BRITISH STANDARD

BS EN 14879-6:2009

Organic coating systems and linings for protection of industrial apparatus and plants against corrosion caused by aggressive media

Part 6: Combined linings with tile and brick layers

ICS 25.220.60

British Standards

National foreword

This British Standard is the UK implementation of EN 14879-6:2009.

The UK participation in its preparation was entrusted to Technical Committee ISE/110, Steel Tubes, and Iron and Steel Fittings.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Organic coating systems and linings for protection of industrial apparatus and plants against corrosion caused by aggressive media - Part 6: Combined linings with tile and brick layers

Systèmes des revêtements organiques pour la protection des appareils et installations industriels contre la corrosion par des fluides agressifs - Partie 6 : Revêtements rapportés associés à des couches de carreaux et de briques

Beschichtungen und Auskleidungen aus organischen Werkstoffen zum Schutz von industriellen Anlagen gegen Korrosion durch aggressive Medien - Teil 6: Kombinierte Auskleidung mit Plattierungen (Plattenlagen) und Ausmauerungen

This European Standard was approved by CEN on 24 October 2009.

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Foreword

This document (EN 14879-6:2009) has been prepared by Technical Committee CEN/TC 360 “Project Committee - Coating systems for chemical apparatus and plants against corrosion”, the secretariat of which is held by DIN.

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of an identical text or by endorsement, at the latest by June 2010, and conflicting national standards shall be withdrawn at the latest by June 2010.

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

EN 14879, *Organic coating systems and linings for protection of industrial apparatus and plants against corrosion caused by aggressive media*, consists of the following parts:

— *Part 1: Terminology, design and preparation of substrate*

— *Part 2: Coatings on metallic components*

— *Part 3: Coatings on concrete components*

— *Part 4: Linings on metallic components*

— *Part 5: Linings on concrete components*

— *Part 6: Combined linings with tile and brick layers*

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

1 Scope

This European Standard describes the requirements for and methods of testing of combined systems with tile and brick layers which are applied to concrete or metallic process engineering equipment that will come in contact with chemical substances (liquids, solids and gases). The requirements specified here may be used for the purposes of quality control (e.g. as agreed between the contract partners or having been given by national regulations[1)]).

The standard applies to systems which serve one or more of the following purposes:

— to protect the component from adverse effects of aggressive substances;

— to protect waters (e.g. ground water) against hazardous substances;

— to protect the charge from becoming contaminated by components released from the substrate material;

— to achieve a particular surface quality.

The described combined systems can be used for concrete or metallic process engineering equipment that will come into contact with chemical substances.

The combined system is a combination of:

— a coating according to EN 14879-2 or EN 14879-3 with an additional layer of tiles or bricks embedded in cement mortar, resin based mortar and/or potassium silicate mortar as an adhesive bonding cement (referred to simply as cement in this standard); or

— a lining according to EN 14879-4 or EN 14879-5 with an additional layer of tiles or bricks embedded in cement mortar, resin based mortar and/or potassium silicate mortar as an adhesive bonding cement (referred to simply as cement in this standard).

For design and preparation of substrate, see EN 14879-1.

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 206-1, *Concrete – Part 1: Specification, performance, production and conformity*

EN 13501-1:2007, *Fire classification of construction products and building elements – Part 1: Classification using data from reaction to fire tests*

EN 14879-1:2005, *Organic coating systems and linings for protection of industrial apparatus and plants against corrosion caused by aggressive media – Part 1: Terminology, design and preparation of substrate*

EN 14879-2:2006, *Organic coating systems and linings for protection of industrial apparatus and plants against corrosion caused by aggressive media – Part 2: Coatings on metallic components*

EN 14879-3:2006, *Organic coating systems and linings for protection of industrial apparatus and plants against corrosion caused by aggressive media – Part 3: Coatings on concrete components*

1) For the purposes of this standard, the contract partners are the coating material, lining, mortar, tiles and bricks manufacturers, the component manufacturer, the person(s) responsible for applying the coating, lining, mortar, tiles and bricks, and the client ordering the finished component(s).

EN 14879-4:2007, *Organic coating systems and linings for protection of industrial apparatus and plants against corrosion caused by aggressive media – Part 4: Linings on metallic components*

EN 14879-5:2007, *Organic coating systems and linings for protection of industrial apparatus and plants against corrosion caused by aggressive media – Part 5: Linings on concrete components*

EN ISO 291, *Plastics – Standard atmospheres for conditioning and testing (ISO 291:2008)*

EN ISO 10545-12, *Ceramic tiles – Part 12: Determination of frost resistance (ISO 10545-12:1995, including Technical Corrigendum 1:1997)*

IEC 60093:1980, *Methods of test for volume resistivity and surface resistivity of solid electrical insulating materials*

IEC 60167, *Methods of test for the determination of the insulation resistance of solid insulating materials*

3 Terms and definitions

For the purposes of this document, the following terms and definitions in addition to those of EN 14879-1:2005, EN 14879-2:2006, EN 14879-3:2006, EN 14879-4:2007 and EN 14879-5:2007 apply.

