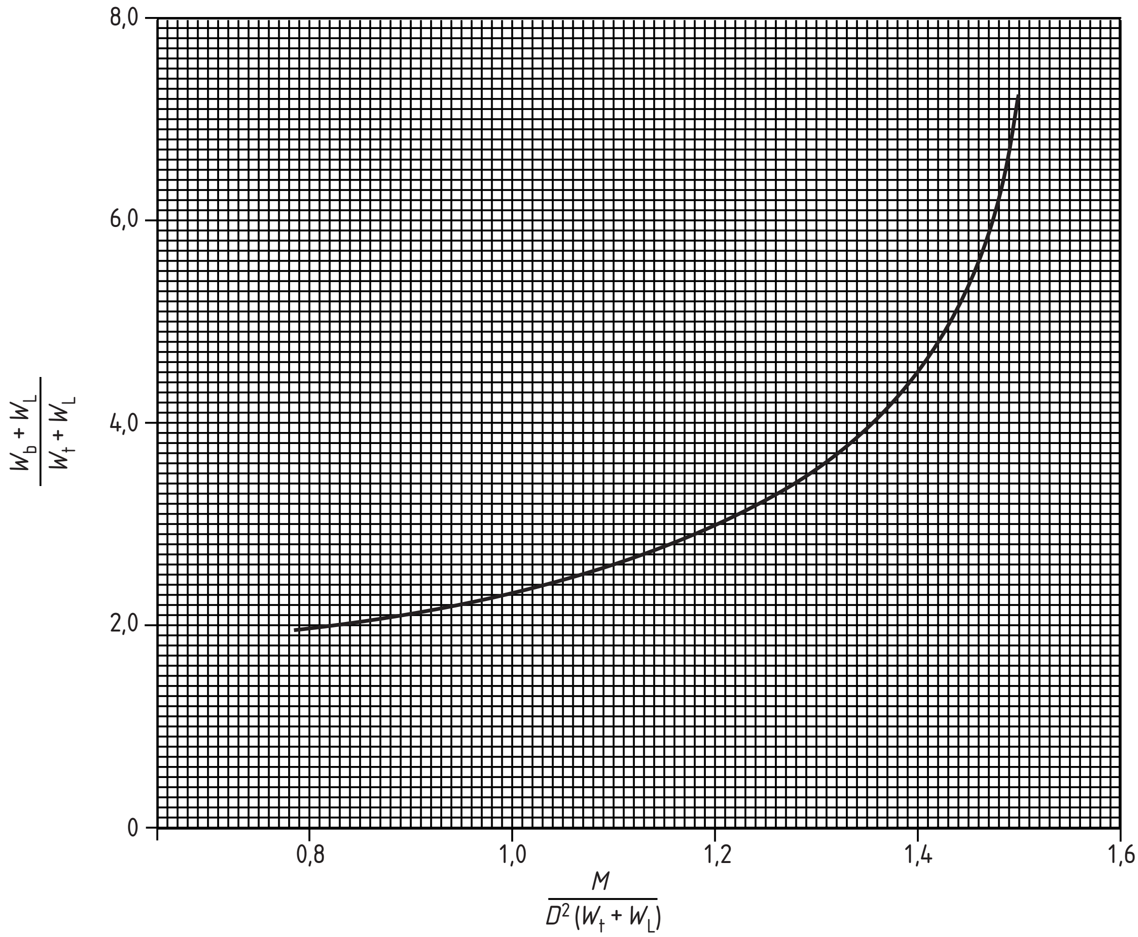


Figure G.4 — Compressive force W_b

G.4.3 Maximum allowable shell compression

The maximum longitudinal compressive stress in the shell, W_b/t_{bs}, in N/mm², should not exceed the maximum allowable stress, F_a, in N/mm², determined as follows:

a) when $\frac{W_s H_T D^2}{t_{bs}^2} \geq 44$ $\quad F_a = 83 \frac{t_{bs}}{D}$ (G.9)

b) when $\frac{W_s H_T D^2}{t_{bs}^2} < 44$ $\quad F_a = 33 \frac{t_{bs}}{D} + 7{,}5 \sqrt{W_s H_T}$ (G.10)

where

t_{bs} is the thickness, excluding corrosion allowance, of the bottom shell course, in mm;

F_a is the maximum allowable longitudinal compressive stress in the shell, in N/mm². The formulae in items a) and b) for F_a take into account the effect of internal pressure due to the liquid contents;

R_{es} is the minimum specified yield strength of the bottom shell course, in N/mm^2.

In no case should the value of F_a exceed 0,5 R_{es}.

G.4.4 Upper shell courses

If the thickness of the lower shell course calculated to resist the seismic overturning moment is greater than the thickness required for hydrostatic pressure, both excluding corrosion allowance, then unless a special analysis is made to determine the seismic overturning moment and corresponding stresses at the bottom of each upper shell course, the calculated thickness of each upper shell course for hydrostatic pressure should be increased in the same proportion.

G.5 Anchorage of tanks

G.5.1 Minimum anchorage required

When anchorage is considered necessary, it should be designed to provide a minimum anchorage resistance (in kN per metre of shell circumference) of:

$$\frac{1{,}273M}{D_2} - W_t \qquad \text{(G.11)}$$

The above anchorage resistance is in addition to that required to resist any internal design pressure on low and high pressure tanks.

NOTE Earthquake and wind loads should not be considered as acting concurrently.

G.5.2 Design of anchorage

G.5.2.1 If an anchored tank is not properly designed its shell can be susceptible to tearing. Care should be taken to ensure that the strength of anchorage attachments to the tank shell is greater than the specified minimum yield strength of the anchors so that the anchors yield before the attachments fail. Experience has shown that properly designed anchored tanks retain greater reserves of strength with respect to seismic overload than do unanchored tanks.

In addition to the requirements of 12.1 to 12.6 the recommendations given in G.5.2.2 to G.5.2.4 should be followed.

G.5.2.2 On tanks less than 15 m in diameter, the maximum spacing of the anchors should not exceed 2 m.

G.5.2.3 The allowable tensile stress in the anchorage due to the loads given in item a) of 12.1 together with the seismic load from G.5.1 should not exceed 1,33 times the stresses given in 12.3.

G.5.2.4 The attachment of the anchorage to the tank shell and the embedment of the anchor into the foundation should be designed for a load equal to the minimum specified yield strength of the anchorage material multiplied by the as-built minimum cross-sectional area of the anchor. For the attachment of the anchorage to the tank shell and the embedment of the anchor into the foundation, the design stress should not exceed 1,33 times that given in 9.1.1.

G.6 Piping

Suitable flexibility should be provided in the vertical direction for all piping attached to the shell or bottom of the tank. On unanchored tanks subject to bottom uplift, piping connected to the bottom should be free to lift with the bottom or be located so that the distance measured from the shell to the edge for the connecting reinforcement is the width for the bottom plate (as calculated by G.3.2) plus 0,3 m.

G.7 Sloshing height

The purchaser may specify if a freeboard is to be provided to minimize or prevent overflow and damage to the roof and upper shell.

Annex H
(informative)

Recommendations for other types of tank bottoms (double bottoms, elevated bottoms etc.)

H.1 Non-fully supported bottoms

H.1.1 Tank bottoms which are not fully supported by a continuous foundation can be supported on structural supports manufactured from structural steel sections or reinforced concrete beams.

H.1.2 Bottom plate materials should be in accordance with Clause 6.

H.1.3 The loads to be taken into consideration in the design should be the weight of the product, the weight of the bottom plates, the design internal pressure, the weight of the test liquid and the test pressure.

H.1.4 The thickness of the bottom plate should be the greater of e_b and e_{bt} and that specified in Table 13.

$$e_b = 7{,}3\, L \sqrt{\frac{98HW + p}{S}} + c \qquad \text{(H.1)}$$

$$e_{bt} = 7{,}3\, L \sqrt{\frac{98HW_t + p_t}{S_t}} + c \qquad \text{(H.2)}$$

where

- c is the corrosion allowance, in mm;
- e_b is the bottom plate thickness required for design conditions, in mm;
- e_{bt} is the bottom plate thickness, required for test conditions, in mm;
- H is the Height of product or test liquid, in m;
- L is the distance between centre lines of supports, in m;
- p is the design pressure, in mbar;
- p_t is the test pressure, in mbar;
- S is the allowable design stress for bottom plate material (see 9.1.1), in N/mm^2;
- S_t is the allowable test stress for bottom plate material (see 9.1.1), in N/mm^2;
- W is the maximum design density of product, in kg/l;
- W_t is the maximum design density of test medium, in kg/l.

H.1.5 The joints between bottom plates should be butt welded.

H.2 Double bottoms

H.2.1 General

The purpose of a double bottom is that in the event of a leak in the upper bottom, the actual product container, there will not be product leakage into the foundation and sub-soil since it is unlikely that both bottoms would start leaking at the same time.

Double bottoms should be designed in such a manner that both bottoms can be checked for liquid tightness while the tank is in operation.

NOTE 1 In the event of a leak being detected in the bottoms of tanks in which combustible liquids are stored, it could be difficult to make the interspace gas and/or liquid free and to clean it, making weld repair of the upper bottom difficult without the risk of fire and/or explosion.

NOTE 2 Double bottom constructions are not recommended for very cold climatic areas.

NOTE 3 Heated tanks could cause high thermal stresses in the bottom area unless steps are taken to heat up the lower bottom as well.

Typical designs for double bottoms for steel storage tanks are shown in Figures H.1 and H.2.

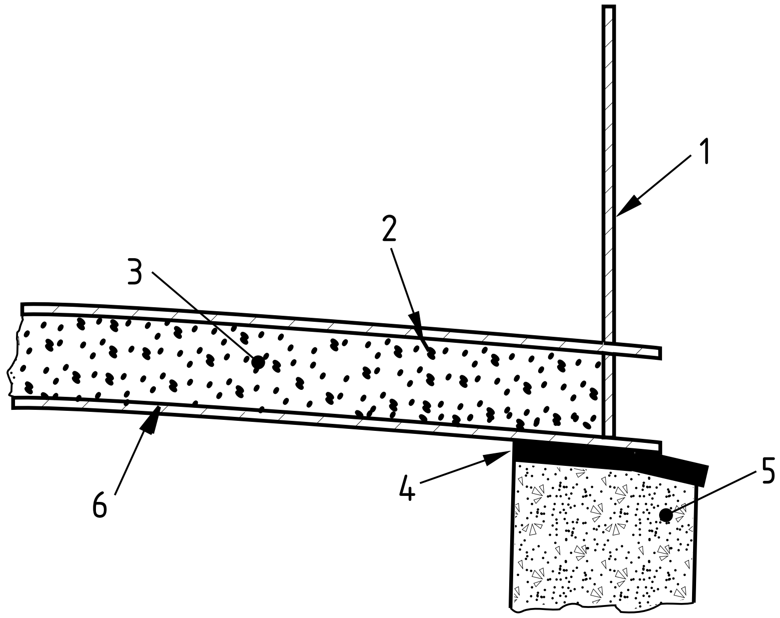
H.2.2 Design

The design should be evaluated to verify that the two bottoms and shell are not overstressed.

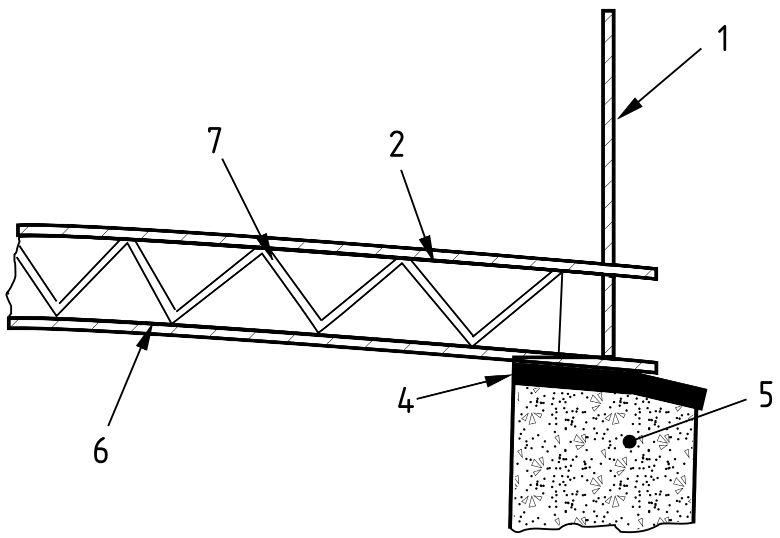
The presently used methods for designing tank bottoms as well as the junctions between the bottom and shell do not cover the design of double bottoms.

Where such a system is proposed, therefore, it is essential that the stresses in these areas are assessed.

Heated tanks could cause high thermal stresses in the bottom area unless steps are taken to heat up the lower bottom as well.



a) Double bottom incorporating infill

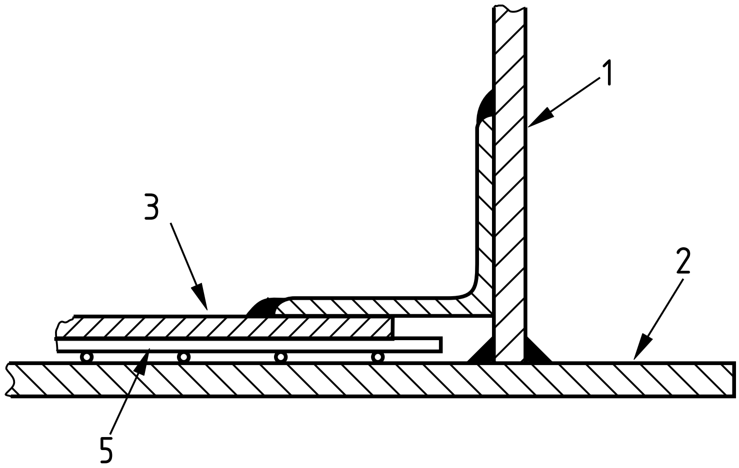


b) Double bottom separated by structural steelwork

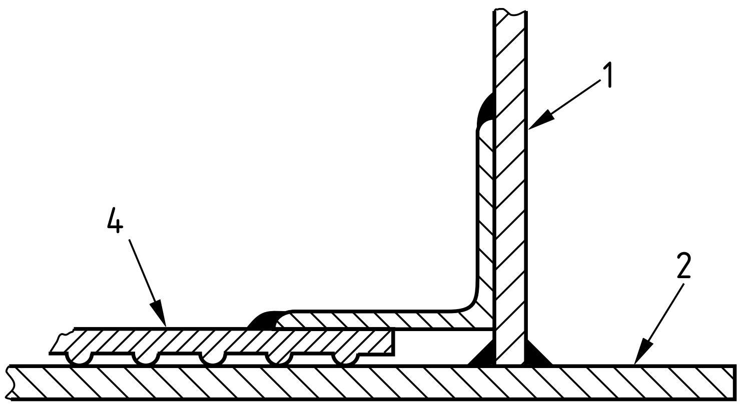
Key

1	Tank shell	4	Elastomeric membrane	7	Structural steel
2	Upper bottom	5	Foundation ring		
3	Sand, pea gravel	6	Lower bottom		

Figure H.1 — Typical arrangement of double bottom tanks



a) Upper bottom made from plate

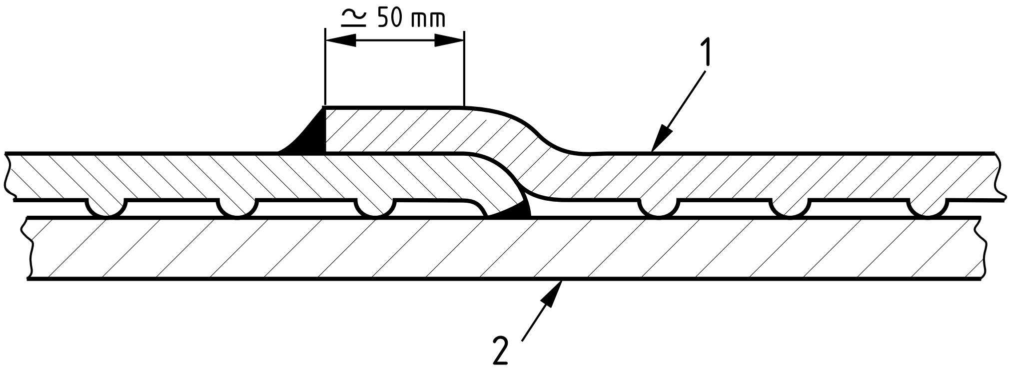


b) Upper bottom made from chequer plate

Key

1	Shell plate	3	Upper bottom from plate	5	Wire mesh
2	Annular plate	4	Upper bottom from chequer plate		

Figure H.2 — Typical design of double bottom and joint to the shell plate



Key

1 Chequer plate

2 Annular plate/bottom plate

Figure H.3 — Separation joint between two monitoring areas of chequer plate bottom (similar with mesh and plates)

H.2.3 Leak detection

A number of methods are available to detect leaks. The method should be selected on the basis of the liquid stored in the tank, and the double bottom design.

The following monitoring methods are the most common:

a) Creation of negative pressure in the space between the bottoms of approximately - 0,5 bar;

b) Installation of leakage detecting cables or point probes;

c) Overpressure monitoring, e.g. by means of nitrogen;

NOTE Care should be taken to limit the pressure so the bottom is not lifted.

d) Nitrogen bleed;

e) Acoustic emission;

f) Electronic sensing.

H.3 Elevated or beam supported tanks

H.3.1 Small in-plant tanks up to about 4 m diameter can be mounted on a beam structure, usually set on a concrete plinth, to allow leaks to be visually detected.

H.3.2 Tank bottoms which are not fully supported by a continuous foundation should be in accordance with H.1.

H.4 Leak test

For tanks equipped with a double bottom, an inspection of its tightness should be carried out prior to any painting or coating.

To conduct this inspection, a negative pressure to a value of approximately - 0,5 bar should be subject to agreement (see A.2) and should be applied to the space between both bottoms. The interspace between the bottoms should be purged to remove moisture. After the required negative pressure has been achieved, the bottom should be isolated and the agreed negative pressure should be held for an agreed period of time (see A.2) and checked for leakage. Account should be taken of variations in temperature.

Annex I
(informative)

Recommendations for tank foundations

I.1 General

The following recommendations are intended to establish general principles for the design and construction of foundations under storage tanks to ensure that they will support the loads, and do not impair the structural integrity of the tank. The recommendations are offered as an outline of good practice, and point out some precautions which should be observed in the design and construction of such foundations.

Because of the wide variety of soil surface and sub-surface, climatic conditions, and design of storage tanks, it is not practicable to establish in this annex design data to cover all situations. The allowable soil load and foundation system needs to be decided for each individual case.

The design of foundations for storage tanks represents an exceptional case for the following reasons:

a) Tank foundations are subject to live loads representing the greatest proportion of total gravity load;

b) The contents of a storage system represent a high concentration of potentially damaging fluid.

I.2 Soil Investigation

I.2.1 General

Wherever possible, storage tanks should be sited in an area where subsoil conditions are homogeneous, and have good characteristics in respect of load bearing and settlement.

Prior to the start of the design and construction of the foundation, a thorough geotechnical investigation should be conducted to determine the stratigraphy and physical properties of the soils underlying the site.

In addition, the soil resistivity, conductivity and thermal properties should be determined.

Additional useful information can be obtained from a review of sub-surface conditions, and the history of similar structures in the vicinity.

I.2.2 Water tables

Full details, including seasonal variation with depth of the ground water table, perched water tables and possible sub-surface water flows, should be obtained for the area of the planned storage, together with data on the permeability of the soils and possible susceptibility to frost heave. Consideration needs to be given to possible changes in the above data that can result from construction works.

I.2.3 Seismic investigations

The extent of the investigation needed will depend on the assessment of seismic intensity for the site and the recurrence interval consistent with the risk levels assumed in the design. Reference should be made to Annex G.

I.2.4 Sites to be avoided

The following are some of the many variations in conditions that will need special consideration as regard foundation design, and they should be avoided if economic considerations permit selection of alternative areas:

a) sites where part of a tank may be on rock or other firm undisturbed ground and part on fill; or where the depth of required fill is variable; or where the ground under part of the tank area has been pre-consolidated;

b) sites on swamps or where layers of highly compressible material occur below the surface;

c) sites where stability of the ground is questionable, e.g. adjacent to deep water courses, mining operations, excavations or steeply sloping hillsides, karst topography or gypsiferous materials which could include weak lenses subject to leeching;

d) sites where tanks may be exposed to flood waters, resulting in possible uplift, displacement or scour, or conversely where any subsequent lowering of the groundwater table could lead to additional differential settlement;

e) sites near to active faults or on soils susceptible to liquefaction in areas subject to earthquakes.