3.1
combined lining system
combined lining system applied as a protection against chemical, mechanical and thermal loading

NOTE Such systems comprise a sealing layer and a service layer (see Figure 1). Taken together, the two layers provide a more effective protection than each layer would provide on its own.

3.2
sealing layer
bottom layer of the combined lining system that is applied to the concrete or metal surface

NOTE It serves both as a primer (promoting adhesion) and as a layer which is impervious to liquids.

3.3
service layer
top layer of the combined lining system, which is made of tiles or bricks bonded to the sealing layer by means of mortar or cement

NOTE It serves to protect the sealing layer from the direct contact with chemical, mechanical and thermal loads.

3.4
semi-finished product
tile, brick, also in other shapes

EXAMPLES Pipes, nozzles.

3.5
jointing mortar
mortar or cement used to fill the joints between the semi-finished products

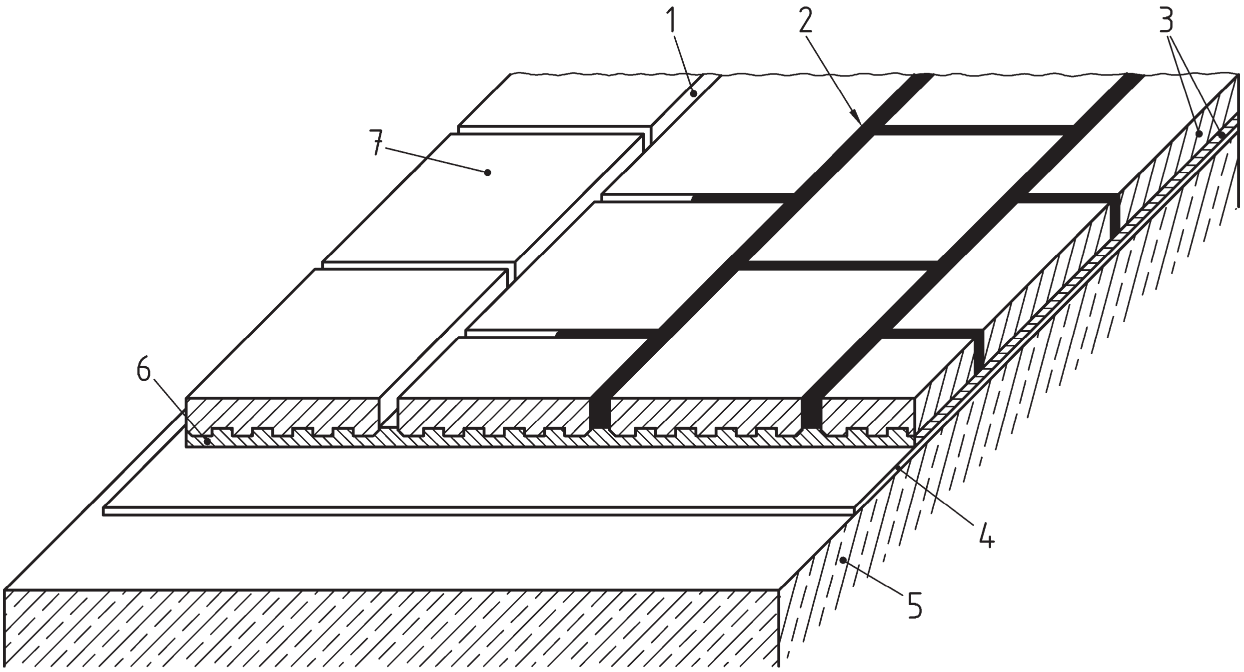
3.6
bedding mortar
mortar or cement used to form the bed between the sealing layer and the surfacing units

3.7
bed joint
layer of mortar between the sealing layer and the service layer

3.8
butt joint
joint between tiles and/or bricks

3.9
"closed-joint" technique
technique by which the bedding is laid and joints between tiles and/or bricks are filled at the same time

3.10
"open-joint" technique
technique by which the joints between tiles and/or bricks are left open and then filled at a later time



Key

1 Hollow joint, 6 to 8 mm wide
2 Butt joints filled with jointing mortar/cement
3 Service layer (Combination of 6 and 7)
4 Sealing layer
5 Steel or concrete substrate
6 Bed joint; bedding mortar/cement
7 Acid-proof tiles, bricks

Figure 1 — Lay-up of a combined lining system

4 General

4.1 Steel vessels and apparatus

4.1.1 Calculating the dimensions of brick-lined steel vessels

The dimensions of brick-lined vessels shall be calculated so that deformations of the structure shall not at any point assume proportions liable to damage the brick lining.

Brick-lined vessels which are operated by heat and/or pressure shall be designed on the basis of principles that go beyond the requirements for pressure vessels, account being taken of the following:

a) The necessary contact between the vessel wall and the brick lining;

b) Protection against crack formation in the brick lining;

c) Swelling of the brick lining (mortar/cement) which is possible.

Harmful tensile stresses in brick linings shall be avoided. These stresses may be calculated primarily on the basis of the following variables:

d) Modulus of elasticity of the casing (E_e) and the brick lining (E_m);

e) Thickness of the vessel wall (S_e) and the brick lining (S_m);

f) Coefficient of linear expansion of the vessel wall (α_e) and the brick lining (α_m);

g) Thermal conductivity of the vessel wall (λ_e) and the brick lining (λ_m);

h) Thermal conductivity of the internal and/or external insulation (λ_i) and (λ_a), if fitted;

i) The internal (α_i) and external (α_a) heat transfer coefficients; allowance shall be made for the (occasionally unilateral) influence which the wind, solar radiation and rainfall may have on the temperature);

j) The swelling factors (q) of the materials used for the brick lining.

The properties of the materials shall be obtained from the manufacturer's information. Guideline values can be found in 4.5.

A stress determination for the brick lining shall be required if very high stresses of thermal origin and/or excess pressure are present. Stress determination may be omitted if experience is available on vessels of similar design operated under similar conditions.

The calculation of the thickness of the vessel wall and brick lining shall preferably be based on values established by experience, bearing in mind that swelling can cause the stresses in the casing and the brick lining to be greater when they are cold than when they are in operation. A subsequent calculation may be carried out to establish whether the stresses in the brick lining and the casing remain within the permissible limits in all cases. Otherwise, different building materials shall be selected, the dimensions shall be modified and/or the casing shall resist an initial tensile stress and the brick lining an initial compressive stress.

The thickness of the vessel walls may also be calculated from the requirement relating to compliance with the permissible tolerances in 4.1.2.

In calculations of the wall thickness of cylindrical or spherical vessels the influence of the brick lining may be taken into account in case of certain pressure and temperature conditions.

Careful account shall be taken of the deformation of the vessel casing by the imposed loads, especially in horizontal vessels. This can reach proportions that lead to damage to the brick lining without the permissible stresses in the casing being exceeded.

This type of deformation shall be kept to a low level by suitable design of the imposed loads and adequate reinforcement of the casing, according to national regulations, e.g. DIN 28080, DIN 28081-1, DIN 28081-2, DIN 28083-1, DIN 28084 (all parts), DIN 28082-1 and DIN 28082-2.

A deflection of $f \leq \frac{a}{1\,000}$ may be assumed as an indicative value when calculating the dimensions of flat vessel components, where *a* denotes the bearing width. Bearing widths that are common in practice are between 600 mm and 900 mm.

4.1.2 Dimensional tolerances (for steel and non-ferrous vessels)

For test methods for dimensional tolerances see Annex D.

After final installation the radii in the cylindrical part may not deviate from the mean value of the plane of measurement by more than ± 0,4 %; in vessels whose diameter exceeds 7 500 mm they may not deviate by more than ± 15 mm. The planes of measurement have a common centre axis. Generally speaking the circumference of the measurement circle U shall be divided into 16 equal segments U/16 in order to determine the measurement points. The adjustment of the deviation to the normal circle shall cover at least 1/16 of the length of the circumference, or at least 1 500 mm for diameters in excess of 7 500 mm. The maximum deviations of successive measurement points will therefore not exceed 0,4 % or 15 mm.

The distance between planes of measurement shall be 1 000 mm to 2 500 mm. These planes of measurement, which are perpendicular to the vessel axis, shall be 100 mm from the weld seams of the cylindrical courses with the exception of the first or last plane of measurement in the case of bases or covers according to DIN 28011, DIN 28013 and DIN 28014. With these torispherical or ellipsoidal heads the distance between the nearest plane of measurement and the weld seam between the base and the cylindrical part shall be 1 000 mm.

The roundness tolerances for bases and covers are given in national regulations, e.g. DIN 28011, DIN 28013 and DIN 28014, calculation according to EN 13445-3.

The straightness tolerance of flat walls shall be 10 mm for any profile lines in the vessel wall between 900 mm and 1 500 mm long. According to EN ISO 1101:2005 the straightness tolerance is defined as the distance between two parallel lines or planes, between which all points on the profile line in question shall lie.