I.3 Foundation design

I.3.1 General

The foundation should be designed to transmit all of the loads to a suitable load bearing strata, and to be able to accommodate the anticipated differential and total settlement without distress.

I.3.2 Loading conditions

The different stages in the life of the structure should be considered in the design of the foundations, i.e. construction, testing, commissioning, service and maintenance. Exceptional events also need to be considered. The normal service loads and the exceptional loads that need to be taken into account are given in Clause **7**.

I.3.3 Allowable soil loading

The allowable load bearing capacity should be decided on the basis of the geotechnical investigation, giving due consideration to the accuracy of predictions of the ultimate load bearing capacity and settlement.

I.3.4 Settlement

The foundation designer should determine the predicted maximum total and differential settlements for the life of the facility so that comparison can be made with permissible settlements.

The permissible differential settlements are the maximum allowable design limits for deformation of the tank after allowance has been made for construction tolerances. These may comprise combinations of:

a) tilt of the tank;

b) tank floor settlement along a radial line from the periphery to the tank centre;

c) settlement around the periphery of the tank.

The considerations affecting the limits of permissible settlement include, but are not necessarily limited to:

1) dimensions and aspect ratio of the tank and the stiffness of its foundation;

2) stiffness of the tank and its components;

3) reliability of the investigation;

4) possibility of any interactive effects with adjacent tanks or structures and integral earth embankments.

Settlement calculations are of limited accuracy even with detailed investigation and sophisticated analysis. Tank foundations should therefore be designed using safety margins.

Where significant settlement is predicted, it is recommended that actual settlements are monitored during the various phases covering the complete life of the installation including construction, hydrostatic testing, commissioning and operation. The monitoring frequency should be commensurate with the predicted time and load dependent rate of change of settlement.

I.3.5 Soil improvement and piling

If the subsoil supporting the foundations is weak and inadequate to carry the load of the filled tank, the following methods of improvement may be considered.

a) Removal and replacement of unsatisfactory material by suitable compacted granular fill that is not frost susceptible;

b) Improvement of the soft or loose materials by vibration or dynamic compaction;

c) Pre-loading with a temporary overburden;

d) Enhanced subsoil drainage with or without pre-loading;

e) Stabilisation by chemical or grout injection methods;

f) Piling.

I.3.6 Drainage

Areas around storage tanks should be properly drained away from the tank to prevent water accumulation, including firewater run off, where applicable, around the foundations.

Control systems should be provided to prevent the product contaminating the drainage system in the event of spillage.

I.3.7 Resistance to uplift

Anchorages are required to resist uplift of the shell due to the effects of internal tank vapour pressure (and wind load or earthquake when applicable). Anchorages are specified in Clause 12.

I.3.8 Membrane vapour barrier

Where a membrane barrier is provided, the membrane should be below and around the material supporting the tank. In the selection of the membrane, consideration should be given to the temperature and stresses to which it may be subject in service and under exceptional conditions. Only materials that have been proved capable of retaining their impermeability in these conditions should be used. If the membrane takes the form of a coating applied to the concrete slab, its coefficient of thermal expansion/contraction should be compatible with that of concrete throughout the relevant temperature range.

I.4 Types of foundations

I.4.1 General

One of the following four types of foundations should be used for storage tanks:

- Pad (see Figure I.1)
- Concrete ring beam (see Figure I.2)
- Concrete surface raft (see Figure I.3)
- Pile supported raft

I.4.2 Pad foundations

The material in the foundation should serve to raise the tank above the surrounding area and provide a competent founding material for the tank.

The foundation should comprise a surface dressed coating of bitumen-sand mix to a minimum depth of 50 mm.

The top surface of the pad should incorporate a permeable free draining layer of suitable filter material.

A geotextile separator material should be laid underneath the free draining layer so as to prohibit the contamination of the free draining layer from the underlying fill material.

The fill material should replace any pockets of soft soil or loose material and be spread in layers. After compaction, each layer should, if voids remain, be blinded with an approved class of granular material, so that all surface voids are filled before any further fill material or granular material is constructed.

Where necessary an annular ring of coarse granular material should be provided to distribute the edge loads into the surrounding foundation media.

75 mm drainage pipes should be provided at no more than 5 m centres around the perimeter of the free draining layer.

Appropriate gradients should be provided to all finished surfaces to ensure natural draining of the tank area.

I.4.3 Ring beam foundations

Where the surface and sub-surface soils have the capability to support adequately all applied loads from the tank and contents, an earth mound foundation may be considered. A concrete ring beam may be required to resist uplift of the tanks and provide a foundation for high tank shell loads. The ring beam should be designed to withstand horizontal pressures from the contained earth mound including all surface effects from the tank and contents. Some form of transition support is advisable between the inside of the ring beam and the compacted earth mound, to smooth out sharp changes in settlement.

I.4.4 Surface raft foundations

Where sub-surface soils exhibit suitable characteristic properties to support all possible loads, a soil supported reinforced concrete surface raft may be suitable. Such a raft or slab normally incorporates an increased thickness as necessary under the shell of the tank, depending on the dead loads (concrete, steel etc.) and imposed loads (including exceptional loads) that apply.

In the design of the slab, provision should be made to accommodate the effects of local differential settlements, drying shrinkage, creep and thermal strains during service or under upset conditions. Such provisions may involve:

- additional reinforcement;
- prestress;
- constructing the slab in bays. In this case, the construction joints should incorporate suitable barriers to prevent the passage of liquid, gas or water vapour;
- the use of special curing techniques and/or concrete admixtures.

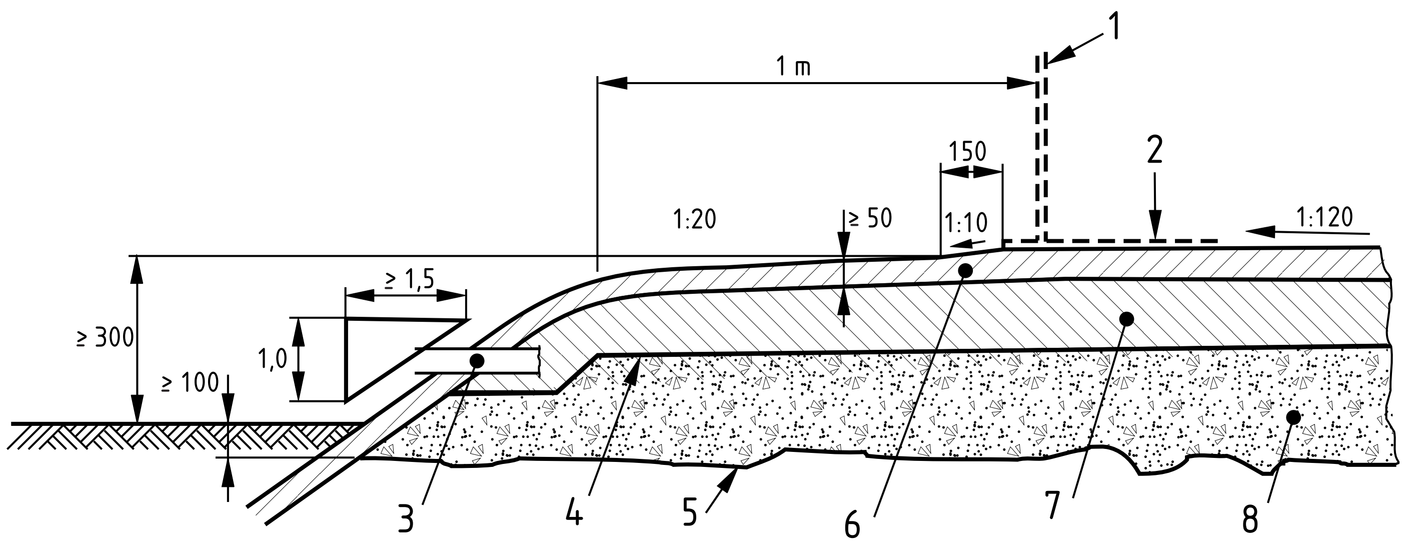
I.4.5 Pile supported raft

I.4.5.1 When subsoil conditions do not permit a soil supported foundation, the slab may be supported on piles.

The slab design should take account of potential variations in pile stiffness. The integrity of the piles should be checked on completion of the installation. Unless the design of the piling system is such that it is possible to prove the integrity of each pile by field tests, consideration should be given to designing the slab and pile system to accommodate redistribution of load to adjacent piles in the event of failure of an individual pile.

I.4.5.2 Drying shrinkage, creep and thermal changes will cause horizontal deformations in the slab, the amount of deformation decaying towards the centre of the slab. Vertical thermal gradients and variations of the overall settlement will also tend to induce moments in the slab and piles. For these effects, consideration should be given to the fact that the cracking reduces the stiffness of the slab. Careful consideration should be given to the joint between pile supports and the base slab. If the subsoil characteristics are suitable, closely spaced short slender piles could be rigidly connected to the base slab. Where large diameter in-situ formed piles are used, it may be possible to use rigid connections for the piles near the centre of the tank, and provide a sliding joint for the remainder.

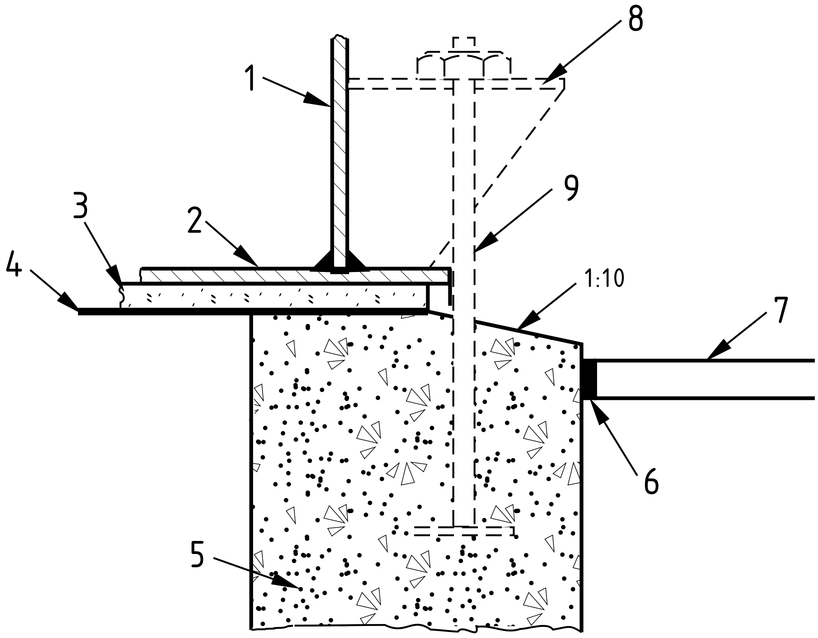
I.4.5.3 It is essential that attention be given to possible problems of ground heave and/or pile heave, if a displacement pile system is adopted.



Key

1	Tank shell	3	Drain pipe	5	Geotextile	7	Compacted sand
2	Tank bottom	4	Membrane	6	Bitumen sand mix	8	Compacted crushed rock

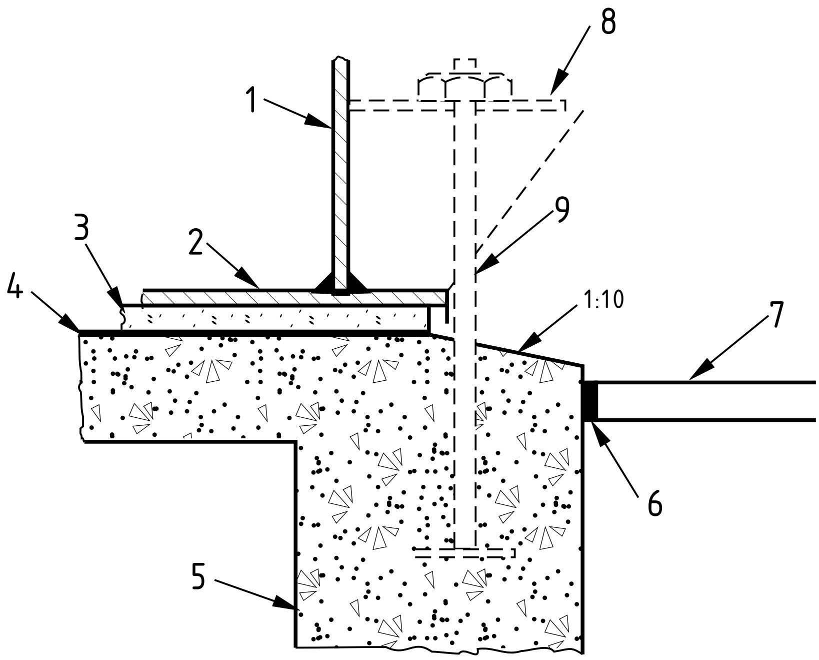
Figure I.1 — Typical tank pad foundation



Key

1	Tank shell	4	Membrane	7	Bund surface
2	Tank bottom	5	Foundation ring	8	Chair (when required)
3	50 mm sand/bitumen	6	Auxiliary seal	9	Holding down bolt (when required)

Figure I.2 — Typical concrete ring beam foundation



Key

1	Tank shell	4	Membrane	7	Bund surface
2	Tank bottom	5	Foundation raft	8	Chair (when required)
3	50 mm sand/bitumen	6	Auxiliary seal	9	Holding down bolt (when required)

Figure I.3 — Typical concrete raft foundations

Annex J
(informative)

Example calculations of stiffening rings (wind girders)

J.1 General

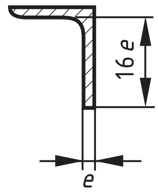
Stiffening rings (wind girders) can be formed from standard steel angles conforming to EN 10056-1, channels conforming to EN 10279, and from folded plate of material equivalent to the material of the shell to which it is attached.

J.2 Section moduli

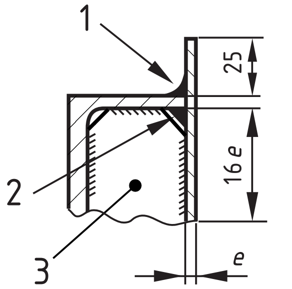
When calculating the section modulus of the wind girder, part of the shell itself up to a maximum of 16*e* above and below the point of attachment, can be used.(see Figure J.1).

J.3 Worked examples of design of secondary stiffening rings (wind girders)

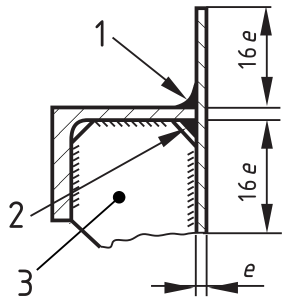
The following two worked examples serve to illustrate how the requirements of 9.3.3. are applied to the design process.



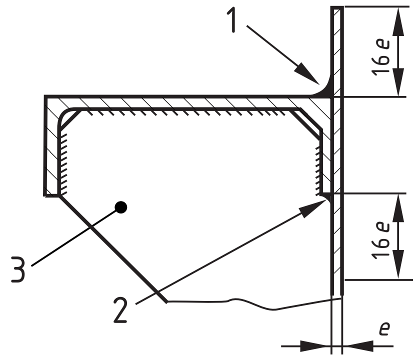
a) Top corner ring



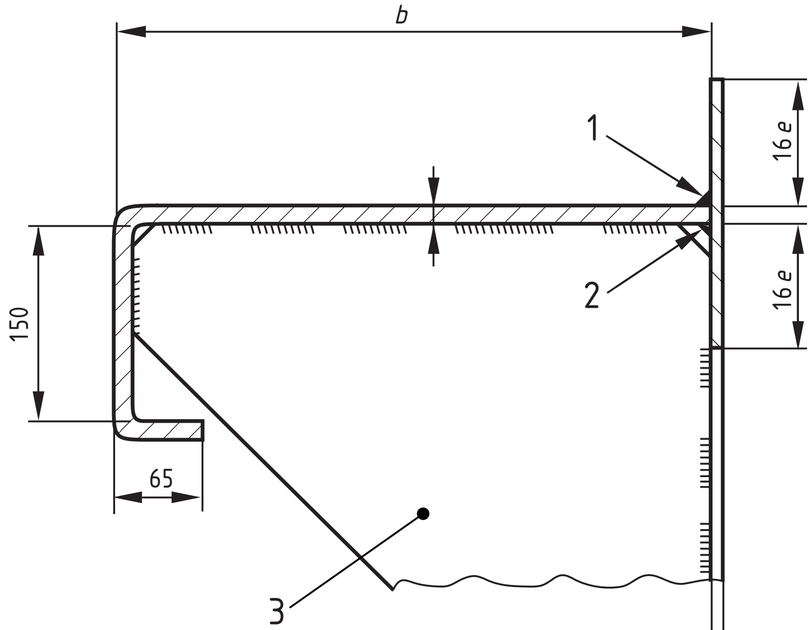
b) Top corner ring



c) Single angle



d) Channel



e) Formed plate

Key

1 Continuous fillet weld 2 Intermittent weld 3 Bracket

Figure J.1 — Sections through stiffening rings (wind girders)

J.4 Example 1

A floating-roof tank 95 m diameter, 20 m high having eight 2,5 m courses of thicknesses 12,0, 12,0, 14,2, 19,7, 24,7, 29,8, 34,9 and 39,9 mm is to be designed for a wind speed of 60 m/s. The primary ring is located 1,0 m from the tank top. How many secondary stiffening rings are required and what are their sizes and location?

Course	h	e	H_e
	m	mm	m
8	1,5	12,0	1,5000
7	2,5	12,0	2,5000
6	2,5	14,2	1,6412
5	2,5	19,7	0,7240
4	2,5	24,7	0,4113
3	2,5	29,8	0,2572
2	2,5	34,9	0,1733
1	2,5	39,9	0,1240
		H_E =	7,3310 m

V_w = 60 m/s, p_v = 5 mbar, so K = 6,040644 (J.1)

Hence

$$H_p = 6{,}040644\sqrt{\frac{12^5}{95^3}} = 3{,}254 \text{ m} \quad \text{(J.2)}$$

Since $2H_p < H_E < 3H_p$, two secondary stiffening rings are required.

These are ideally located at $H_E/3$ and $2H_E/3$, i.e. 2,444 m and 4,888 m below the primary ring on the shell of equivalent height H_E.

The upper ring is on a shell course of minimum thickness, so no adjustment of its location is needed.

The lower ring is not on a course of minimum plate thickness, so an adjustment is needed and its position below the primary ring will be:

$$\{4{,}888 - (1{,}5 + 2{,}5)\}\sqrt{\left(\frac{14{,}2}{12{,}0}\right)^5} + 4{,}0 = 5{,}353 \text{ m} \quad \text{(J.3)}$$

The secondary rings are thus 2,444 m and 5,353 m below the primary ring, and are angles 200 mm × 100 mm × 12 mm.

J.5 Example 2

A fixed-roof non-pressure tank 48 m diameter 22,5 m high having nine 2,5 m courses of thicknesses 8, 8, 10,6, 14,3, 17,9, 21,6, 25,3, 29 and 32,6 mm is to be designed for a wind speed of 55 m/s. How many and what is the location and size of secondary stiffening rings?

Course	h	e	H_e
	m	mm	m
9	2,5	8,0	2,500
8	2,5	8,0	2,500
7	2,5	10,6	1,237
6	2,5	14,3	0,585
5	2,5	17,9	0,334
4	2,5	21,6	0,209
3	2,5	25,3	0,141
2	2,5	29,0	0,100
1	2,5	32,6	0,075
		H_E =	7,681 m

V_w = 55 m/s, p_v = 5 mbar, so K = 6945 (J.4)

Hence

$$H_p = 6{,}945\sqrt{\frac{8^5}{48^3}} = 3{,}780 \text{ m} \quad \text{(J.5)}$$

Since $2H_p < H_E < 3H_p$, two secondary stiffening rings are required.

These are ideally located at $H_E/3$ and $2H_E/3$, i.e. 2,561 m and 5,122 m from the tank top.

The upper ring is on a shell course of minimum plate thickness, so no adjustment is needed.

The lower ring is not on a course of minimum plate thickness, so an adjustment is needed and its position from the tank top will be:

$$(5{,}122 - 5{,}0)\sqrt{\left(\frac{10{,}6}{8{,}0}\right)^5} + 5{,}0 = 5{,}250 \text{ m} \quad \text{(J.6)}$$

The secondary rings are therefore 2,561 m and 5,250 m from the top and are angles 150 mm × 90 mm × 10 mm.

Since the top stiffener comes within 150 mm of a horizontal seam, it has to be moved. Whether it is moved up say 211 mm to 2,35 m or down say 89 mm to 2,65 m from the tank top, the three portions of the tank are still stable against the design conditions as the positions resulting from moving the upper stiffener either up or down still gives a distance between the stiffeners less than H_p (= 3,78 m).