The straightness tolerance of flat, rectangular or round bases shall be 10 mm for any profile lines in the vessel wall between 900 mm and 1 500 mm long.

Deviations from the ideal line (allowances) between one measurement point and another may not exceed half the tolerance and may only occur gradually.

4.1.3 Construction of steel vessels

Flat surfaces present problems with respect to brick linings. They shall therefore:

a) be kept as small as possible;

b) be strongly reinforced against bending;

c) be designed so as to have flexural strength at the corners;

d) have a retaining point for the brickwork on the free edge, if necessary (see Figure 2);

e) be designed with an inclination ≥ 2 % if necessary.

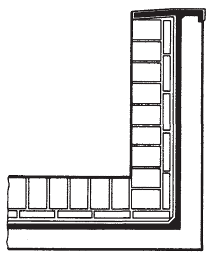


Figure 2 — Flat plate wall

Base and lateral supports shall only be fitted where absolutely necessary.

If vessel covers are to be brick-lined they shall be curved and have a support for the lining.

4.1.4 Installation of brick-lined vessels

The vessel shall be placed in its final position before being brick-lined. If this is not possible, any required transportation of brick-lined vessels shall be undertaken only if the brick lining is adequately stable. It is advantageous to install struts carefully for the transportation. The stability can be favourably affected by generation of a pre-stress. Rolling of brick-lined apparatus is not permissible.

Environmental and/or safety requirements are to be observed.

4.1.5 Leak tests

All vessels shall be leak-tested before being brick-lined.

4.1.6 Repairs and modifications

If brick-lined vessels require welding, the brick lining within a reasonable distance of the weld point shall be removed before welding takes place. The regulations that apply to brick-lined vessels shall also be observed.

4.2 Concrete vessels and apparatus

4.2.1 Calculating the dimensions of brick-lined concrete vessels

Dimensions of the vessels to be brick-lined are to be statically calculated so that the structural deformations are limited in such a way that no possibility of damages in the brick lining can occur. Here special attention should be paid to reduce cracks in the concrete, in relation to the sealing layer to be used. With consideration of thickness and elasticity of the sealing layer, the width of cracks in the concrete must be limited to 0,1 mm to 0,3 mm. The reinforcement is to be laid out in accordance with EN 206-1. When calculating and executing the concrete structure the operating temperature and pressure and the possible swelling of the brick lining should be considered. Damaging tensile strengths shall be avoided. The properties of the materials should be taken from the manufacturer's specifications. Typical values are given in 4.5. In case of higher temperatures and/or excess pressure a tensile appraisal will become necessary. Practical references can be applied.

4.2.2 Dimensional tolerances

At this time no regulated specifications exist. Admissible deviations shall be agreed with the manufacturer of the brick lining.

4.2.3 Requirements to the concrete construction

Requirements to the concrete construction and surface shall be in accordance to EN 14879-1.

4.3 Substrate preparation

For preparation of substrate see EN 14879-1.

4.4 Sealing layer

The sealing layer shall be either a coating according to EN 14879-2 and/or EN 14879-3 or a lining according to EN 14879-4 and/or EN 14879-5.

The sealing layer of a combined lining system serves as a sealing of the component and crack bridging of the concrete. Since in most cases the service layer also protects the sealing layer from direct exposure to chemical, mechanical or thermal loads, the suitability may only be determined by testing the system as a whole.

Taking into consideration the particular requirement and the expected life the combination of sealing layer and service layer that has the best all-around resistance shall be selected. As a rule, the system shall be designed either for the expected loads or (in special cases) for higher loads than expected.

a) Leak tightness

To prevent the leakage of fluids, the sealing layer shall be free of pinholes, inclusions and other defects, and shall be continuous in all areas, which need protection.

b) Vapour and/or liquid impermeability

The sealing layer shall be sufficiently impervious to vapour and/or liquids, that is, the substrate shall not be exposed to chemical attack, nor shall the layer disbond when loaded.

c) Chemical resistance

The sealing layer in combination with the service layer shall be adequately resistant to chemicals. A sealing layer — though not sufficiently resistant to long-term direct exposure — may fulfil its function, because the service layer above makes the attacking agent stagnant in that it hinders a direct contact with the agent and thus reduces the impact on the sealing layer.

d) Resistance to mechanical loading

The sealing layer has to be resistant enough to absorb the mechanical stress on the service layer and conduct it into the supporting substrate without any disadvantageous change of its structure or function. This applies to both resting loads and rolling loads which can also cause horizontal stress in addition to vertical compression. In this case the loading frequency is important. Deformation of the substrate due to shrinkage and creep, stresses caused by different rates of thermal expansion in the substrate and service layer, and the nature of cracking in the concrete substrate (see EN 14879-1 for a classification of cracks) shall also be taken into consideration when selecting sealing layer materials.

e) Thermal stability

Sealing layers shall be sufficiently resistant to heat. The thermal transmittance of the wear layer and the heat dissipation properties of the substrate shall be taken into consideration when designing the coating or lining system. In cases of doubt, the thermal behaviour of the entire system shall be calculated.

f) Resistance to ageing

The service layer protects the sealing layer from most external factors which could lead to premature ageing. However, the sealing layer's ageing behaviour can be adversely affected by long-term exposure to elevated temperatures. It shall be ensured that there is no loss of adhesion or an inability to bridge cracks caused by an increasing brittleness of the layer.

g) Maintenance

It shall be possible to repair the sealing layer.

4.5 Service layer

4.5.1 Bedding and jointing mortar/cement

4.5.1.1 General

In combined lining systems, the mortar is used for bonding the sealing layer to the service layer and for jointing the tiles and/or bricks of the service layer.

As a rule, the mortar is in direct contact with the process medium. After longer operating time even the mortar bed usually comes into contact with the medium.

The mortar used shall be selected on the basis of the expected loading, taking the load profile according to 4.7.1 to 4.7.5 and the following requirements into consideration.

a) Chemical resistance

The mortar that will come into contact with the medium shall be resistant to that medium. The duration of exposure to the medium, and concentration and temperature of the medium shall be taken into consideration.

b) Resistance to mechanical loading

The mortar shall be capable of transmitting any static or dynamic mechanical loads (including vibration) to the substrate via the sealing layer without becoming damaged, even under concurrent thermal loading.

The allowable, temperature depending surface pressure of materials with thermoplastic properties like bitumen, shall especially be considered.

c) Thermal stability

The mortar shall be resistant to any expected thermal loads. Especially to be considered are the maximum and minimum temperatures to which the mortar will be exposed, the duration of exposure, and the speed and frequency of any temperature changes.

d) Shrinkage

While hardening, mortar shrinks to an extent which depends on its specific material properties. In combined lining systems, this shrinkage and any changes in length are hindered, resulting in shrinkage stress. The mortar used shall form a solid bond with the sealing layer and tiles or bricks in the service layer. Additional measures such as sanding, keying or priming may be used to improve adhesion.

There shall be no cavities or cracks in the service layer. Shrinkages can be reduced by using for example thicker tiles or bricks.

e) Capability of dissipating electrostatic charges

If necessary, the resin based mortar's conductivity may be increased by adding suitable materials (e.g. carbon fillers).

The dissipation resistance is tested according to Annex C (normative) with a measuring voltage of 100 V.

The insulation resistance (surface resistance) is measured according to IEC 60167 with 100 V DC voltages. EN 1081 may still be used.

4.5.1.2 Materials

4.5.1.2.1 General

The following materials may be used for bedding and jointing:

a) cement mortar;

b) potassium silicate mortar;

c) bituminous compounds;

d) resin-based mortars (e.g. based on epoxy (EP), furan (FU), phenol formaldehyde (PF), unsaturated polyester (UP), or vinyl ester (VE)).

Table 1 presents the general characteristics of cement mortar, potassium silicate mortar and bituminous compounds. The general characteristics of the resin-based cement are presented in Table 2. Physical properties are given in Table 3.

Table 1 — General characteristics of cement mortar, potassium silicate mortar and/or bituminous compounds

	Cement mortar	Potassium silicate mortar	Bituminous compounds
Binder	Portland, blast furnace or high alumina cement	Potassium silicate, sodium silicate	Oxidized bitumen
Filler	Quartz, trass	Quartz	Quartz, kaolin, carbon, barites
Catalyst	Water	Neutralising agent	—
Processing aid	Non saponifiable resin emulsion	—	—
Hardening principle	Hydration	Coagulation	Solidification
Pot life	30 min to several hours	30 min to 2 h	—
Shrinkage, as a percentage by mass	0,6 to 0,9	1,5 to 2,5	[b]
May be subjected to loading after	several days	several days	after cooling
Adhesion to:			
— carbon	(not applicable)	(not applicable)	+
— ceramics	+	+	+
— steel	+	+	+
— concrete	+	+[a]	+
— rubber	–/+[a]	–	+
— thermoplastics	–/+[a]	–/+[a]	+
— resin coatings	–/+[a]	–/+[a]	
Use for:			
— floors and walls	++	○	+
— vessels and apparatus	+	++	+
— chemical loading	Suitable only at a pH > 4	Highly suitable at a pH < 5	+
— mechanical loading	+	+	○
— thermal loading	++	++	–

[a] With priming and sanding.

[b] The term "shrinkage" is not applicable to bituminous materials. The corresponding property in bitumen is the coefficient of cubic expansion, which is 0,000 61 within a temperature range of 15 °C to 200 °C.