Annex K
(normative)

Design rules for tanks with frangible roof to shell joints

K.1 General

Unanchored fixed roof storage tanks which have:

— a self supporting cone or dome roof without roof supporting structure;

— a column supported cone roof;

shall be in accordance with Table K.1 and paragraphs K.2 to K.4.

Table K.1 — Characteristics of cone or dome roofs

Symbol	Description		Value
D_F	Internal diameter of tank with frangible roof to shell joint		≥ 5000 mm
D_r	Effective diameter for calculation purposes		
e_a	Annular plate thickness	(corroded condition)	≥ 5 mm
e_{cyl}	Upper course thickness	(non-corroded condition)	≥ 5 mm
e_{cylb}	Lower course thickness	(corroded condition)	≥ 5 mm
e_{ring}	Reinforcing ring thickness	(non-corroded condition)	≥ 5 mm
e_{roof}	Roof thickness	(non-corroded condition)	≥ 5 mm
R_1	Radius of dome roof (see Figure K.2)		
tan θ	Slope of a cone roof (see Figure K.1) or Slope of the tangent to the meridian at the roof-to-shell connecting point for a dome roof (see Figure K.2) where $0{,}8\ D_r \le R \le 1{,}5\ D_F$		1/16 to 1/5
NOTE For the arrangements shown in Figures K.3 a) and b) and Figures K.4 a) to d) $D_r = D_F$			

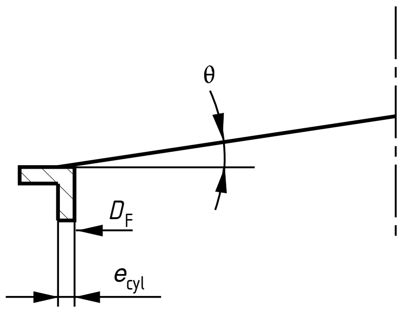


Figure K.1 — Cone roof

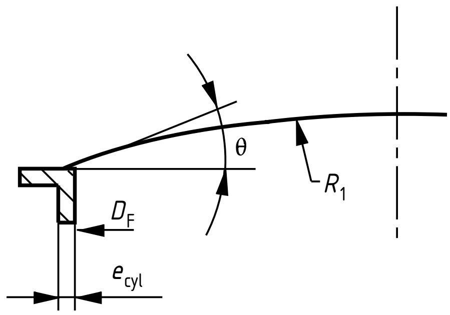


Figure K.2 — Dome roof

K.2 Construction

Roof plates shall not be attached to the internal roof supporting structure.

A curb angle welded to the top corner ring and intended to support insulation or other fittings shall be permissible, if the section of this angle is less than or equal to 15 % of the section of the top corner ring.

The requirements specified in K.4 shall apply to tanks with butt welded annular plates. For tanks without annular plates, the minimum length of bottom plate weld of 150 mm specified in 8.4.3 shall be increased to 500 mm to make the tanks applicable for a frangible roof-to-shell junction.

Where these design rules are not met, the method of assessing frangibility shall be subject to agreement (see A.2).

NOTE The pressure calculated hereafter should only be used to check the frangibility of a tank, and not for any other purpose.

K.3 Materials

Carbon and carbon manganese steels with a maximum allowable strength ≤ 260 N/mm^2 shall be used for the shell upper course, stiffening rings and roof.

The mechanical characteristics of the lower course and annular or bottom plates shall be equal to or greater than those of upper course and roof plates.

K.4 Design rules

The unstiffened length l_{cyl} and l_{cylb} in metres, of the upper and lower courses shall meet the following requirements:

$$l_{cyl} \geq 2{,}5\sqrt{\frac{D_F\ e_{cyl}}{2000}} \quad \text{for the upper course} \tag{K.1}$$

$$l_{cylb} \geq 2{,}5\sqrt{\frac{D_F\ e_{cylb}}{2000}} \quad \text{for the lower course} \tag{K.2}$$

For the roof-to-shell junction of tanks without anchorage to be considered frangible, the following design calculations shall be carried out:

a) The design roof failure pressure p_r in mbar shall be calculated as follows:

1) for arrangements shown in Figure K.3

$$p_r = \alpha_1 \left\{\frac{\min\left(e_{ring}\ ;\ e_{roof}\right)}{D_r}\right\}^{\alpha_2} \left[\tan\theta\right]^{\alpha_3} \left\{\frac{e_{cyl}}{D_F}\right\}^{\alpha_4} \tag{K.3}$$

for arrangements shown in Figure K.4

$$p_r = \alpha_1 \left\{\frac{\min\left(e_{cyl}\ ;\ e_{roof}\right)}{D_r}\right\}^{\alpha_2} \left[\tan\theta\right]^{\alpha_3} \left\{\frac{e_{cyl}}{D_F}\right\}^{\alpha_4} \tag{K.4}$$

where

$\alpha_1 = 2{,}175 \times 10^7$

$\alpha_2 = 1{,}253$

$\alpha_3 = 0{,}18$

$\alpha_4 = 0{,}14$

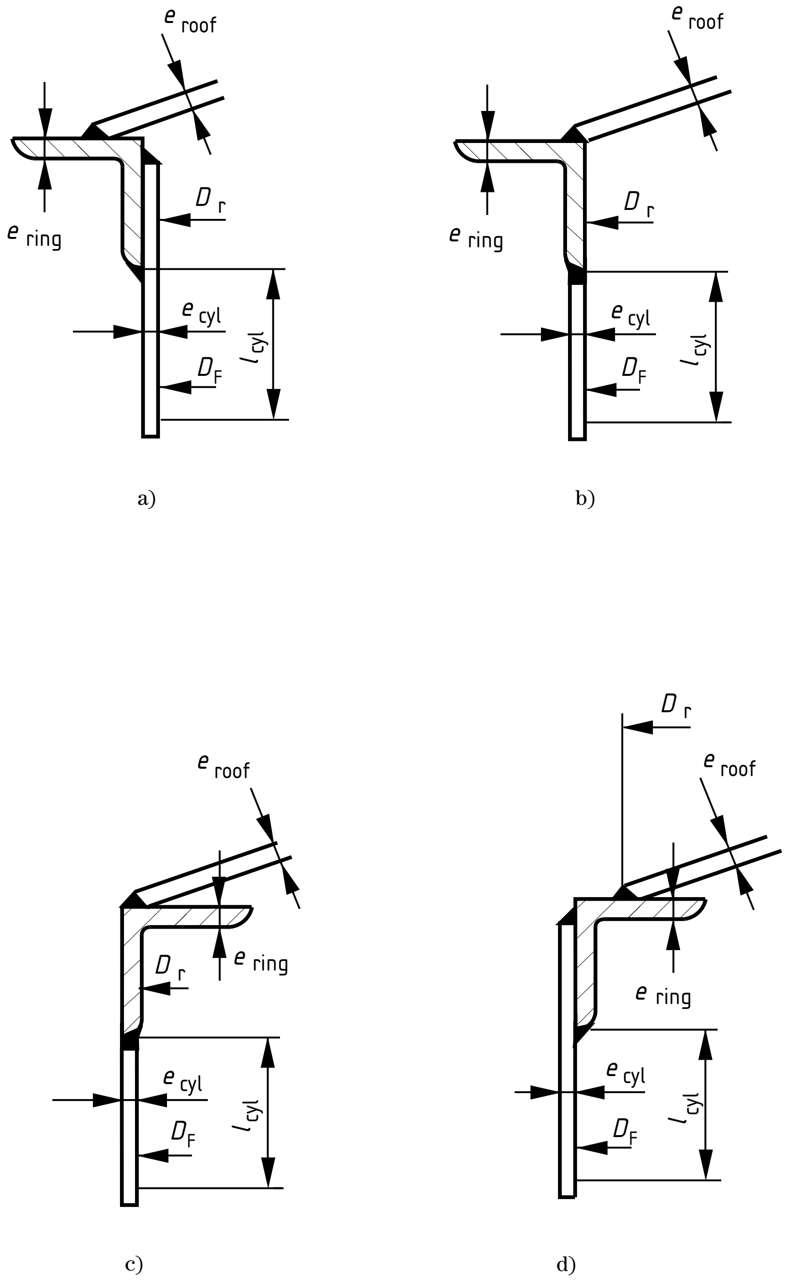


Figure K.3 — Roof to upper course junctions: roof welded to ring

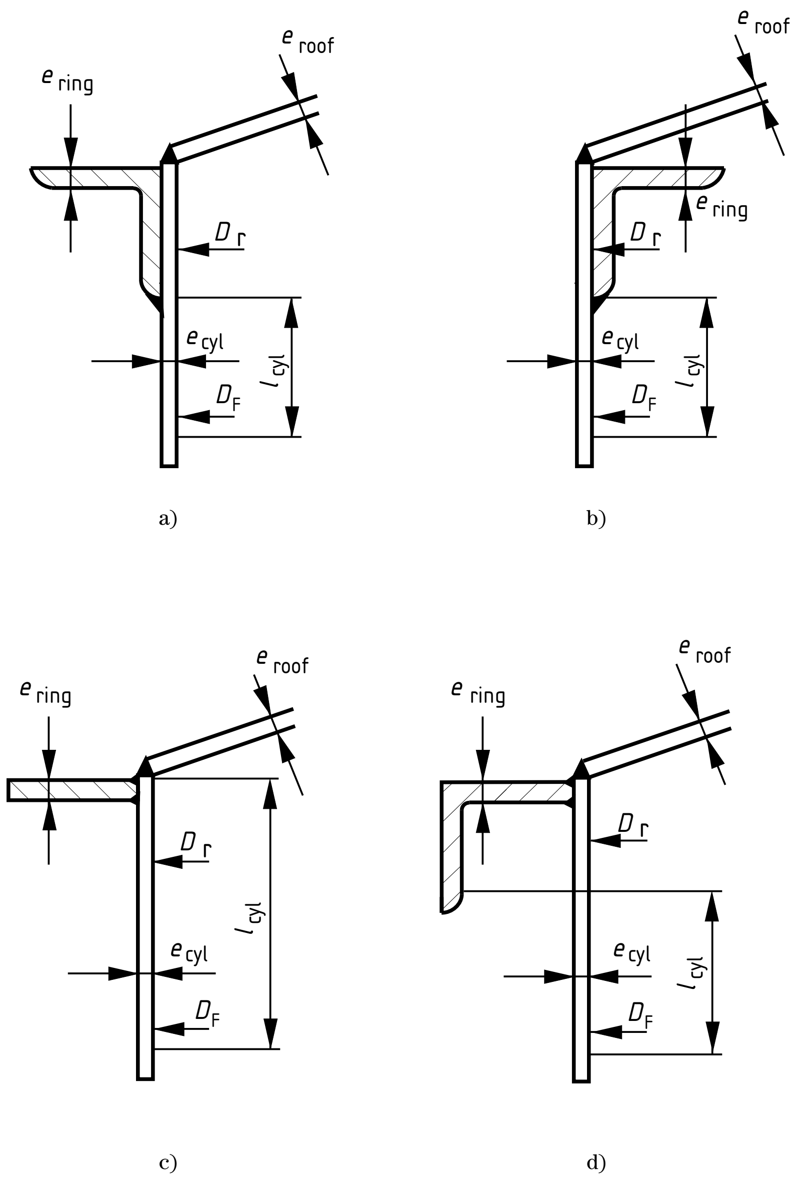


Figure K.4 — Roof to upper course junctions: roof welded to the upper course

b) The design bottom failure pressure p_b in mbar shall be calculated as follows:

$$p_b = (\beta_0 + \beta_1 X + \beta_2 X^2)\ \varepsilon \qquad \text{(K.5)}$$

where

$$\varepsilon = \min\ [\{(242{,}64X + 0{,}45) + 0{,}65Y^{10}\};\ 1] \qquad \text{(K.6)}$$

$$X = \frac{\min(e_{\text{cylb}}\ ;\ e_{\text{a}})}{D_{\text{F}}} \qquad \text{(K.7)}$$

$$Y = \frac{\min(e_{\text{cylb}};e_{\text{a}})}{\max(e_{\text{cylb}};e_{\text{a}})} \qquad \text{(K.8)}$$

$$\beta_0 = 37{,}40 \qquad \text{(K.9)}$$

$$\beta_1 = 7{,}56 \times 10^5 \qquad \text{(K.10)}$$

$$\beta_2 = 1{,}48 \times 10^8 \qquad \text{(K.11)}$$

c) Then these design pressures shall verify the following formula:

$$p_b \geq 2\ \gamma p_r \qquad \text{(K.12)}$$

where

γ is the agreed safety coefficient ($1 < \gamma \leq 1.5$) (see A.2).

NOTE The thickness and/or the length of the annular plate should be checked according to 8.3.2 and 8.4.1, when the thickness of the lower course and/or the annular plates is increased in order to meet frangibility criteria.

Annex L
(normative)

Requirements for venting systems

L.1 General

This annex gives requirements for the normal pressure, normal vacuum and emergency venting of fixed-roof tanks with or without internal floating roofs constructed to conform to this document.

Provision is made to enable evaluation of venting requirements arising from the following sources.

a) Normal pressure venting requirements resulting from the maximum specified rate of import of product to the tank;

b) Normal pressure venting requirements resulting from the maximum anticipated increase in tank surface temperature;

c) Normal vacuum venting requirements resulting from the maximum specified rate of export of product from the tank;

d) Normal vacuum venting requirements resulting from the maximum anticipated decrease in tank surface temperature;

e) Emergency pressure venting requirements resulting from the exposure of the tank to an external fire.

f) Other emergency conditions (see L.4.3, L.4.4 and L.5).

Under normal operating conditions it shall not be possible to isolate the venting system from the tank, and the venting system shall be sized to prevent the design pressure and the design internal negative pressure of the tank being exceeded for all operating conditions.

For the sizing of venting systems, the maximum flow rates of the pumps as well as of the maximum possible flow rates caused by thermal influence shall be taken into account in the total venting requirements.

NOTE For other influences which might lead to an increase of flow rate, see L.4 and L.5.

The venting systems shall be protected against penetration of rain water, foreign matter, condensation, polymerisation and sublimation of product, and freezing of water or product condensate.

The systems shall be resistant against corrosion for the operating conditions for which they are intended.

If extremely high outbreathing rates are necessary due to a fire on the external surfaces of the tank or malfunction of special tank equipment (e.g. tank blanketing system), additional emergency relief valves shall be used, or the tank shall meet the requirements of Annex K.

L.2 Types of vents and valves

L.2.1 General

Outbreathing and inbreathing flow requirements for free vents and valves shall be determined in accordance with L.3, L.4 and L.5.

L.2.2 Free vents for outbreathing and inbreathing

Free vents shall be applied to non-pressure tanks only.

L.2.3 Pressure and vacuum relief valves

Pressure and vacuum relief valves shall be applied to low-pressure tanks, high-pressure tanks and very high-pressure tanks.

The overpressure (accumulation) shall be considered for the design of pressure and vacuum relief valves, i.e. the chosen value for valve set pressure or set vacuum shall neither exceed tank design pressure nor design internal negative pressure at the required flow capacity.

L.2.4 Vent pipes

When designing pipework to the pressure/vacuum relief valve (pipe-away valve), the influence of the following shall be considered on the valve set pressure, the valve set vacuum and on the flow rate:

a) flow resistance of pipes, bends and installed equipment;

b) possible back pressure or vacuum within the system.

L.2.5 Emergency venting valves

Tanks connected with a pipe-away system (flares, vapour recovery plants) or tanks with blanketing systems, shall be fitted with an additional venting system, or emergency venting valves to handle the total venting requirements for tank outbreathing into the atmosphere and tank inbreathing from the atmosphere.

The pressure and vacuum settings of these valves shall be arranged to ensure that these valves do not relieve during normal operating conditions, i.e. during full flow rate of the normal pressure and vacuum relief valves.

NOTE For the sizing of the emergency valves, the flow capacity of the normal pressure and vacuum relief valves can be taken into account.

L.2.6 Venting systems with flame arresting capability

When specified (see A.1), the venting systems shall be capable of preventing the transmission of flame into the tank when storing flammable liquids that can lead to an explosive atmosphere in the tank.

NOTE Attention is drawn to possible local regulations.

L.3 Calculation of maximum flow rates for normal outbreathing and inbreathing

L.3.1 General

Outbreathing and inbreathing of vents and valves shall be a combination of pump capacity and thermal effects.

L.3.2 Pump capacities

L.3.2.1 Outbreathing

The outbreathing shall be:

a) The maximum specified pump filling capacity for the tank for products stored below 40 °C or with a vapour pressure less than 50 mbar.

$$U_{op} = U_{pf} \tag{L.1}$$

where

U_{op} is the outbreathing venting requirement, in normal m^3/h of air;

U_{pf} is the maximum filling rate, in m^3/h.

b) For spiked products (e.g. with methane) the maximum venting capacity shall be increased by a multiplication factor of 1,7 to correct the pumping rate to take into account the gas evolved from spiked products during the filling process.

$$U_{op} = 1{,}7 U_{pf} \tag{L.2}$$

c) For products stored above 40 °C or with a vapour pressure greater than 50 mbar, the outbreathing shall be increased by the evaporation rate which shall be specified (see A.1).

L.3.2.2 Inbreathing

The inbreathing shall be the maximum specified pump discharging capacity for the tank.

$$U_{ip} = U_{pe} \tag{L.3}$$

where

U_{ip} is the inbreathing venting requirement, in normal m^3/h of air;

U_{pe} is the maximum rate of pump discharging, in m^3/h

L.3.3 Thermal outbreathing and inbreathing

L.3.3.1 General

Thermal outbreathing and inbreathing due to atmospheric heating or cooling of the external surfaces of the tank, comprising the area of the shell and the projected area of the roof, shall be considered.

L.3.3.2 Thermal outbreathing

L.3.3.2.1 Tanks without insulation

The maximum possible flow rate caused by heating shall be calculated in accordance with the following formula:

$$U_{OT} = 0{,}25 V_T^{0{,}9} R_o \quad \text{(L.4)}$$

and

$$R_o = \left(1 - \frac{\Delta P_{ap}}{140}\right)^{1{,}6} \quad \text{(L.5)}$$

where

ΔP_{ap} is the accumulation pressure, in mbar gauge;

NOTE 1 If ΔP_{ap} is < 5 mbar or unknown, use $R_o = 1$.

R_o is the reduction factor for thermal outbreathing;

U_{OT} is the thermal outbreathing - maximum thermal flow rate for heating up, in normal m^3/h of air;

V_T is the tank volume, in m^3.

NOTE 2 The factor 0,25 is valid for latitudes between 58 ° to 42 °.
North of 58 ° latitude, use factor 0,2 and south of 42 ° latitude, use factor 0,32.

L.3.3.2.2 Tanks with insulation or a containment tank

The thermal flow rate for heating is reduced when the tank is partially or completely insulated or fitted with a containment tank (see L.3.3.4 and L.3.3.5).

L.3.3.3 Thermal inbreathing

L.3.3.3.1 Tanks without insulation

The maximum possible flow rate caused by cooling down shall be calculated in accordance with following formula:

$$U_{IT} = C V_T^{0{,}7} R_I \quad \text{(L.6)}$$

$$R_I = \left(1 - \frac{\Delta P_{av}}{140 + P_{vp}}\right)^{1{,}6} \quad \text{(L.7)}$$

where:

C is 3 for hexane and products with a similar vapour pressure and stored at temperatures below 25 °C;

C is 5 for products with a vapour pressure higher than hexane and, or stored at temperatures of 25 °C or above;

NOTE 1 If vapour pressure is unknown, use C = 5.

NOTE 2 The factors C = 3 and C = 5 are valid for latitudes between 58 º and 42 º. North of 58 º latitude, use factor C = 2,5 and C = 4, and South of 42 º latitude, use factor C = 4 and C = 6,5.

P_{vp} is the vapour pressure of the liquid at highest temperature, in mbar;

NOTE 3 If P_{vp} is unknown, use R_I = 1.

ΔP_{av} is the accumulation vacuum, in mbar gauge internal negative pressure;

R_I is the reduction factor for thermal inbreathing;

U_{IT} is the maximum thermal flow rate during cooling down, in normal m^3/h of air;

V_T is the tank volume, in m^3.

L.3.3.3.2 Tanks with insulation or containment tank

The thermal flow rate for cooling down is reduced when the tank is partially or completely insulated or fitted with a containment tank (see L.3.3.4 and L.3.3.5).

L.3.3.4 Reduction factor for tanks with insulation

The thermal flow rate for heating up (thermal outbreathing) or cooling down (thermal inbreathing) is reduced by insulation and depends upon the quality and thickness of the insulation.