Key to symbols:

++ very good/highly suitable

\+ good/suitable

○ good/suitable only under certain conditions

– poor/unsuitable

Table 2 — General characteristics of resin-based mortars

	Mortars on the basis of				
	EP	FU	PF	UP	VE
Number of components	2 to 3	2 to 3	2 to 3	2 to 4	2 to 4
Binder	EP	FU	PF	UP	VE
Filler	Quartz, carbon, barites	Quartz, carbon, barites	Quartz, carbon, barites	Quartz, carbon, barites	Quartz, carbon, barites
Hardener	Polyamine	Organic acids	Organic acids	Organic peroxide	Organic peroxide
Processing aid	—	—	—	Organic accelerator	Organic accelerator
Curing reaction	Polyaddition	Polycondensation	Polycondensation	Polymerisation	Polymerisation
Pot life at 20 °C, in hours	½ to 1	½ to 1	½ to 1	½	½
Curing time at 20 °C, in hours	24	24	24	12	12
Shrinkage, as a percentage by mass	0,2 to 0,4	0,3 to 0,8	0,3 to 0,6	0,2 to 0,5	0,2 to 0,5
May be subjected to chemical loading after curing at 20 °C for	2 to 7 d	2 to 7 d	2 to 7 d	1 to 7 d	1 to 7 d
Adhesion to:					
— Ceramics	++	++	++	+	+
— Carbon	++	+	+	+[a]	+[a]
— Rubber	– to +	– to +	– to +	– to +	– to +
— Thermoplastics	○ to ++	○ to ++	○ to ++	○ to ++	○ to ++
— Resin based coatings					
Use for:					
— Floors and walls	++	++	++	++	++
— Vessels and tanks	+	++	++	++	++
— Chemical loads	+	++	++	+	+
— Mechanical loads	++	++	++	++	++
— Thermal loads	○	++	+	+	+

[a] Only with primer.

Key to symbols:

++ very good/highly suitable

\+ good/suitable

○ good/suitable only under certain conditions

– poor/unsuitable

Table 3 — Physical properties of mortars and bituminous compounds

Material	Density, in g/cm^3	Water, absorption, as a percentage by mass	Compressive strength, in N/mm^2	Bending strength, in N/mm^2	Modulus of elasticity[b] (compressive/ flexural), in 10^4 N/mm^2	Coefficient of linear thermal expansion, in 10^{-6} K^{-1}	Thermal stability at temperatures up to (in °C)
Cement mortar	About 2,1	About 15	> 10	—	1,5	10	250
Potassium silicate mortar	2,0 to 2,3	About 10	20 to 40	5 to 10	About 1	12	900
Bituminous compounds	About 1,7	< 1	—[a]	—	—	—	—
Resin-based mortar with mineral fillers	1,7 to 2,2	< 1	50 to 100	20 to 40	1 to 2	20 to 50	180
Resin-based mortar with carbon fillers	1,4 to 2,0	< 1	50 to 100	20 to 30	About 0,8	20 to 30	250

[a] It is not possible to determine strength values and the thermal stability of bitumen owing to their thermoplastic properties. A relevant characteristic, however, is the permissible surface pressure, which is about 0,2 N/mm^2 at 20 °C and which decreases as the temperature increases.

[b] In the case of potassium silicate mortar and cement mortar, this is the modulus in compression, while for resin-based cement, this is the flexural modulus.

4.5.1.2.2 General material characteristics

The general characteristics listed in Tables 1 and 2 have been taken from information provided by various manufacturers and serve only as guidelines, since the type and composition of binders, catalysts, accelerators and fillers can vary considerably.

Appraisal of suitability shall be carried out on the basis of the manufacturer's information (e.g. technical data sheet).

4.5.1.2.3 Physical properties

Table 3 lists the physical properties of various mortars and bituminous compounds. These values are guidelines only, since the type and composition of binders, hardeners, accelerators and fillers, as well as ageing conditions and the effects of temperature can influence the properties.

Appraisal of suitability shall be carried out on the basis of the manufacturer's information (e.g. technical data sheet).

4.5.1.2.4 Chemical resistance

Table 4 is informative and only to be used as a guideline. The values should indicate the relation of the material resistances to each other. The table lists mortars and bituminous compounds according to their resistance to various chemicals at ambient temperature and under continuous loading. Resistance is higher with short periods of loading (e.g. floor tilings).

Appraisal of suitability shall be carried out on the basis of the manufacturer's information (e.g. data sheet).

The influence of medium temperature and concentration is considerable and shall be considered.

Potassium silicate mortar and cement mortar are not completely impervious to liquids and will be penetrated where there is continuous loading under pressure. Nevertheless, due to stagnation and/or using appropriate sealing layers and tiles or bricks, potassium silicate mortar and cement mortar have proven useful in various applications where the semi-finished products may become saturated by the medium but are not penetrated by it, and an appropriate sealing layer has been provided. Cement mortars are used on floors and potassium silicate mortars are applied in vessel masonries.

Table 4 — Resistance of mortar and bituminous compounds to various chemicals at ambient temperature

Group	Chemical type	Examples		Cement mortar	Potassium silicate mortar	Bituminous compounds	Mortars based on				
							UP	VE	EP	FU	PF
I. Inorganic Chemicals											
1	Inorganic, non-oxidizing acids	HCl H_2SO_4 H_3PO_4	Hydrochloric acid Sulphuric acid, up to 70 % Phosphoric acid	–	+	+	+	+	○	+	+
2	Inorganic, oxidizing acids	HNO_3 H_2SO_4 CrO_3, H_2CrO_4 $HClO_3$	Nitric acid Sulphuric acid, over 70 % Chromic acid Chloric acid	–	+	○	+	+	○	○	○
3	Inorganic acids, dissolving SiO_2	HF H_2SiF_6 HBF_4	Hydrofluoric acid Hexafluorosilicic acid (contains HF) Tetrafluoroboric acid (contains HF)	–	–	+	+	+	+	+	+
4	Salts	NaCl $FeSO_4$ Na_2CO_3	Sodium chloride Iron (II) sulphate Sodium carbonate	○	+	+	+	+	+	+	+
5	Bases	NaOH KOH CaO, Ca (OH_2) NH_4OH	Sodium hydroxide Potassium hydroxide Calcium oxide, calcium hydroxide Ammonium hydroxide solution	○	–	+	○	+	+	+	○
6	Oxidizing bases	NaOCl	Sodium hypochlorite	○	–	○	+	+	○	○	–
II. Organic Chemicals											
7	Organic acids	HCOOH CH_3COOH $CH_2ClCOOH$ $(COOH)_2$ $CH_3CHOHCOOH$	Formic acid Acetic acid Chloroacetic acid Oxalic acid Lactic acid	–	+	○	+	+	○	+	+
8	Aliphatic hydrocarbons	C_6H_{14} C_8H_{18}	Hexane Octane	○	+	–	+	+	+	+	+
9	Aromatic hydrocarbons	C_6H_6 C_7H_8 $C_6H_4(CH_3)_2$	Benzene Toluene Xylene	○	+	–	–	+	○	+	+
10	Alcohols	CH_3OH C_2H_5OH C_4H_9OH $CH_2OH\text{-}CH_2OH$	Methanol Ethanol Butanol Ethanediol	+	+	○	+	+	○	+	+
11	Ketones, esters	CH_3COCH_3 $C_2H_5COCH_3$ $CH_3COOC_2H_5$	Acetone Methyl ethyl ketone (2-butanone) Ethyl acetate	–	+	–	–	○	○	+	+
12	Aldehydes	CH_2O	Formaldehyde	○	+	○	○	○	○	+	+
13	Aliphatic halogenated hydrocarbons	CH_2Cl_2 C_2HCl_3 $C_2Cl_3F_3$	Dichloromethane Trichloroethylene Trichlorotrifluoroethane	○	+	–	–	○	–	+	+
14	Aromatic halogenated hydrocarbons	C_6H_5Cl $ClC_6H_4CF_3$	Chlorobenzene Chlorobenzotrifluoride	○	+	–	–	○	–	+	+
15	Aliphatic amines	CH_3NH_2 $(C_2H_5)_3N$	Methylamine Triethylamine	+	+	–	○	+	–	+	+
16	Aromatic amines	$C_6H_5NH_2$	Aniline	+	+	–	–	○	–	+	+
17	Phenols	C_6H_5OH $CH_3C_6H_4OH$	Phenol Cresol	–	○	–	–	○	–	+	+
18	Fats, oils		Vegetable and animal fats, oils	○	+	–	+	+	○	+	+

The information provided here is informative only.

Key to symbols:

\+ recommended

– not recommended

○ recommended only under certain circumstances

4.5.2 Jointing materials for expansion joints

Structurally necessary expansion joints in the concrete parts must be continued in the combined lining. Due to the given chemical loads in process plant, special designs are required for such joints. Once the combined lining system has been applied, expansion joints in the system shall be filled with an elastic compound. Such joint filling components may be elastomer or plastics based on silicon, polysulphide or polyurethane, for example. Since these materials often do not have the same level of resistance as the used mortars, they require regular monitoring and maintenance. When properly applied, joint sealants keep aggressive media from penetrating through to the sealing layer, at least temporarily.