Reduction factor for complete insulation, R_{in}, shall be given by:

$$R_{in} = \frac{1}{1 + \frac{hL_{in}}{\lambda_{in}}} \tag{L.8}$$

where

h is the heat transfer coefficient, in W/m^2K;

L_{in} is the wall thickness of the insulation, in m;

λ_{in} is the thermal conductivity, in W/mK.

NOTE For an insulation thickness L_{in} = 0,1 m and a thermal conductivity of the insulation λ_{in} = 0,05 W/mK as well as an inside heat transfer coefficient of h = 4 W/m^2K (these are values often used in practice) the reduction factor is R_{in} = 0,11.

For partial insulation, the reduction factor R_{inp} shall be given by:

$$R_{inp} = \frac{A_{inp}}{A} R_{in} + \left(1 - \frac{A_{inp}}{A}\right) \tag{L.9}$$

where

A is the total tank surface area (shell and roof) in m^2;

A_{inp} is the insulated surface area of the tank, in m^2.

L.3.3.5 Reduction factor for tanks with containment tank

For tanks with an additional collecting tank (containment tank) the reduction factor, R_c, shall be given by:

$$R_c = 0,25 + 0,75 \frac{A_c}{A} \tag{L.10}$$

where

A_c is the tank surface area not inside of the containment tank (part of shell and roof), in m^2.

L.4 Calculation of maximum flow rates for emergency pressure venting

L.4.1 General

In the case of external fire, or malfunction of other systems (i.e. of blanketing system) very high outbreathing capacities may be needed. If the existing pressure relief valves for normal operating conditions are not capable of handling such high capacities, emergency outbreathing systems shall be provided.

The emergency relief shall be capable of handling any combination of possible malfunctions in addition of the flow required for fire.

L.4.2 Fire

L.4.2.1 General

The tank can be heated up by a nearby fire leading to a sudden large expansion of the gas volume in a few minutes, and after hours to a full evaporation of the product (product boiling).

Emergency vent valves shall be fitted, unless the requirements of Annex K are met.

Sizing of emergency valves depends upon the maximum allowable tank operating pressure as well as the flow rate determined in accordance with L.4.2.2 or L.4.2.3. When a product boiling is not possible, it shall be sufficient to calculate the capacity of the emergency vent on the basis of the gas expansion situation (see L.4.2.2).

When product boiling is possible, the capacity of the emergency vent shall be calculated for evaporation of product (see L.4.2.3).

NOTE The flow capacity of normal pressure relief venting may be taken into account in sizing the emergency venting.

L.4.2.2 Flow rate by gas expansion in case of fire

The flow rate shall be given by:

$$U_{FE} = 15\ V_T^{0,7}\ R_{inf} \qquad R_{inf} = \frac{1}{1 + \frac{h_f L_{in}}{\lambda_{in}}} \qquad h_f = \frac{40}{A_w^{0,18}} \qquad \text{(L.11)}$$

where

A_w is the surface area of the tank shell heated by fire, in m²;

NOTE Only heights up to 9 m above the tank bottom have to be considered.

h_f is the heat transfer coefficient, in W/m²K;

L_{in} is the wall thickness of insulation, in m;

R_{inf} is the reduction factor for insulation (if available) in case of fire;

U_{FE} is the flow rate by gas expansion in case of fire, in normal m³/h of air;

V_T is the tank volume, in m³;

λ_{in} is the thermal conductivity, in W/mK.

L.4.2.3 Flow rate by evaporation of product (Product boiling)

The flow rate shall be given by:

$$U_{FB} = 4 \times 10^4\ A_W^{0,82}\ \frac{R_{inf}}{H_v}\sqrt{\frac{T}{M}} \qquad \text{(L.12)}$$

where

A_w is the surface area of the tank shell heated by fire, in m² (see L.4.2.2);

H_v is the heat of vaporisation, in kJ/kg;

M is the molar weight of the product, in kg/kmol;

R_{inf} is the reduction factor for insulation (see L.4.2.2);

T is the boiling temperature, in K;

U_{FB} is the flow rate by evaporation, in normal m³/h of air.

NOTE 1 For hexane (M = 86 kg/kmol; H_v = 335 kg J/kg; T = 342 K) and similar products, and R_{inf} = 1, the equation simplifies to:

$U_{FB} = 238\ A_w^{0,82}$

NOTE 2 The flow rate calculated for evaporation of product (see L.4.2.3) will always cover the flow rate required for gas expansion (see L.4.2.2).

L.4.3 Malfunction of blanketing system

If the inert gas blanketing system malfunctions, high quantities of gas can be introduced into the tank and this excess gas shall be vented from the tank by the tank venting and emergency venting system without exceeding the tank design pressure.

The maximum possible gas flow under fault conditions shall be specified (see A.1).

L.4.4 Other possible causes

The emergency flow capacity required to allow for other possible causes shall be specified (see A.1).

These shall include:

a) malfunction of tank heating regulators (if applicable);

b) leakage of tank heating system (if applicable);

c) exceeding the maximum allowable pumping capacity due to wrong connections within the pumping systems;

d) chemical reactions;

e) poor pipe cleaning;

f) product transfer by pressurized gas.

L.5 Emergency vacuum venting

The emergency vacuum flow capacity required to allow for the following possible causes shall be specified (see A.1):

a) a sudden cool-down due to cold liquid being sprayed into a hot, empty tank;

b) malfunction of a sprinkler system;

c) excessive liquid flow out of the tank.

L.6 Testing venting devices

L.6.1 General

L.6.1.1 Flow capacity

The flow capacity for pressure/outbreathing and the flow capacity for vacuum/inbreathing shall be established in accordance with the methods described in L.6.3. These methods shall apply to free vents as well as to pressure and/or vacuum valves (end-of-line valves and in-line valves).

L.6.1.2 Flow capacity curves

The flow capacity curves shall be measured for each type of device and for every nominal size.

L.6.1.3 Tests

Tests shall be carried out with air at ambient temperature, unless otherwise agreed between the purchaser and device manufacturer.

Flow capacity curves or formula shall refer to air at normal conditions (temperature 0 °C, pressure 1,013 bar, density 1,29 kg/m^3).

Test results with other fluids or different conditions shall be converted to air at standard conditions.

L.6.1.4 Plotting of capacity curves

The capacity curves shall be plotted for volume flow relative to tank pressure or vacuum (flow rate/pressure curves, flow rate/vacuum curves).

The accumulation pressure shall be stated.

NOTE 1 The flow capacity curves refer to clean devices, i.e. dirt substances adhering to the device which might reduce capacity, are not considered.

NOTE 2 It is recommended, that testing facilities, methods, procedures and results are supervised and confirmed by an independent party.

L.6.2 Test apparatus

L.6.2.1 General

The test apparatus shown in Figure L.1 is suitable for end-of-line venting devices and for in-line devices and shall consist of the following:

L.6.2.2 Test medium supply

The test medium supply (item 1) shall be a blower, a fan etc.

L.6.2.3 Volume flow measuring device

The flow meter (item 2) shall be calibrated annually.

NOTE It is recommended that a mass flow meter is used, in order to avoid conversion to standard conditions.

L.6.2.4 Test tank

For the test tank (item 3) the following shall be taken into account:

a) Flow velocity within the tank shall be ≤ 2,0 m/s, and the test tank shall be constructed to prevent high velocity jets from impinging on the venting device;

b) Pulsations which might possibly be generated by the test medium supply (e.g. blower or fan) shall be dampened to avoid errors in flow metering;

c) The entrance connection for the test medium shall be placed at the lower part of test tank;

d) In order to minimize the effect of entrance losses, the venting device to be tested (item 7) shall be mounted on top of the test tank;

e) The venting device shall be mounted on a straight-pipe that has the same nominal diameter as the test device, and a length (*L*) of 1.5 times of the diameter, and shall be placed vertically with its end flush with the inside of test tank;

f) For testing in-line valves, a pipe (item 8) shall be fitted to the discharge connection of the test device. This pipe shall have the same diameter as the discharge connection of the test device;

g) For testing vacuum valves, the flow direction shall be reversed, i.e. air is sucked through the test device into the test tank.

L.6.2.5 Pressure/vacuum measuring device

The measuring device (item 4) for pressure and vacuum shall be calibrated annually.

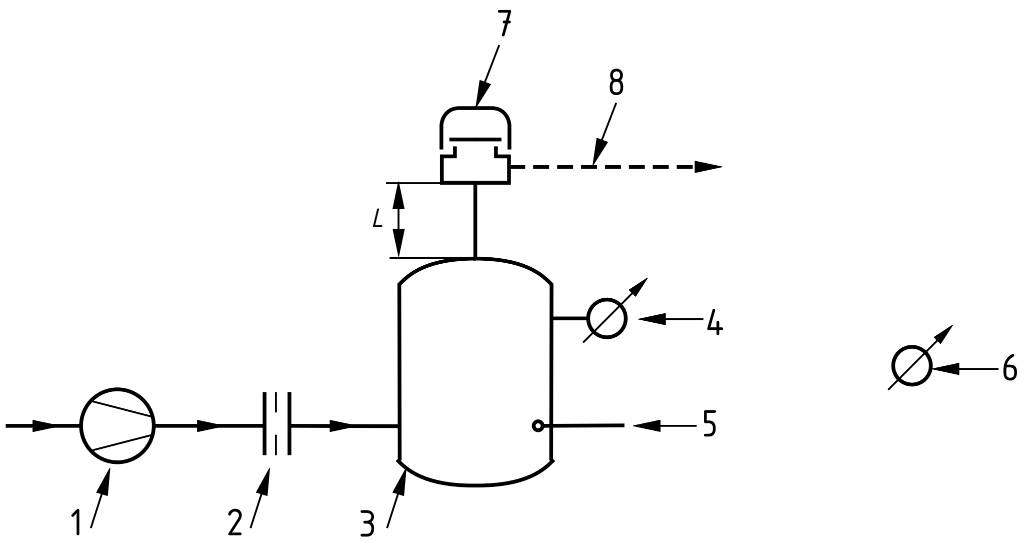
L.6.2.6 Temperature measuring device

The temperature measuring device (item 5) for measuring the temperature of test medium, shall be calibrated annually.

L.6.2.7 Barometer

Measuring device for atmospheric pressure (item 6).

NOTE When using a mass flow meter (item 2) it is not necessary to measure the temperature of the test medium and atmospheric pressure.



Key

1 Test medium supply (e.g. blower or fan)

2 Calibrated flow meter

3 Test tank

4 Calibrated measuring device for pressure and vacuum

5 Temperature measuring device

6 Barometer - measuring device for atmospheric pressure

7 Device to be tested

8 Pipe-away if fitted

L Length of connecting pipe (straight pipe nipple)

Figure L.1 — Test apparatus for flow testing of venting devices

L.6.3 Method

L.6.3.1 General

If pressure and/or vacuum devices are combined with flame arrestors, tests shall be done with the combined devices.

L.6.3.2 Free vents

Starting with zero flow, the tank pressure or vacuum shall be measured in five equal steps up to the maximum value of 50 mbar.

L.6.3.3 Pressure and vacuum valves

The flow capacity curves shall be determined for the lowest and for the highest set pressure and/or set vacuum, as well as for three intermediate settings.

Measuring of tank pressure or vacuum shall start at the corresponding adjusted valve setting (zero flow) and is continued in appropriate steps until the maximum value or fully open position.

NOTE 1 It is recommended that the volume flow is measured at tank pressures of 1,1; 1,2; 1,5 and 2 times the adjusted set pressure or vacuum. If full lift of the valve disc is not achieved at two times of adjusted valve setting, additional measuring points are required until the fully open position is reached.

NOTE 2 If several measuring points were determined after the valve had reached its fully open position, the curves may be extrapolated for higher pressure or vacuum.

L.7 Manufacturers documentation and marking of venting devices

L.7.1 Documentation

A certificate shall be issued by the manufacturer or supplier of the venting equipment recording the set pressure, the set vacuum, and the flow rate at the indicated overpressure or the tank design pressure, and tank design internal negative pressure.

NOTE It is recommended that the flow rate/pressure loss diagram (flow capacity curve) or coefficient of discharge for the relief valve should also be supplied.

L.7.2 Marking

L.7.2.1 General requirements

Each venting device (free vents, pressure and/or vacuum valves) shall be marked with all the required data. The marking shall be readable during the lifetime of the tank. The marking shall be placed on the valve or on a plate, or plates, securely fastened to the valve.

The required data shall be stamped onto, etched in, impressed on or cast in the valve or nameplate.

L.7.2.2 Free vents

The marking shall include the following as a minimum:

a) name or identifying trademark of the manufacturer;

b) manufacturer’s design or type number;

c) number and year of the appropriate European Standard;

d) pipe size of the device inlet;

e) rated capacity for the tank design pressure and tank design internal negative pressure, in m^3/h air at standard conditions.

L.7.2.3 Pressure relief valves

The marking shall include the following as a minimum:

a) name or identifying trademark of the manufacturer;

b) manufacturer’s design or type number;

c) number and year of the appropriate European Standard;

d) pipe size of the device inlet;

e) set pressure, in mbar;

f) rated capacity at the maximum relieving pressure (tank design pressure), in m^3/h air at standard conditions.

L.7.2.4 Vacuum relief valves

The marking shall include the following as a minimum:

a) name or identifying trademark of the manufacturer;

b) manufacturer's design or type number;

c) Number and year of the appropriate European Standard;

d) pipe size of the device inlet;

e) set vacuum, in mbar;

f) rated capacity at the maximum relieving vacuum (tank design internal negative pressure), in m^3/h air at standard conditions.

L.7.2.5 Combined pressure/vacuum relief valves

Each combined pressure/vacuum relief valve shall be marked in the manner as described in L.7.2.3 and L.7.2.4.

L.7.2.6 Venting devices with flame arresters

For venting devices combined with flame arresters, or with integrated flame arrester elements, the marking required in EN 12874, shall be added.

Annex M
(informative)

Tank anchorages

M.1 General

Various types of anchorage are suitable for storage tanks built to this document. The most appropriate detail for a specific application should be evaluated by the manufacturer and subject to agreement (see A.2). The following examples are not intended to preclude the use of other design details when so agreed between purchaser and contractor.

M.2 Holding down strap

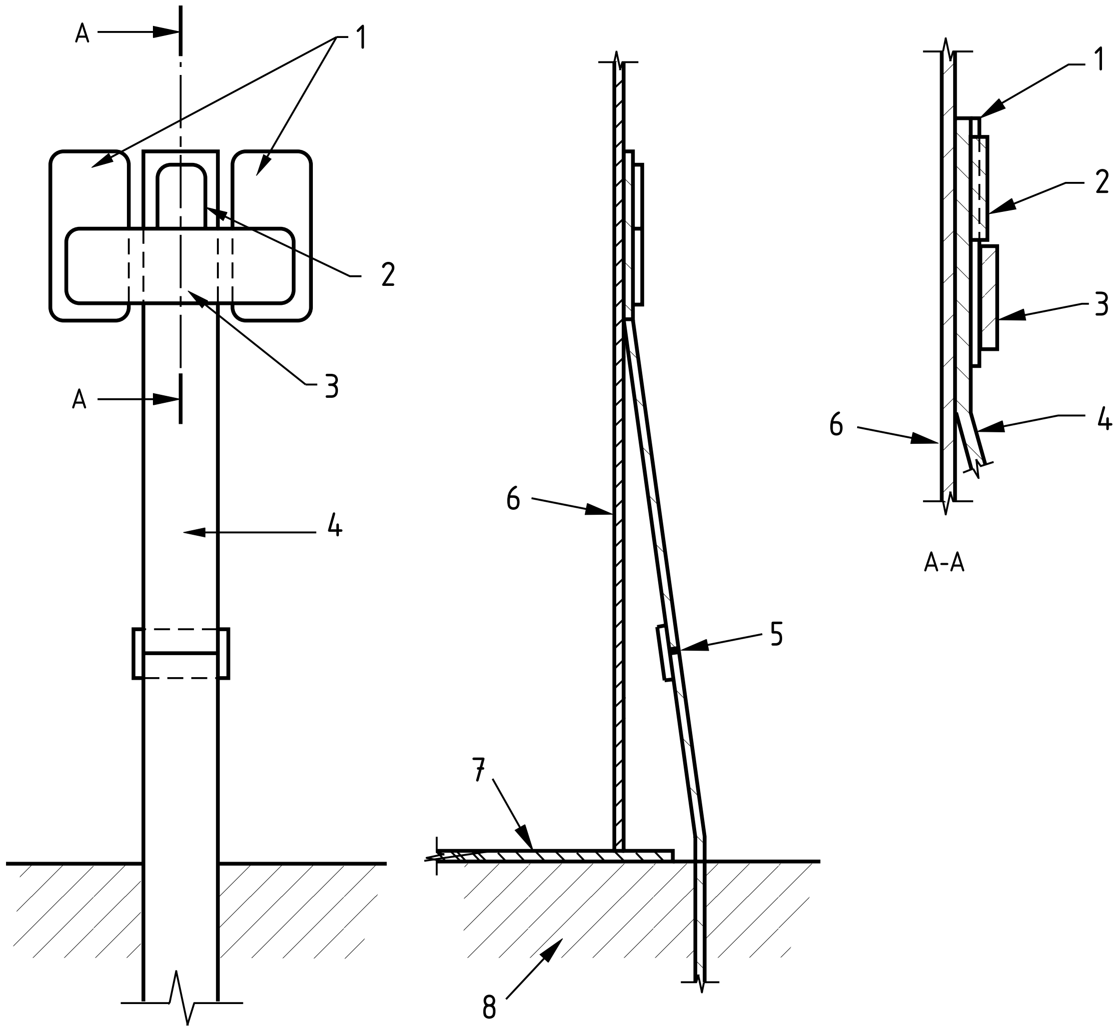
A typical arrangement for a holding down strap is shown in Figure M.1.

M.3 Holding down bolt with individual chair

A typical arrangement for a holding down bolt using individual chairs is shown in Figure M.2.

M.4 Holding down bolt with continuous support ring

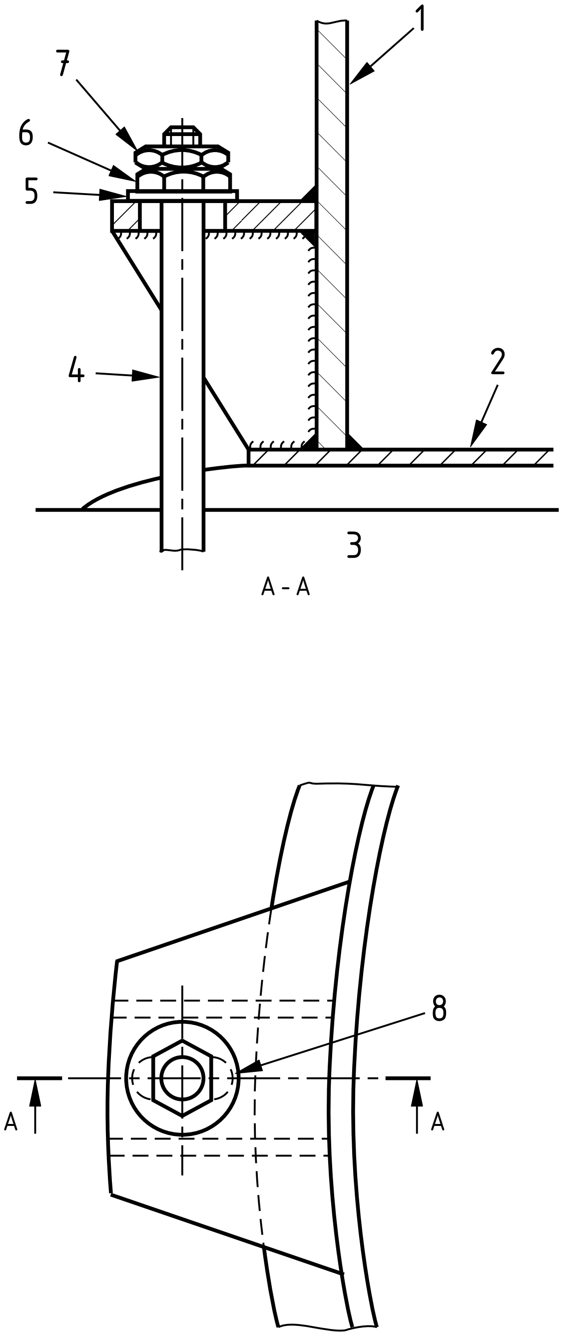
A typical arrangement for a holding down bolt using a continuous ring is shown in Figure M.3.



Key

1	Shell pads	5	Butt joint
2	Stopper plate	6	Tank shell
3	Cross plate	7	Tank bottom
4	Holding down strap	8	Base foundation

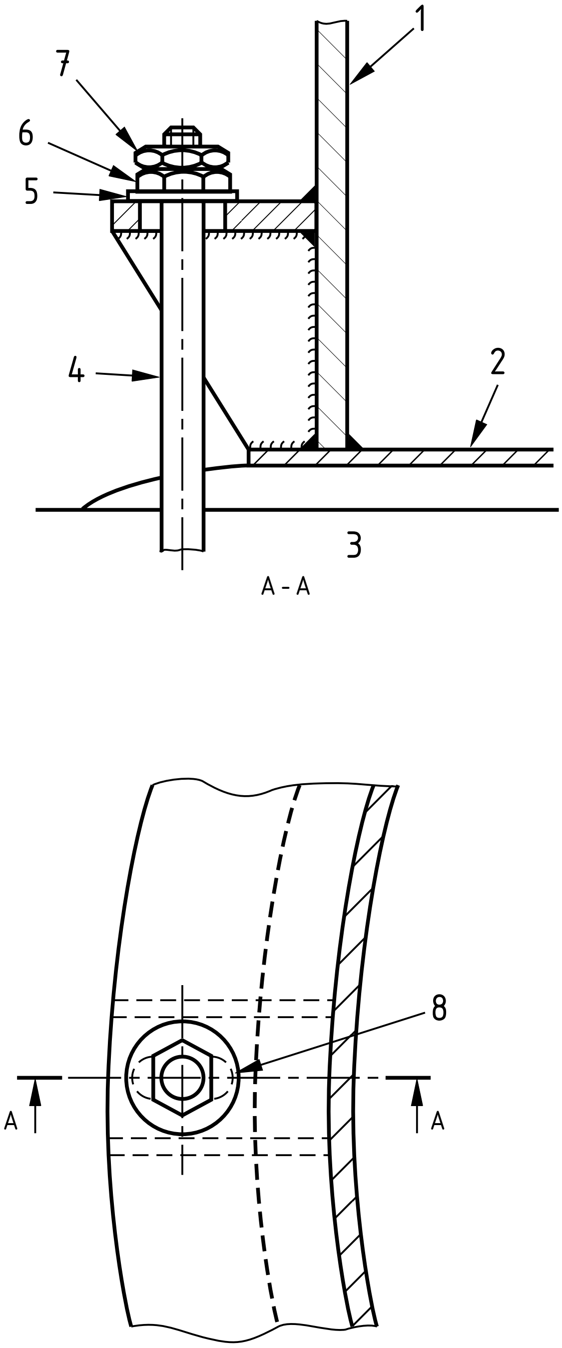
Figure M.1 — Typical arrangement of a holding down strap



Key

1	Tank shell	5	Spreader washer
2	Tank bottom	6	Nut
3	Base foundation	7	Locknut
4	Holding down bolt	8	Slotted hole in bracket

Figure M.2 — Typical arrangement of a holding down bolt with an individual chair



Key

1	Tank shell	5	Spreader washer
2	Tank bottom	6	Nut
3	Base foundation	7	Locknut
4	Holding down bolt	8	Slotted hole in bracket

Figure M.3 — Typical arrangement of a holding down bolt with a continuous support ring

Annex N
(informative)

Weld details for the connection of mounting

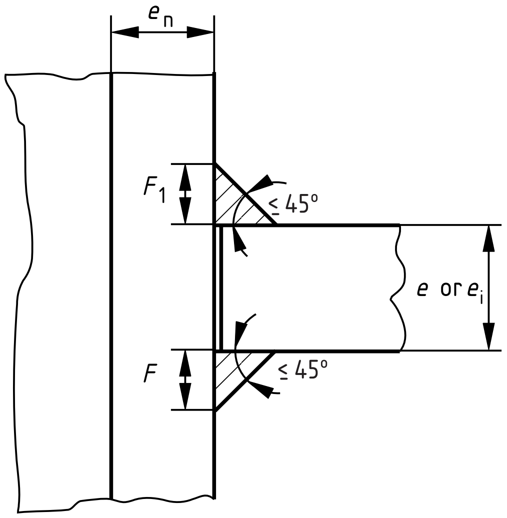
N.1 Set-through mountings

Set-through mountings should conform to one of the examples shown in Table N.1 and Figure N.1.

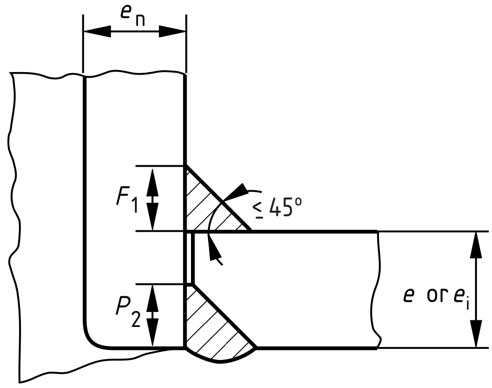
Table N.1 — Dimensions of welds for set-through mounts

Dimensions in millimetres

Figure	e or e_1	e_n	e_r	F_1	F_2	P_1	P_2	P_3
a 1)	≤ 20	≤ 12,5	-	lesser of e or e_n	lesser of e or e_n	-	-	-
a 2)	≤ 20	≤ 12,5	-	lesser of e or e_n	-	-	lesser of e or e_n	- -
b 1)	≤ 20	-	-	lesser of $\frac{e}{2}$ or $\frac{e_n}{2}$	lesser of $\frac{e}{2}$ or $\frac{e_n}{2}$	$P_1 + P_2 \geq e - 3$		-
b 2)	≤ 20	-	-	lesser of e or e_n	-	$P_1 + P_2 \geq e - 3$		-
b 1)	> 20 ≤ 40	≤ 12,5	-	≤ 13	≤ 13	$F_1 + P_1 \geq e_n$	$F_2 + P_2 \geq e_n$	-
b 2)	> 20 ≤ 40	≤ 12,5	-	≤ 13	-	$F_1 + P_1 \geq e_n$	$\geq e_n$	-
b 1)	> 20 ≤ 40	-	-	$\leq \frac{e}{4}$	$\leq \frac{e}{4}$	$P_1 + P_2 = e - 5$		-
b 2)	> 20 ≤ 40	-	-	$\leq \frac{e}{4}$	-	$P_1 + P_2 = e - 5$		-
c	-	-	-	lesser of e_n or e_r	$\leq \frac{e_n}{3}$	$F_1 + P_1 \geq$ lesser of e_n or e_r	e	-
d	-	-	-	$\leq \frac{e_n}{3}$	$\leq \frac{e_n}{3}$	e_r	$P_2 + P_3 \geq e - 3$	
e	-	-	-	≤ 6	≤ 6	$F_1 + P_1 \geq$ lesser of e_n or e_r	$F_2 + P_2 \geq$ lesser of e_n or e_r	$P_1 + P_3 \geq e_r - 3$
NOTE F_1 and F_2 minimum 6 mm.								

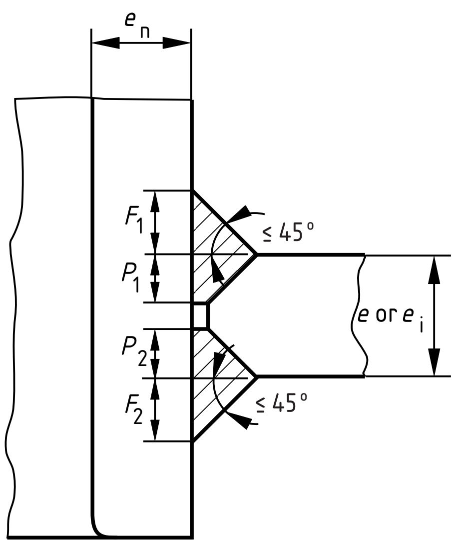


1)

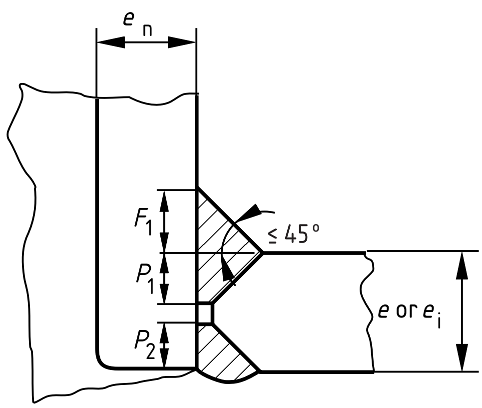


2)

a)



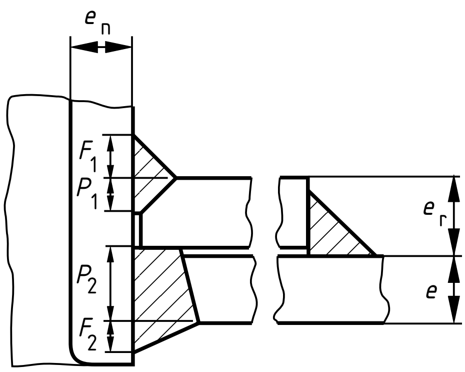
1)



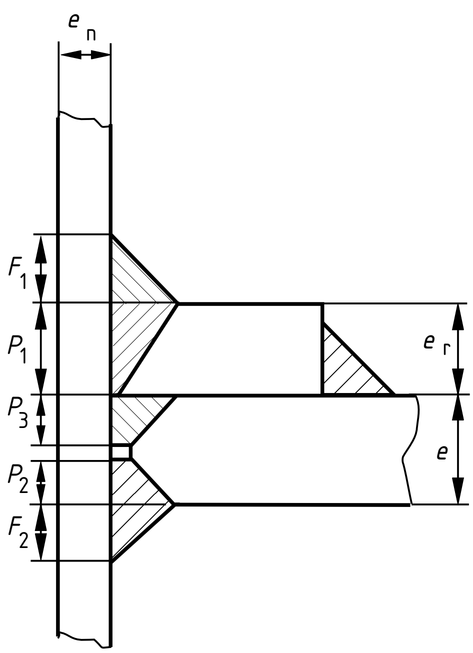
2)

b)

Figure N.1 — Typical set-through mountings

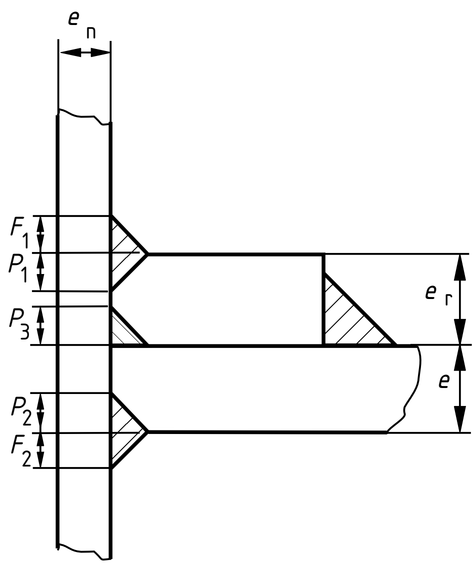


c)



d)

Figure N.1 — Typical set-through mountings *(continued)*



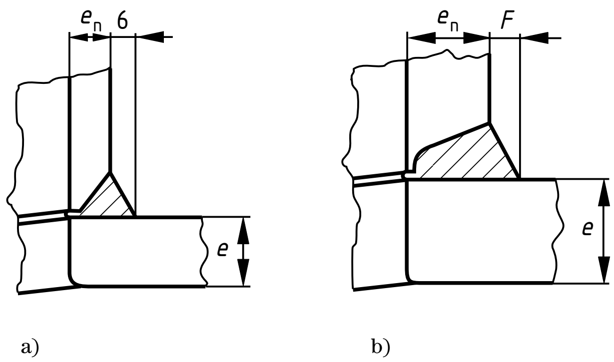
e)

Figure N.1 — Typical set-through mountings *(concluded)*

N.2 Set-on mountings

When the shell nozzle has an outside diameter < 80 mm, set-on mountings can be used (see Figure N.2).

Dimensions in millimetres



e_n = 16 max. e_n > 16 $F = e_n/3$

Attention is drawn to the necessity to examine the shell plate for laminations around the branch hole when set-on nozzles are used (see 13.2).

If the welding procedure does not ensure sound positive root penetration, these joints should be back chipped or gouged and back welded. The internal penetration bead of joints welded from one side only are to be ground smooth and flush with the inside bore.

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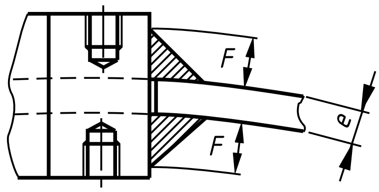
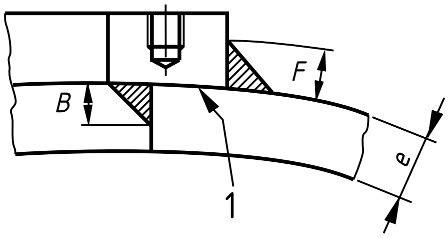
Figure N.2 — Typical weld details for connection of set-on mountings

N.3 Studded pad connections

Typical weld details for studded pad connections are shown in Figure N.3.



a)



1 The ring should fit closely to the shell or the roof plate

NOTE The gap should not exceed 3 mm at any point

b)

$F > e$ or 6 mm max

$B < e$ or 6 mm max

Figure N.3 — Typical details for studded pad connections

Annex O
(informative)

Flush-type clean-out doors and water draw-off sumps

O.1 Flush-type clean-out doors

O.1.1 General

Typical designs of flush-type clean-out doors to meet the requirements of 13.6.2 are based on experience and have proved to be satisfactory.

O.1.2 Flush-type clean-out doors with insert plate reinforcement.

O.1.2.1 Figure O.1 shows details of a typical insert plate reinforcement for a 915 mm × 1 230 mm opening with the following restrictions:

Bottom tier plate material strength yield ≤ 275 N/mm^2

Bottom tier plate thickness (e_1) ≤ 18,5 mm

Insert plate thickness (e_i) = 2e_1 + 3 ≤ 40 mm

Bottom plate reinforcing plate thickness (e_{br}) = $7\sqrt{H+3}$

Thickness of cover and flange (e_f) = 0,78 H + 11

where

H is the height of the tank, in metres

O.1.2.2 Figure O.2 shows details of a typical insert plate reinforcement for a 300 mm ×1 230 mm opening with the following restrictions:

Bottom tier plate material - all materials in Clause 6

Bottom tier plate thickness (e_1) ≤ 18,5 mm

Insert plate thickness (e_i) = 2e_1 + 3 ≤ 40 mm

Bottom reinforcing plate thickness (e_{br}) = $7\sqrt{H+3}$

Thickness of cover and flange (e_f) = 0,52 H + 6

where

H is the height of the tank, in metres.

O.1.3 Flush-type clean-out doors with plate reinforcement

O.1.3.1 Figure O.3 shows details of a typical plate reinforcement for a 915 mm × 1 230 mm opening with the following restrictions:

Bottom tier plate material yield strength ≤ 275 N/mm^2

Bottom tier plate thickness (e_1) ≤ 37 mm

Reinforcing plate material = bottom tier plate material

Reinforcing plate thickness (e_r) = e_1 + 3 ≤ 40 mm material

Bottom reinforcing plate thickness (e_{br}) = $7\sqrt{H+3}$

Thickness of cover and flange (e_f) = 0,78 H + 11

where

H is the height of the tank, in metres.

O.1.3.2 Figure O.4 shows details of a typical plate reinforcement for a 300 mm × 1 230 mm opening with the following restrictions:

Bottom tier plate material - all material in Clause 6

Bottom tier plate thickness (e_1) < 40 mm material

Reinforcing plate material = bottom tier plate

Reinforcing plate thickness (e_r) = e_1 ≤ 40

Bottom reinforcing plate thickness (e_{br}) = $7\sqrt{H+3}$

Thickness of cover and flange (e_f) = 0,52 H + 6

where

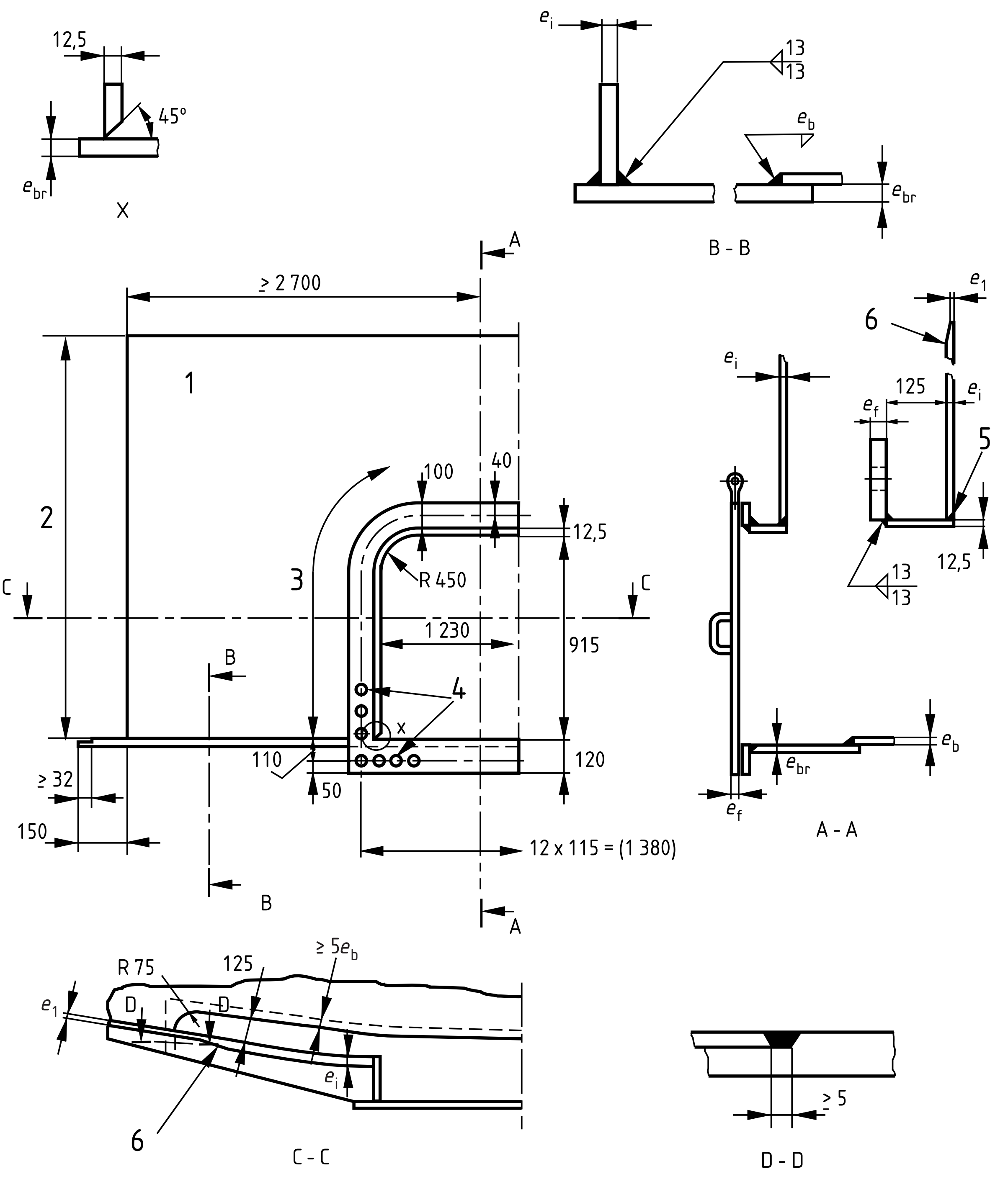
H is the height of the tank, in metres.

O.2 Water-draw-off sumps

Typical design details for water draw-off sumps as specified in 13.6.3, are given in Figure O.5.

O.3 Combined water draw-off and clean-out sump

Typical design details for a combined water draw-off and clean-out sump as specified in 13.6.4 are given in Figure O.6.



Key All dimensions in millimetres, unless otherwise stated.

e_1 is the bottom course shell thickness

e_i is the insert plate thickness

e_f is the cover and flange thickness

e_{br} is the bottom reinforcing plate thickness

e_b is the tank bottom plate thickness

1 Insert plate

2 Plate width

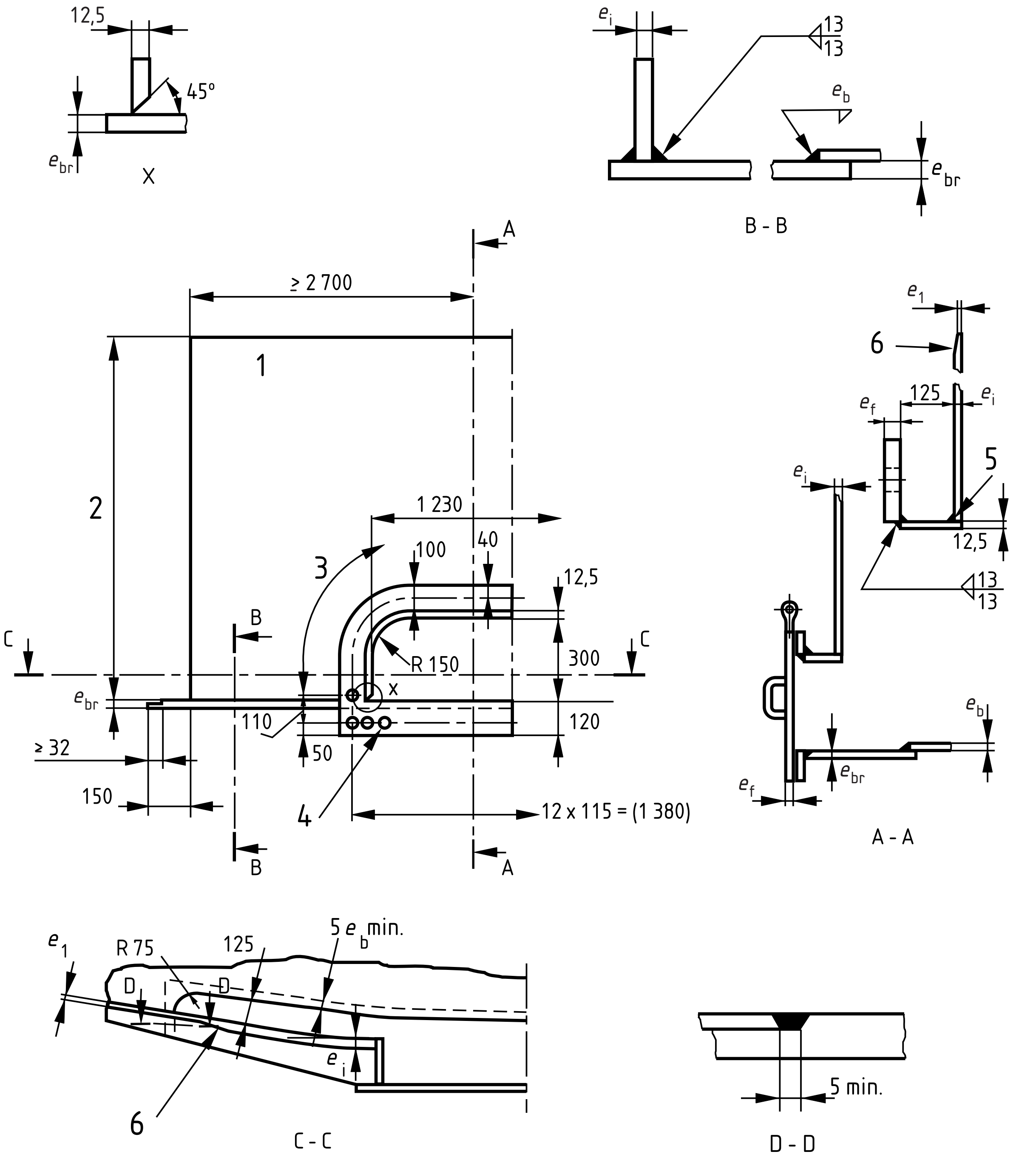
3 32 equal pitches

4 46 × ∅ 28 holes for M24 bolts

5 Weld detail (see Figure 11 c))

6 Slope 1:5 edge preparation

Figure O.1 — Typical flush-type clean-out door with insert plate reinforcement for a 915 mm × 1230 mm opening



Key All dimensions in millimetres, unless otherwise stated.

e_1 is the bottom course shell thickness

e_{br} is the bottom reinforcing plate thickness

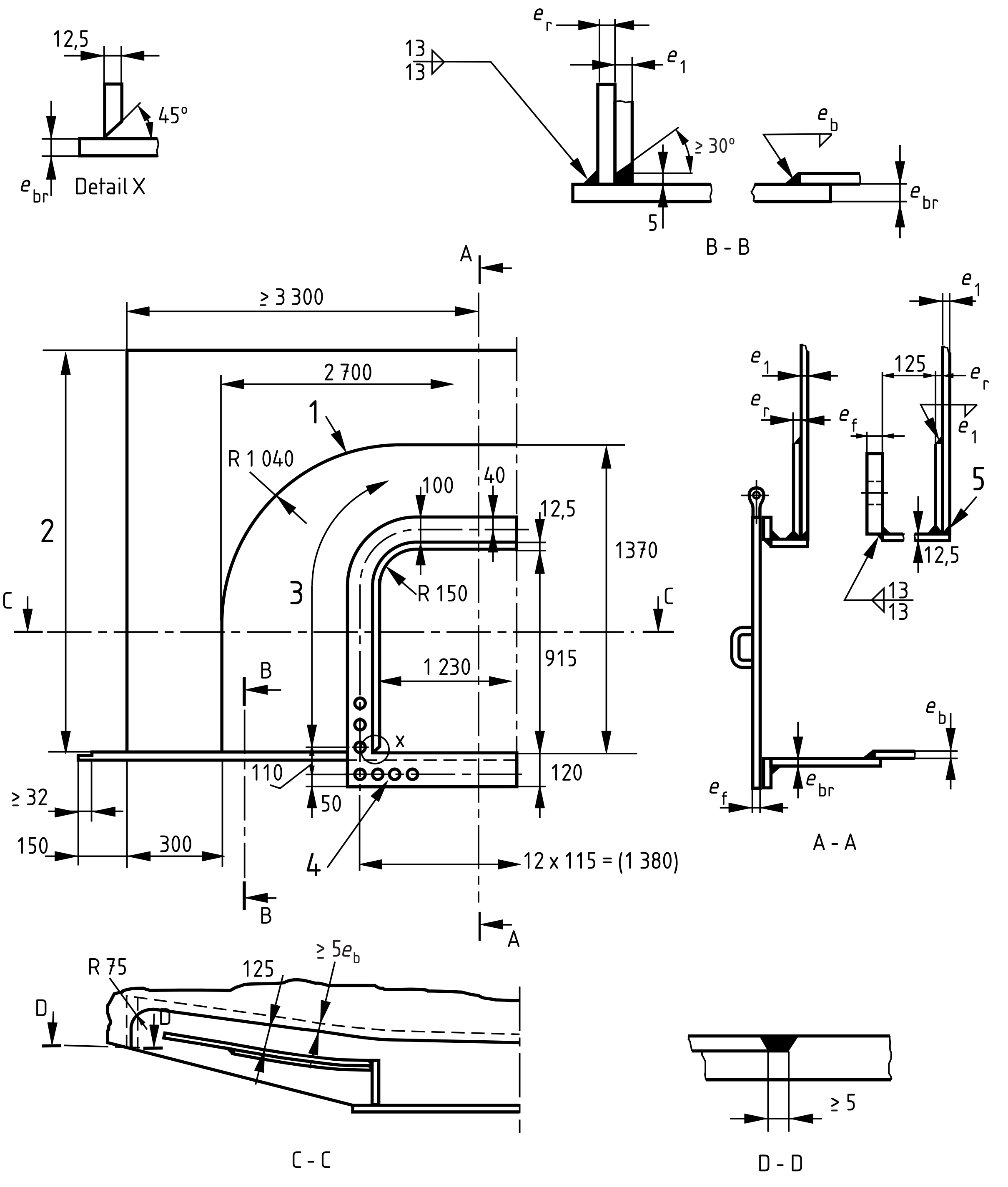
e_i is the insert plate thickness

e_b is the tank bottom plate thickness

e_f is the cover and flange thickness

1	Insert plate	3	20 equal pitches	5	Weld detail (see Figure 11c))
2	Plate width	4	34 × ∅ 28 holes for M24 bolts	6	Slope 1:5 edge preparation

Figure O.2 — Typical flush-type clean-out door with insert plate reinforcement a 300 mm × 1230 mm opening



Key

All dimensions in millimetres, unless otherwise stated.

e_1 is the bottom course shell thickness

e_i is the insert plate thickness

e_f is the cover and flange thickness

e_{br} is the bottom reinforcing plate thickness

e_b is the tank bottom plate thickness

1 Reinforcing plate

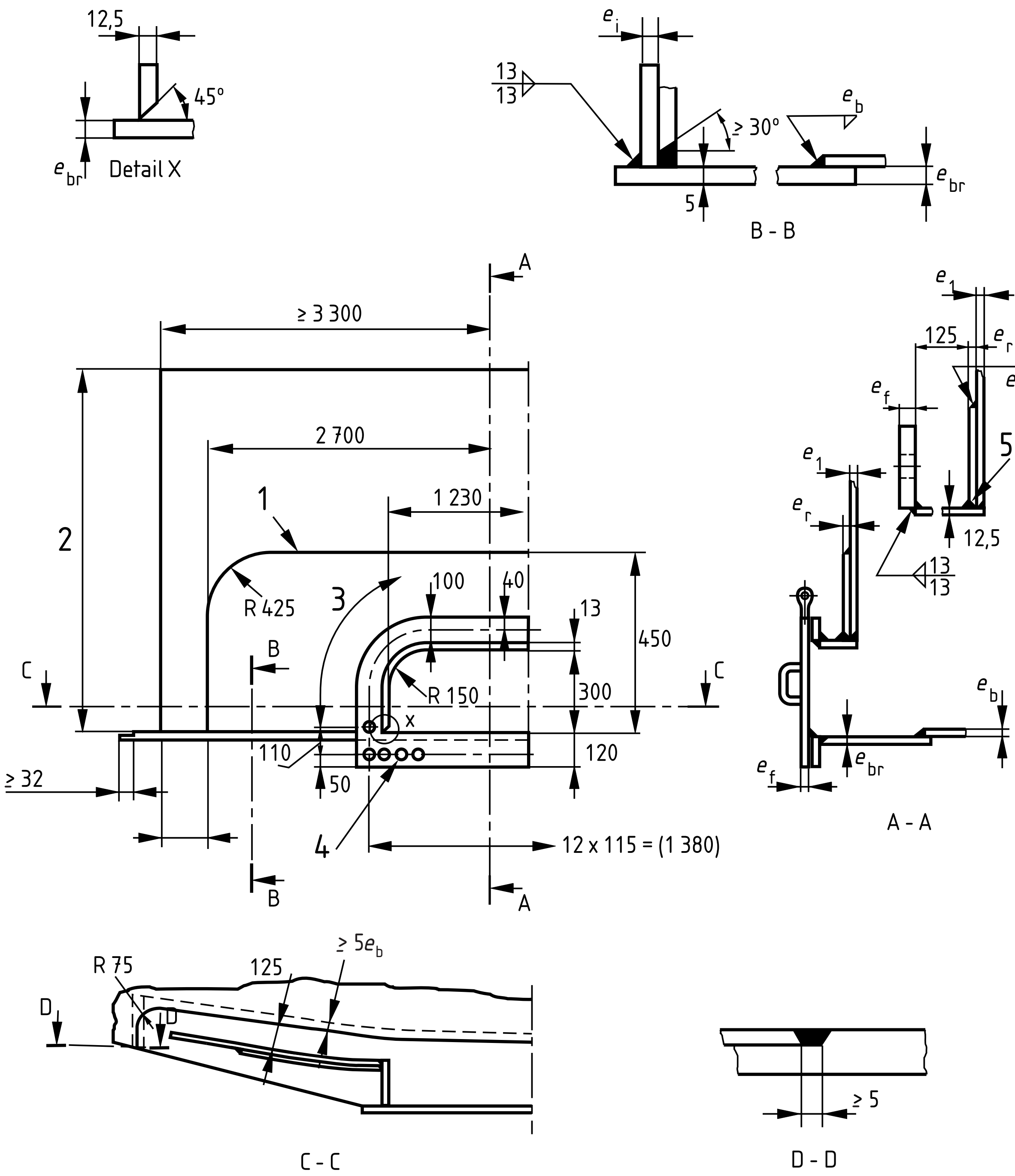
2 Plate width

3 32 equal pitches

4 46 × ∅ 28 holes for M24 bolts

5 Weld details (see Figure 11 b))

Figure O.3 — Typical flush-type clean-out door with plate reinforcement for a 915 mm × 1230 mm opening



Key All dimensions in millimetres, unless otherwise stated.

e_1 is the bottom course shell thickness

e_i is the insert plate thickness

e_f is the cover and flange thickness

e_{br} is the bottom reinforcing plate thickness

e_b is the tank bottom plate thickness

1 Reinforcing plate

2 Plate width

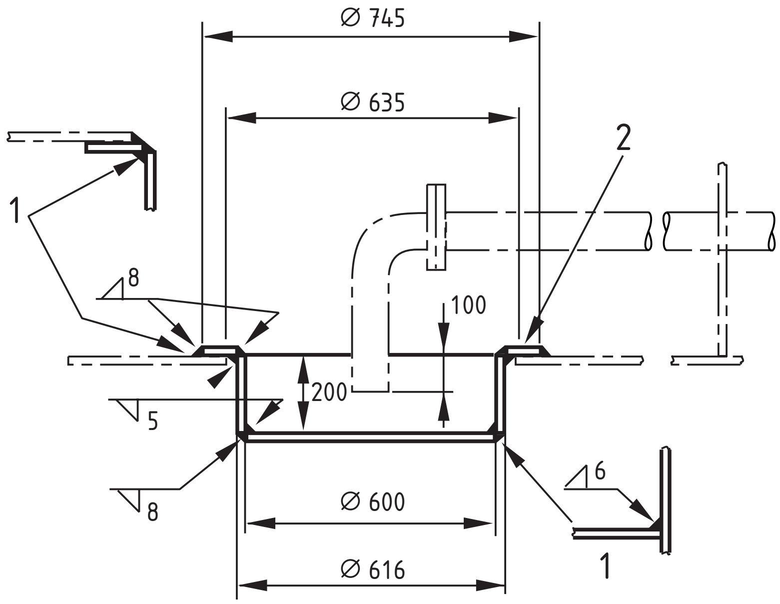
3 20 equal pitches

4 34 × ∅ 28 holes for M24 bolts

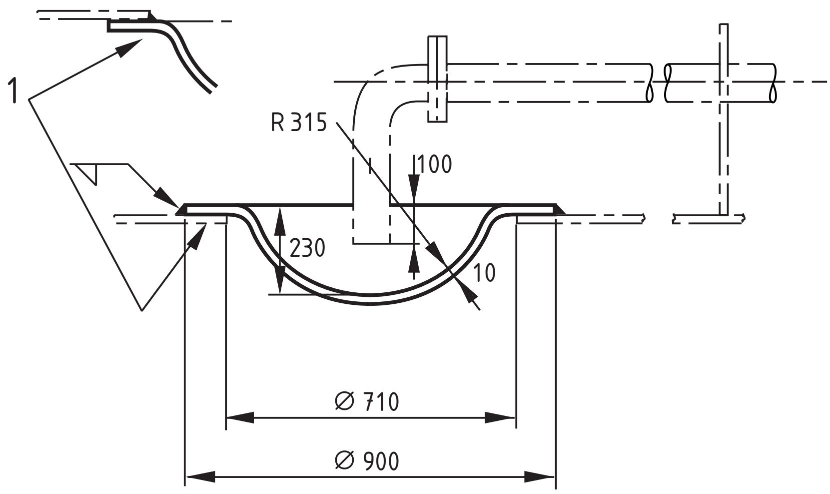
5 Weld detail (see Figure 11b)

Figure O.4 — Typical flush-type clean-out door with plate reinforcement for a 300 mm × 1230 mm opening

Dimensions in millimetres.



a)



b)

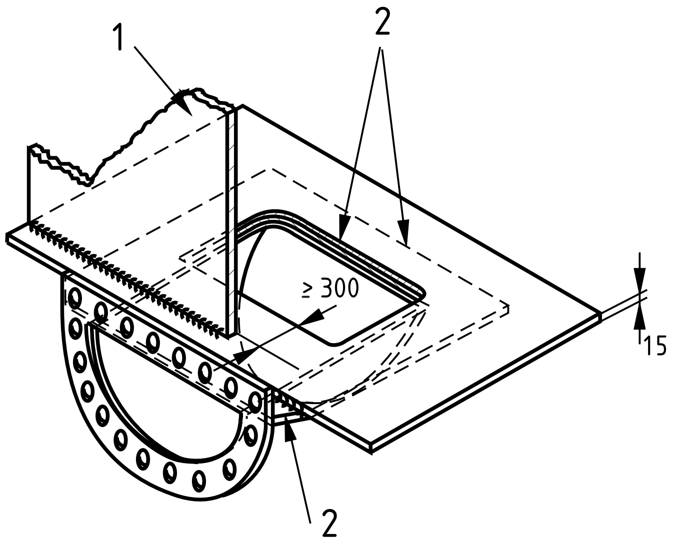
Key

1 Alternative detail

2 Alternatively, the flange may be swaged

Figure O.5 — Typical water draw-off sumps

Dimensions in millimetres



Key

1 Shell plate

2 Site weld

A grating may be fitted to the sump as a safety precaution

Figure O.6 — Typical combined water draw-off and clean-out sump

Annex P
(informative)

Heating and/or cooling systems

P.1 General

Heating and/or cooling down of the stored products can be achieved by the flow-through of a heat transfer fluid.

NOTE Electrical means of heating are outside the scope of this annex.

P.2 Heat transfer fluid

The commonly used heat transfer fluids are:

- water;
- glycol-based water;
- demineralised water;
- superheated steam;
- saturated vapour;
- special oils.

The choice of the fluid is dictated by safety provisions; the main ones being:

- risk of pollution from stocked product;
- risk of exothermal reaction;
- risk of explosion.

P.3 Type of heating or cooling devices

Heating and cooling devices which can be used are as follows:

Installed on the tank bottom:

- horizontal coils;
- standard horizontal or vertical appliances interconnected by headers;
- panels of welded construction (different surface types).

Installed on the tank shell:

- vertical coils installed inside or outside the tank;
- panels of welded construction (different surface types).

Installed on the tank roof:

- panels or panels with welded or removable plates;
- coils;

Installed independent of the tank:

- external heat exchangers.

P.4 Installation

The type, design, dimensions and location of the heating or cooling device should be determined by a qualified person.

Removable or semi-removable devices are generally installed above the bottom of tanks. They may however be placed along the tank shell or on the tank roof but should be installed sufficiently distant from the walls and roof in order not to create a hot point and consequent expansion stresses which the walls and supports cannot accept.

In the case of a heating device located above the tank bottom, the minimum height should be 80 mm, but it should be higher in the case of sediment-laden products and may also be dependent on the tank cleaning cycles.

The use of internally or externally welded heating or cooling surfaces should form the subject of a special study.

The heating or cooling circuit for the product contained in a tank may be considered as pressure equipment and should be designed, manufactured, installed and tested in accordance with EN 13445 prEN 13480 as appropriate. It should also undergo a pressure test as required by the rules connected with the heat transfer product which it contains.

The tubular devices making up the circuit should be manufactured from straight, U-bent or spiral-shaped, smooth or finned tubes. They may be:

- manufactured on request, or be standard manufactured parts;
- arranged in coils in a single or multi-layer construction depending on the required heating or cooling output;
- arranged with one or more inlets.

Tubes used for the manufacture of the circuit(s) should be made from a metal which is compatible with the products with which they are in contact, and should be smooth or finned depending on the exchange coefficient and on the cleaning requirements.

Depending on the product being stored, and for safety reasons, the presence of braces may be prohibited on heating circuits.

The supports for the heating or cooling device should be designed and located such that no stresses are occasioned on the walls by welding the supports onto plates which are themselves welded onto the wall plates.

The tubes should move freely in relation to the supports, and where frequent temperature variations are likely to occur the manufacturer should provide a wear prevention assembly on the tubes.

The supply and evacuation of the heat transfer fluid can be carried out via one or more nozzles which pass through the tank wall.

Tube ducts in the tank wall should be designed with nozzles comprising a reinforcement as the tank wall is generally considered to be a fixed point.

Annex Q
(informative)

Recommendations for the design and application of insulation

Q.1 General

While not attempting to specify in detail the insulation systems themselves, this annex is intended to provide a sound basis on which these systems can be specified, and particularly to facilitate the provision of suitable mechanical supports for the insulation material, these supports forming an integral part of the tank fabrication. The recommendations cover storage tanks operating at temperatures at or above ambient and of a size where banding is unreliable and direct fixing to the tank is necessary.

In order that the correct choice may be made of the type and method of providing the insulation attachments, it is emphasized that, where new tanks are concerned, early consideration of the need for insulation is essential so that the necessary provisions for it could be integrated with the tank design and erection programme. This consideration should also include the possible need for insulation of the tank roof.

On small tanks the problem of attaching the insulation securely is not serious, but for tanks above 10 m to 15 m diameter, problems due to wind loads, associated vacuum effects, differential thermal expansion and hydraulic pressure expansion become significant. Bands longer than about 12 m are not recommended without special care in band design.

Wherever possible, the insulation system should be secured by direct attachment to the tank. This could be achieved by sprayed-on insulation, by foaming in situ or by mechanical attachments to the tank. While welding of studs or steel members to small tanks may be satisfactory, welding on large tanks could materially affect the design and integrity of the construction, but it is permissible when considered as part of the tank design. The use of adhesives is a possible alternative method of fastening attachments where welding cannot be permitted, but is subject to temperature limitations, and should only be carried out by specialists in this field.

The basis of all welded-on attachments should be to provide a series of points disposed circumferentially on the tank at a number of vertical intervals, on to which vertical and/or horizontal members could be fastened. The support structure and welded-on attachments should be designed so as to transmit back to the tank all the dead loads and superimposed wind loads expected to be experienced at the location concerned.

Design aspects which are not dealt with in this annex should conform to the requirements in this document.

The basic considerations necessary on methods to be employed to achieve acceptable insulation systems are set out below. These insulation systems, which are suitable for large tanks include:

a) man-made mineral fibre or preformed foam block with cladding;

b) in situ foam behind cladding;

c) foam/cladding laminate sheets;

d) sprayed foam.

For a particular installation, a proprietary system of insulation including fixing and weather protection may be suitable. The use of a proprietary system should be subject to an agreement (see A.2). The element of the system that constitutes the mechanical support which forms part of the tank fabrication should be clearly identified.

In this annex, separate references are made to the tank designer, and the tank erector.

NOTE This annex may be used for the installation of insulation to existing tanks.

Q.2 Design considerations

Q.2.1 General

The design of an insulation system, which incorporates the insulating material, its means of attachment to the tank and its means of weather protection, should take into account the following:

a) product in the storage tank under its operating conditions;

b) storage tank itself;

c) insulation materials;

d) mechanical support system associated with the insulation system;

e) means whereby the insulation and its support system enable it to withstand climatic conditions.

The insulation system to be used should be agreed between the tank designer, the insulation contractor and the purchaser.

The system, including its mechanical supports and fastenings, should be designed to withstand the mechanical and thermal stresses to which it could be subjected, resulting from all known factors, including those listed in Q.2.2 to Q.2.5. These factors should be assumed to act simultaneously.

Because relatively large forces are involved the provision of the mechanical support arrangements could be extensive and could frequently be attached to the outer face of the tank itself. The design of the attachment of the support system should be subject to scrutiny by the tank designer to ensure that a minimum number of attachments are used.

Preliminary discussions with insulation contractors are often helpful in identifying suitable systems and the type of supporting arrangements likely to be necessary.

Q.2.2 Dead load

Dead loads result from the weight of all parts of the insulation system.

Q.2.3 Wind loads

In the design of the insulation system, account should be taken of the effect of wind loads (see 7.2.10)

The basis on which the wind load calculations are to be made should be subject to agreement (see A.2).

Q.2.4 Thermal expansion

The possibility of relative thermal movement between the tank and the insulation system should be taken into account in the design. The range of operating temperatures should be supplied (see A.1).

Q.2.5 Movements due to hydrostatic pressure

The pressure of the tank contents causes slight bulging which could account for an increase in tank diameter of the order 0,1 %. This may need to be taken into account in designing the insulating system and the actual value should be provided by the tank designer.

Q.3 Mechanical support arrangement

Q.3.1 General

The mechanical supports could be divided into the following types.

a) *Primary mechanical supports*, where the members form part of the mechanical support system and are directly attached to the tank surface;

b) *Secondary mechanical supports,* where the members form part of the mechanical support system and are not directly attached to the tank but are fixed to the primary support members or to other secondary support members.

Suitable mechanical supports for the insulation system should be provided by one of the following means or a combination thereof.

1) Primary supports, welded to the tank, to which the insulation system is attached either directly or by secondary supports.

2) Primary supports fixed to the tank by adhesive, to which the insulation system is attached.

3) A structural frame that is substantially self-supporting.

Welding is the preferred method of attachment, but it may not always be possible. While in each case the system chosen should be with the agreement of all parties concerned, the direct responsibilities will be as follows unless otherwise agreed.

i) In cases 1) and 2), the insulation contractor should agree with the tank designer the locations of the supports to which the insulation system is to be attached, the loads that will be transmitted to the tank, the basis on which the calculations have been made or other reference data used. If required, the insulation contractor should provide details of the calculations for approval by the tank designer.

ii) In case 3) where an external structure or frame is intended, this should be regarded as part of the insulation system to be provided by the insulation contractor. The design and erection procedure should be agreed with the tank designer.

The dimensions of the mechanical supports normal to the surface to which the insulation is to be attached should be an agreed size to suit the insulation thickness.

Q.3.2 Supports attached by welding

The tank designer should be responsible for approving the materials and the welding procedures of the primary mechanical supports which form part of the tank structure. The tank erector should be responsible for fixing the primary supports to the tank surface. Welding of primary supports to the tank should be completed before hydrostatic testing is carried out. The number of multiple-welded insulation support attachments to steel with specified yield strength ≥ 275 N/mm^2 should be minimized. The centre-to-centre distance between them should not be less than 3 m. All welds should be ground smooth and subjected to magnetic particle examination (see 19.6). These supports should take one of the following forms.

a) Pads (not smaller than 100 mm square) with corners rounded to a radius not less than 12 mm, spaced not closer than 150 mm to any other weld and welded along horizontal edges only (see Figure Q.1);

b) Angles or plates welded on-edge to the tank having a circumferential length of not less than 100 mm at a spacing not closer than 150 mm to any other weld, welded along horizontal edges only (see Figure Q 2).

Materials used for the primary supports should be selected according to the requirements of Clause 6 of this document. In cases a) and b), secondary supports may be welded or attached to the pads, plates or cleats. In the case of circumferential angles, the welds should not be closer than 150 mm to other horizontal welds. The welding should be carried out by approved welders and the welding and non-destructive testing procedures should be agreed between the tank designer and the purchaser.

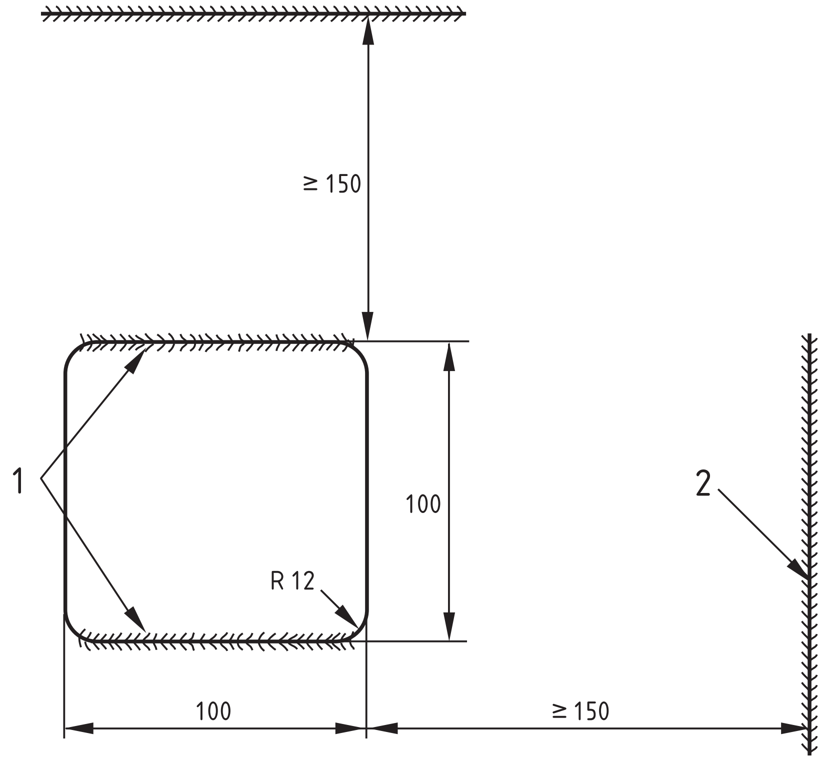
Plates welded on-edge or pads should be placed in horizontal rows at a suitable vertical pitch which should be, typically, 2 m to 3 m. Horizontal support angles, whether primary or secondary, should be of a minimum size 40 mm × 40 mm × 5 mm and of radial dimension compatible with the insulation system (see Q.8.1.3). The spacing between adjacent members should be not more than ± 15 mm from the specified dimensions with the spacing between the highest and lowest members being not more than ± 25 mm from the specified dimensions. The outer leg of the member should be pointing downwards in order to shed water during construction.

Q.3.3 Supports attached by adhesive

Q.3.3.1 General

If an adhesive system is used, the materials and procedure should be such as to withstand the working conditions of the tank including both mechanical and thermal conditions. The surface of the tank in the vicinity of the fixing and the contact surface of the member to be fixed should be shot-blasted and the adhesive applied only to clean, dry, metal and strictly in accordance with the instructions of the adhesive manufacturer. Account should be taken of the suitability of the adhesive formulation for the ambient conditions, particularly temperature, at the time of application. Procedure, qualification and acceptance tests should be carried out as specified (see A.1).

Dimensions in millimetres

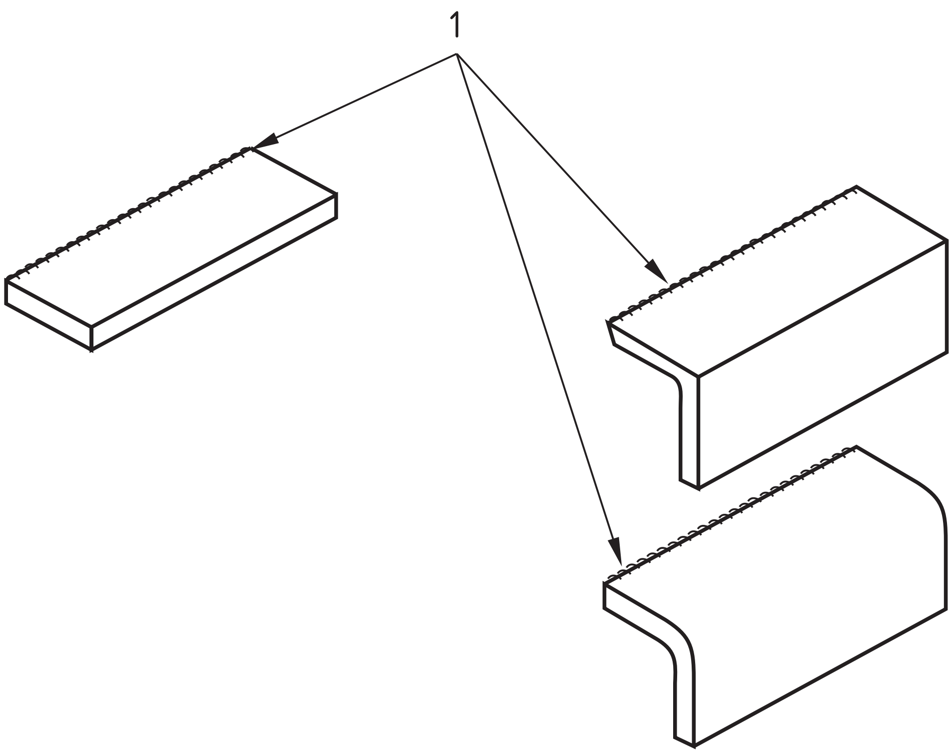


Key

1 Continuous weld

2 Welded seam

Figure Q.1 — Pad support



1 Continuous weld

Figure Q.2 — Angle section and plate supports

Q.3.3.2 Procedure tests

Tests should be carried out using the proposed procedure to demonstrate to the satisfaction of the purchaser that it is capable of providing 12 times the strength required as calculated from the wind loads and any other loads if applicable (see Q.2.2 to Q.2.5). Such tests should include exposure for not less than 2 months at the temperature that the surface of the tank will reach in service and with temperature cycling if appropriate.

Q.3.3.3 Qualification tests

Only trained personnel should be employed in making the adhesive joints, and each individual to be employed on this work should carry out the qualification test within one month of commencement of adhesive joint preparation. Six joints should be prepared in the manner proposed for the contract and in the presence of such persons as may be agreed between the purchaser and the tank designer.

When tested according to the agreed procedure, the strength of these joints should exceed 12 times the minimum required strength.

Q.3.3.4 Acceptance tests

Records should be kept to permit identifications of supports attached with adhesive from each separate batch. A proof load should be applied equal to three times the calculated load. If more than 5 % of the batch fails, the whole batch should be removed and replaced.

Q.3.4 External structural frame

A structural frame attached to the tank structure at the top and bottom may be used in certain circumstances. This could be in contact with the tank or external to the insulation.

Q.3.5 Secondary support members

The design of secondary support members and their attachments to the primary support should be the responsibility of the insulation contractor who should obtain the agreement of the tank designer for the design and means of attachment. Holes made in any support member welded to the tank should be drilled, not punched, and if self-tapping screws are used, they should be not larger than 6 mm diameter.

Q.3.6 Roof insulation

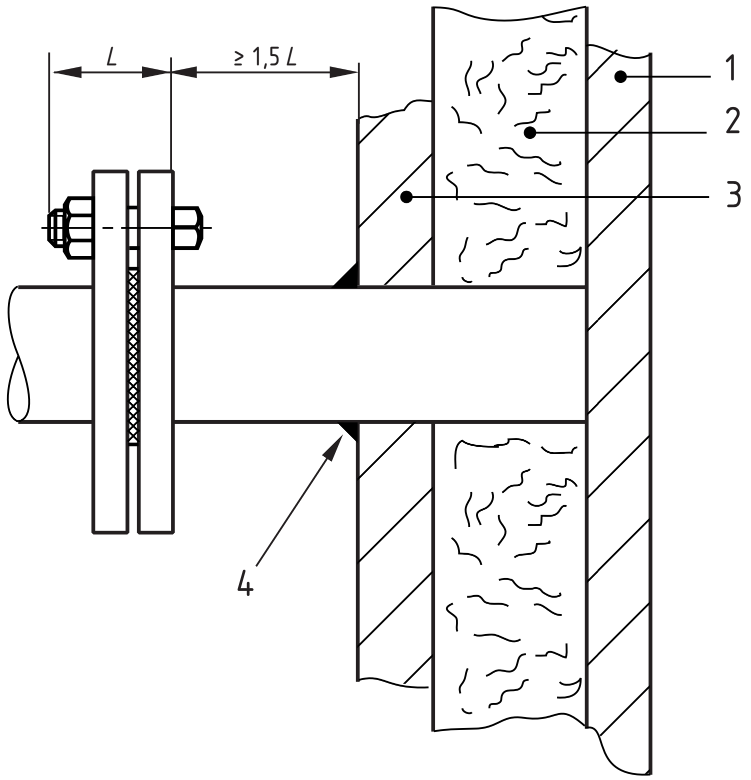
Early consideration of the possible need for roof insulation is important. A roof construction of adequate stiffness to minimise flexing is required with a slope adequate to permit satisfactory weather protection of the insulation.

In the case of tanks with an insulated shell, and where the tank roofs are not insulated, calculations should be carried out to check the stresses in the roof supporting structure caused by the difference in temperature of the roof plates and the supporting structure, e.g. when cold rain falls on the roof plates, are acceptable.

Q.4 Design details

Q.4.1 Nozzles and manholes

Where nozzles and manholes are flanged, they should project a distance from the tank shell not less than the insulation thickness plus 1,5 times the bolt length unless otherwise agreed (see Figure Q.3). If a nozzle projects a greater distance from the tank, it should be insulated (see Q.6.1). Where adjacent nozzles are close together, they should be offset to ensure 50 mm minimum clearance between the insulated flanges. All nozzle and manhole connections requiring insulation should be clearly indicated.



Key

1 Tank shell

2 Insulation

3 Cladding

4 Waterproof seal

Figure Q.3 — Typical flanged nozzle or manhole

Q.4.2 Stairway connections

The inner stringer of double-stringer staircases should be spaced away from the tank a distance sufficient to ensure not less than 75 mm between it and the outer face of the insulation system. Stairways with treads welded directly to the shell should not be fitted to insulated tanks.

Q.4.3 Supports near stiffening rings (wind girders)

Horizontal supports should be fitted not further than 300 mm below and 150 mm above stiffening rings (wind girders). Intermediate stiffeners should also be included in the insulation of the shell unless the stiffening angles are welded on the inside of the tank shell.

Q.4.4 Roof projection

If the tank roof is designed to project beyond the tank shell, the projection should be not less than the thickness of the insulation system plus 50 mm. If the roof weather protection is provided as part of the insulation system, the overlap should similarly be not less than 50 mm beyond the thickness of the insulation on the tank shell. The overhanging part of the roof should be completely included in the insulation. Details of this should be agreed between the designer and the insulation contractor.

Q.4.5 Stiffening rings (wind girders)

In certain circumstances, it could be desirable to locate the stiffening rings on the inside of the tank shell (see Q.6.3).

Q.4.6 External shell stiffening rings (wind girders) and bottom-to-shell insulation

External shell stiffening rings (wind girders) and bottom-to-shell insulation represent a discontinuity in the envelope for the tank and require detailed consideration by the insulation system designer in conjunction with the tank designer to avoid the following:

a) unacceptable thermal gradients in the tank plate material due to part exposure;

b) corrosion due to such areas forming a lodgement for corrosive fluids.

Consideration should be given to enveloping all such structural elements with the insulation, particularly if the storage temperature is high, but each case should be taken on its merits.

Q.5 Corrosion protection

The presence of insulation prevents inspection of the tank surface and priming is therefore required before the insulation is applied. The tank shell and welded attachments should be dry, free from grease and loosely adhering particles and coated with a suitable primer, all to a specification agreed by the purchaser. If the roof is to be insulated, two coats of primer are recommended. If shop priming is employed, care should be taken to make good any defects in the priming caused during site erection.

In the case of in situ spraying or foaming, the paint system should be such that it is compatible with the foam system and unaffected by any foaming reaction or in-service condition. Where foam insulation is used with fire retardant formulations, protection against the possibility of halogen-induced accelerated corrosion should be considered.

Q.6 Insulation

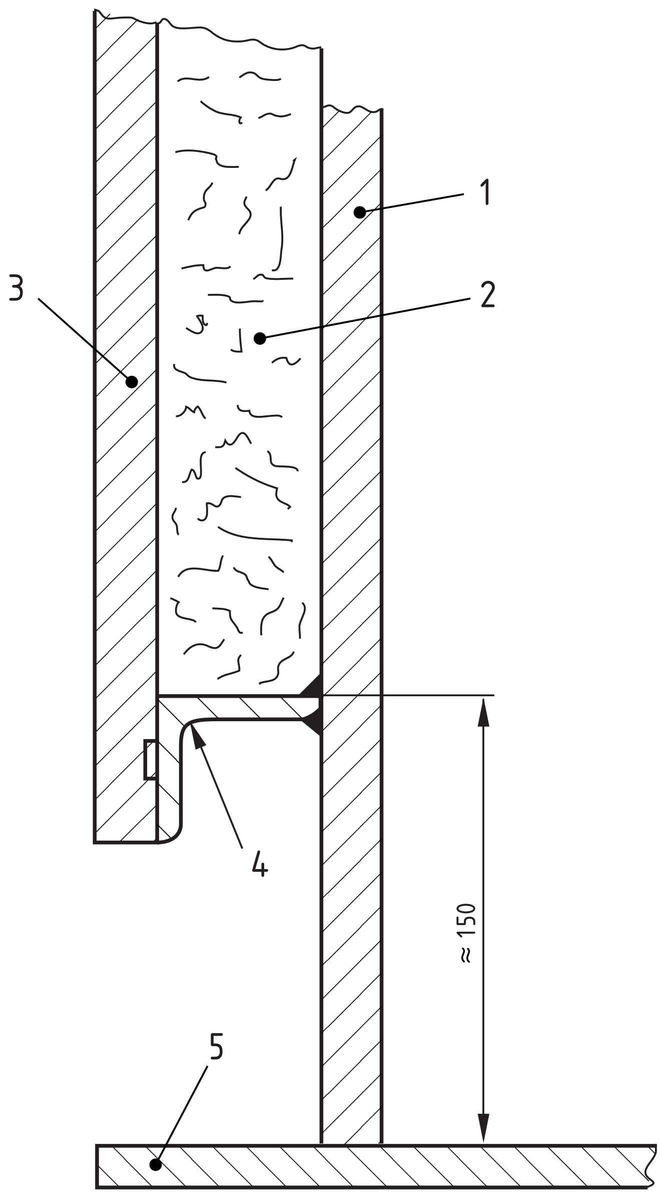
Q.6.1 General

Insulation thickness should be specified or designed to meet the specified heat loss requirements (see A.1). Unless the stresses produced are unacceptable, the insulation should terminate approximately 150 mm from the tank base to avoid corrosion and to allow inspection at the bottom of the tank (see Figure Q.4). Where the stresses are unacceptable, foamed glass slabs set in bitumen or other suitable adhesive may be used for insulation of the tank shell below the lowest horizontal support.

The shell insulation should fit closely under the roof overlap and be sealed against ingress of water (see Figure Q.5).

Special care should be taken where roof insulation is to be carried out to avoid corrosion (see Q.4.4, Q.7.3 and Q.8.4).

Dimensions in millimetres



Key

1 Tank shell

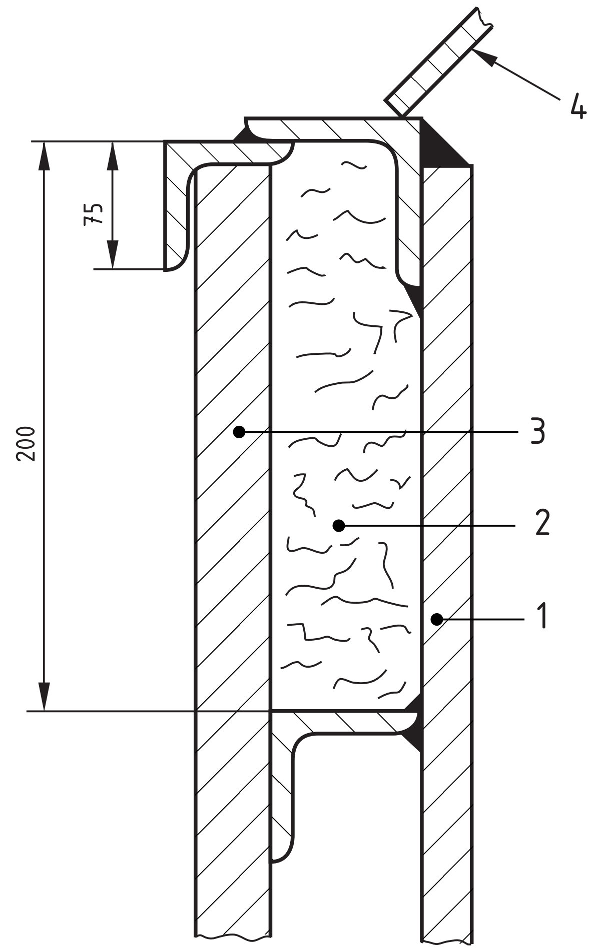
2 Insulation

3 Cladding

4 Bottom member

5 Bottom or annular plate

Figure Q.4 — Typical arrangement showing termination of insulation adjacent to the tank bottom



Key

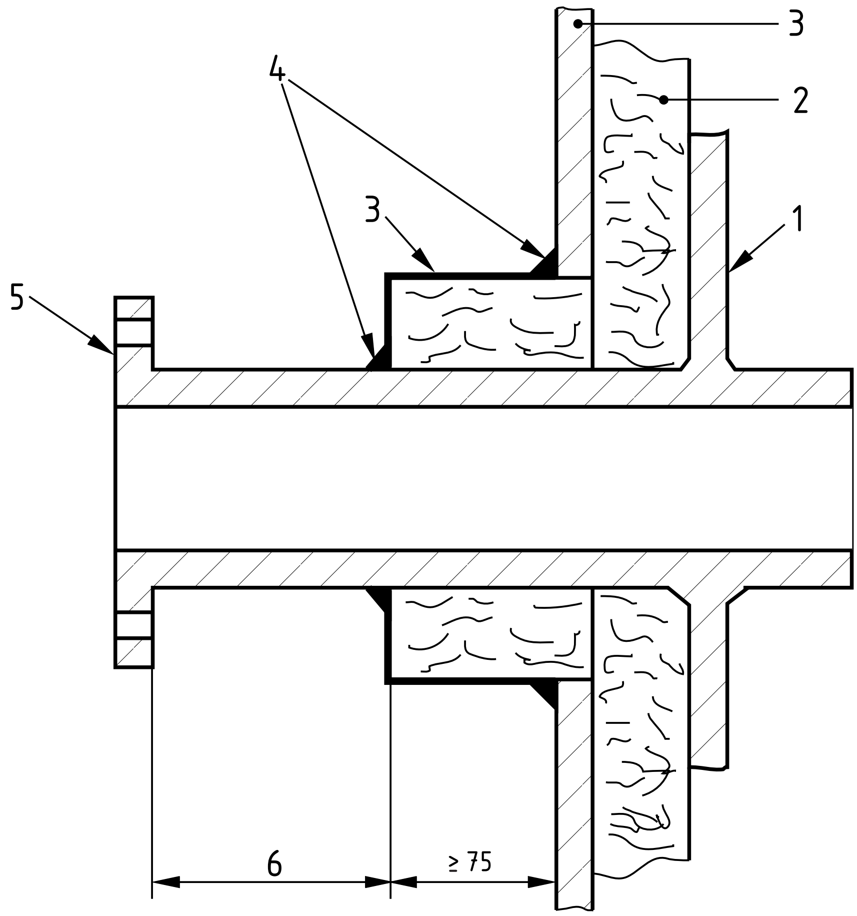
1	Tank shell	3	Cladding
2	Insulation	4	Roof plate

Figure Q.5 — Typical arrangement of insulation under roof overlap with insulation attached to the shell only

Q.6.2 Nozzle connections and manholes

Where these project up to a distance equal to the sum of the insulation thickness plus depth of cladding profile plus 1,5 times the bolted length, they should be insulated with the main shell/roof insulation (see Figure Q.3). Where the projection is in excess of the above, they should be insulated and finished prior to the application of insulation to the shell/roof (see Figure Q.6).

Dimensions in millimetres



Key

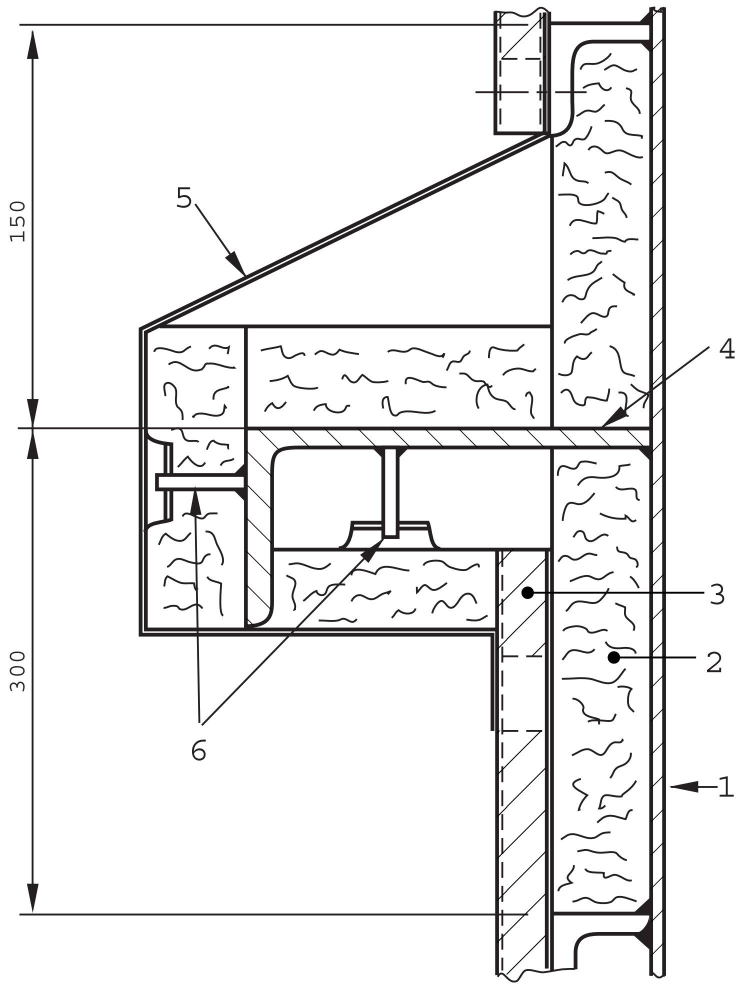
1	Tank shell	3	Cladding	5	Nozzle flange
2	Insulation	4	Waterproof seal	6	> 1½ bolt length

Figure Q.6 — Typical flanged nozzle or manhole with additional branch insulation

Q.6.3 Stiffening rings (wind girders)

The stiffening rings (wind girders) and their associated supports should be enclosed by the shell insulation to minimize the temperature difference. The insulation should be attached to the stiffening rings by plate or expanded metal washers and speedfix fasteners to Ø 6 mm mild steel pins whose length is equal to the insulation thickness minus 6 mm. Figure Q.7 shows a typical construction local to a stiffening ring.

Dimensions in millimetres



Key

1	Tank shell	3	Cladding	5	Stiffening ring flashing
2	Insulation	4	Stiffening ring	6	6 mm mild steel pins

Figure Q.7 — Typical construction of insulation local to stiffening ring (wind girder)

Q.7 Cladding

Q.7.1 General

Cladding is a feature common to most insulation systems. The effectiveness of the insulation depends particularly on the care applied in the design and installation of the cladding. The type and quality of cladding should be selected bearing in mind environmental conditions on either side.

It is essential that all cladding be kept clean, free from grease, free from corrosion and dry on the inner surface prior to erection and until the installation is complete and all joints are well sealed.

Q.7.2 Side-wall cladding

Care should be taken to prevent direct contact between stairway supports and cladding. Cut-outs in cladding for stairway supports should be permanently sealed with mastic to prevent ingress of water. Sealant is not normally considered necessary for vertical or horizontal joints in the cladding.

The tank side-wall cladding should be troughed aluminium or hot-dip zinc coated structural steel sheet attached to the support members. The minimum depth of trough is to be 25 mm. Corrugated sheet having sinusoidal profiles should receive special attention in view of the need to avoid the ingress of water and ensure adequate fixing. The minimum nominal thickness of sheet should be:

a) 1,0 mm for aluminium;

b) 0,7 mm for hot-dip zinc or plastics-coated steel.

Aluminium sheet should be to EN 573-3, Grades EN AW 3103, 3105 or 5251.

Hot-dip zinc coated structural steel should be to EN 10326.

In any horizontal ring, adjacent sheets should have a minimum overlap of one trough profile and be secured with bulb-type blind pop-rivets at not greater than 100 mm pitch. The rivets should be of material compatible with the cladding and be such as to secure the overlap to accommodate the maximum design wind-suction.

Each horizontal ring of cladding should overlap the lower horizontal ring by a minimum of 75 mm and be secured with bulb-type blind pop-rivets at a distance not less than 25 mm from the edges of the sheets.

Sheets should be secured to support members using fastenings designed to accommodate the agreed wind loads and tank movements due to thermal expansion and hydrostatic pressure.

Q.7.3 Roofing cladding

Metal cladding for the tank roof should be plain or embossed and the minimum nominal thickness should be:

a) 1,0 mm for aluminium;

b) 0,9 mm for hot-dip zinc or plastics-coated steel.

All overlaps in the cladding should be not less than 100 mm and be so arranged as to shed water. All joints should contain a continuous strip of a sealant approved by the purchaser and be secured by bulb-type blind pop-rivets of a material compatible with the cladding. The pop-rivets should be at a maximum pitch of 75 mm.

Consideration should be given to draining rainwater over the edge of the roof in such a way that it does not affect the integrity of the insulation system.

Q.8 Securing insulation materials

Q.8.1 Slab or block insulation with metal cladding

Q.8.1.1 Bonded man-made mineral fibre with metal cladding

The insulation should consist of bonded mineral wool with a bulk density of not less than 48 kg/m^3.

The insulation material should be supported on the horizontal support members and held in place with 1 mm (minimum) galvanized tie wires for use with galvanized steel cladding and 0,5 mm (minimum) stainless steel wire for use with aluminium cladding or plastics-coated steel cladding. The insulation slabs should be fitted tightly between the horizontal support members with all edges closely butted and vertical joints offset from those in adjacent courses. The tie wires should be at a pitch not greater than 450 mm with a minimum of two tie wires per insulation slab.

Q.8.1.2 Other slab or block insulation with metal cladding

Performed slabs of polyurethane or polyisocyanurate may be used on the tank sides as an alternative to mineral wool, the method of fixing being similar to that described for mineral wool slabs (see Q.8.1.1) or by adhesives suitable for the operating temperature.

For certain circumstances foamed glass blocks may be required. Where this material is used, the blocks should be held in place with 20 mm × 0,8 mm bands of compatible material at centres not exceeding 450 mm. The bands should be secured to vertical tie bars fitted to the horizontal support members at centres not exceeding 12 m. Alternatively, adhesives suitable for the operating temperature may be used.

Q.8.1.3 Horizontal supports

The horizontal supports should have a radial width adequate for support of the insulation and agreed with the insulation contractor.

Q.8.2 In situ foam behind metal cladding

The type of foam and its physical and thermal properties should be agreed between the insulation contractor, the tank contractor and the purchaser. The cladding should be in accordance with Q.7.2 or Q.7.3. The cladding can be supported as recommended in Q.7.2 or can be spaced from the tank using foamed blocks, stuck to the side-wall, of agreed type and size and of thickness equal to the minimum insulation thickness. Provision should be made, in the latter system, to restrain the cladding against distortion and movement due to pressure exerted by the foaming operation. Due regard should be taken in this latter system to the attachment of the insulation to the tank shell and cladding to ensure adequate resistance to wind loads. Flashings or other means of weather protection should be provided where metal connections for walkways, etc. penetrate the insulation. All pipe connections should be insulated prior to fitting the cladding. The insulation at the roof edge should terminate as shown in Figure Q.5.

The sequence of the cladding and foaming procedure, the method of injecting the foam and the foaming pattern should be approved by the tank contractor and the purchaser.

The insulation contractor should define the weather and substrate temperature limits necessary for satisfactory foaming.

Means should be agreed between the insulation contractor, the tank contractor and the purchaser for establishing and checking the satisfactory quality of the foam.

Q.8.3 Spray foam

The type of foam and its physical and thermal properties should be agreed between the insulation contractor, the tank contractor and the purchaser.

The insulation contractor should define the weather and substrate temperature limits necessary for satisfactory spraying.

The thickness of the sprayed foam should not be less than the nominal design thickness. The standard of finish of the sprayed foam should be agreed between the purchaser and the insulation contractor and samples of foam of the agreed appearance prepared and retained for reference. Means should be agreed between the insulation contractor, the tank contractor and the purchaser for establishing and checking the satisfactory quality of the foam.

If a weatherproof finish is required, this should be applied over the foam insulation preferably by spraying after the foam is fully cured. The weatherproof finish should be applied in two coats of different colours. Where extra resistance to mechanical damage and/or bird attack is required, an agreed reinforcing medium should be applied between the two layers of the finish. The weatherproof finish should have a surface spread-of-flame resistance. The insulation contractor should agree suitable means for weather protecting the foam at the top edge of the tank.

The tank should be left uninsulated for a distance of approximately 150 mm from the base.

Q.8.4 Roofs

Where mineral wool and metal cladding form the insulation, the mechanical support system should be in accordance with Q.3.5 and Q.3.6 and be of upstand not less than the thickness of the insulation and not greater than this thickness plus 5 mm. Metal cladding should be as described in Q.7.3 and be fixed to the support system to withstand wind loads and wind induced vibrations. The fastening should be compatible with the cladding.

Additional reinforcement of the insulation system may be necessary where access may be required.

It may be convenient to apply foam insulation to the roof, either sprayed or foamed in situ, even if a mineral wool or other system is specified for the tank sides.

Q.9 Fire hazard

Possible fire hazards exist during construction and operation when organic plastic foam insulation is used. Although some materials and formulations are more resistant to fire than others, they are nevertheless still combustible and may not necessarily alleviate a fire hazard.

Annex R
(normative)

Surface finish

R.1 Internal surfaces in contact with the product

R.1.1 General

All temporary attachments shall be removed by grinding or other appropriate means without tearing the parent plate.

Any remaining areas of weld metal shall be dressed off and there shall be no wall thinning below the design thickness except as permitted by 15.7.

Internal welds shall be cleaned of slag and where lifting appliances have been used these areas shall be cleaned and dressed.

Internal surfaces shall be free of weld spatter.

R.1.2 Carbon and carbon manganese steel tanks

When any part of the tank requires the application of a protective coating, the surface finish of the plates and welds shall be in accordance with that specified by the coating applier and agreed with the manufacturer.

R.1.3 Stainless steel tanks

R.1.3.1 General

The condition of the internal surface of the tank shall be as specified (see A.1), dependent upon the products the tank will contain.

When no indications are given, level 1 shall apply.

The surfaces considered shall include all the plates, accessories and welds in contact with the product held by the tank.

Three levels of surface finish are specified:

Level 1 Normal finish

For tanks which require no special cleaning.

Level 2 Clean finish

Tank can be washed in cold conditions where traces of the product between uses are tolerated.

Level 3 Quality finish

Tank shall be washed under heated conditions and sterilized to remove all traces of the product between uses.

R.1.3.2 Level 1 Normal finish

The finish shall conform to the following:

Bottom, shell, roof:

- Sheet metal surface shall be as supplied;
- Undressed fillet welds shall be permitted;
- Welds shall be brush cleaned or if required, pickled and passivated;
- Examination shall be visual only.

Pipes and accessories:

- Surface shall be as supplied;
- Root penetration shall be as specified;
- Welds shall be brush cleaned or if required, pickled and passivated;
- Examination shall be visual only.

R.1.3.3 Level 2 Clean finish

The finish shall conform to the following:

Bottom, shell, roof

- Surface finish shall have a mean Ra ≤ 5 µm;
- Bottom/shell/roof connections shall have a minimum radius of 6 mm where practical;
- Pickling and passivation of the whole assembly shall be carried out;
- Examination shall be as follows:

  Visual 100 %;

  Verification of root penetration;

  Verification of the corner radius by random checks;

  Random roughness check.

Pipes and accessories

- Surface finish shall have a mean Ra ≤ 5 µms;
- Root penetration shall be between -0 mm and +0,5 mm;
- Long radius bends shall have $r \geq 4\ D$;
- Pickling and passivation of the whole assembly shall be carried out;

— Examination shall be as follows:

Visual 100 %;

Verification of root penetration;

Verification of the corner radius by random checks;

Random roughness checks.

R.1.3.4 Level 3 Quality finish

The finish shall conform to the following:

Bottom, shell, roof

— Surface finish of parent plate and welds, which shall be 100 % polished, shall have a mean Ra ≤ 2.5 µm;

— Welds shall be flush with the plate surface;

— All corner joints shall be radiused to a minimum of 6 mm where practical;

— Pickling and passivation of the whole assembly shall be carried out;

— Examination shall be as follows:

Visual 100 %;

Verification of root penetration;

Verification of the corners radius with a gauge;

Random roughness checks.

Pipes and accessories

— Surface finish, which shall be 100 % polished, shall have a mean R_a ≤ 2,5 µm;

— Root penetration shall be between - 0 mm and + 0,5 mm;

— Long radius bend from seamless and welded pipe with the weld flush;

— Corner radius shall be a minimum of 6 mm where practical;

— Pickling and passivation of the whole assembly shall be carried out;

— Examination shall be as follows:

Visual 100 %;

Verification of root penetration (endoscopy);

Verification of the corner radius with a gauge;

Random roughness check.

R.2 External surfaces

R.2.1 General

All temporary attachments shall be removed by grinding or other appropriate means without tearing the parent plate.

Any remaining areas of weld metal shall be dressed off and there shall be no wall thinning below the design thickness except as permitted by 15.7.

All welds shall be cleaned of slag and where lifting appliances have been used, these areas shall be cleaned and dressed.

Plates surfaces shall be free of weld spatter.

The tank's external appearance and finish shall be as specified (see A.1).

When the tank's surface is to be covered with a thermal or fireproof substance and the support attachments are welded to the tank, the welding shall be carried out before the hydrostatic test by the tank erector or by a suitably approved person with the tank erector's agreement.

R.2.2 Carbon and carbon manganese steel tanks

In order to avoid points of corrosion, the manufacturer shall ensure that there are no areas on the tank that cannot be covered by a protective coating.

The painting system required shall be specified at the order stage (see A.1).

NOTE Attention is drawn to the European Parliament and Council Directive No 94/63/EC [5].

The contractor shall notify the purchaser if he chooses to supply plates prepainted.

R.2.3 Stainless steel tanks

Welds of stainless steel tanks as well as all areas that present a source of contamination due to rust shall be pickled and passivated.

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