Appraisal of suitability shall be carried out on the basis of the material manufacturer's information (e.g. data sheet).

4.5.3 Semi-finished products

4.5.3.1 General

The semi-finished products together with bedding and jointing mortar form the so-called service layer. This shall be capable to protect the sealing layer from chemical, mechanical and thermal loads, or at least to reduce their effect.

Appraisal of suitability shall be carried out on the basis of the manufacturer's information (e.g. data sheet).

4.5.3.2 Materials

4.5.3.2.1 Mineral, non-metallic and inorganic based semi-finished products

Mineral, non-metallic and inorganic based semi-finished products are, for example:

- acid-resistant ceramics;
- stoneware;
- cast basalt tiles;
- natural stone tiles;
- carbon bricks;
- resin impregnated carbon bricks;
- graphite bricks;
- resin impregnated graphite bricks.

4.5.3.2.2 Resin-based semi-finished products

In special cases, resin-based materials may be used as semi-finished products. These include wear- and impact-resistant preformed pieces, slabs, edge covers, and pipes. Such products are suitable for use with resin-based mortars, as these materials have similar compositions and thus similar properties. Resin-based materials are normally more wear- and impact-resistant than mineral products.

Tables 2 to 4 apply to units of resin-based materials by analogy.

4.5.3.2.3 Thermosets and thermoplastics

Units of thermosets (e.g. GFK and CFK) or thermoplastics (e.g. PE, PP, PVC and PVDF) may be used for pipe work, outlets, nozzles, drains, etc.

4.5.3.3 Material characteristics

In the following tables a general review of semi-finished products for the brick lining and/or tiling of chemical equipment and vessels and other apparatus is given.

A list of brick-lining materials, classified on the basis of their external appearance and their material category, is prefixed to the table of material characteristics.

The material characteristics, which are of importance for the choice of semi-finished products, are listed in Table 5 on the basis of this classification. The values given in the tables are guide values, which can vary within certain limits depending on the raw materials and production processes used for the manufacture of the materials. Therefore they may not be used as they stand as a basis for enquiries and orders, since the requirements can on occasion have to be modified in relation to other properties in order to obtain a maximum value for a particular property.

The choice of semi-finished products and other materials requires great experience and should only be made by experts. Expert advice should be sought early during the planning stage, in the case of repairs to brick-linings and before any modification of operating processes.

Different test methods for the examination of the material properties are available; for instance tests can be accomplished in dependence on EN 933 (all parts). Test results will only be comparable if they are obtained by the same test methods. Practical experiences with materials stressed under real operating conditions (references) are of highest value. This finding cannot be replaced by any test.

The performance of creep rupture tests and the use of non-destructive test techniques are particularly important for these materials.

The information given below is to be regarded in the light of these considerations. It is indicative in nature and cannot be given general application, since separate considerations apply in virtually all individual cases.

When considering the use of particular building and other materials under chemical stresses, reference shall be made to the information given by the manufacturer.

The values given are guide values and cannot be used as they stand as a basis for enquiries and orders.

The electrical properties are also relevant in some cases.

Table 5 — Bricks, tiles and shaped components and material characteristics

	Building material	Bulk density	Water absorption	Solubility in sulphuric acid	Compression strength	Bending strength
		kg/dm^3	Wt.%	Wt.%	N/mm^2	N/mm^2
	Acid-resistant bricks, tiles and shaped components	2,0 to 2,2	2 to 8	0,5 to 1,5	50 to 120	12 to 20
	Industrial chemical stone-ware	2,2 to 2,4	0,2 to 3,5	0,5 to 2,5	150 to 400	30 to 60
	Cast basalt	2,8 to 2,9	0	[d]	450 to 550	80
	Natural stone	1,8 to 3,0	[d]	[d]	[d]	[d]
	Carbon brick non-impregnated	1,4 to 1,6	18 to 22	About 0	20 to 40	8 to 12
	Carbon brick synthetic resin-impregnated	1,6 to 1,8	0 to 10[e]	About 0	90 to 110	25 to 35
	Non-impregnated electro-graphite	1,6 to 1,7	17 to 19	About 0	25 to 40	10 to 20
	Synthetic resin-impregnated electro-graphite	1,7 to 1,9	0 to 10[e]	About 0	80 to 100	25 to 35
Footnotes see next page.						

Table 5 (*continued*)

Elasticity modulus compression	Linear expansion coefficient	Heat conductivity	Max. operating temp.[b]	Resistance to cyclic temperature stresses	Wear (abrasion)	
10^4 N/mm^2	10^{-5} K^{-1}	$\frac{W}{(m \bullet K)}$	°C	Quenching	cm^3/ 50 cm^2	
3,0 to 3,5	0,5 to 0,6	0,9 to 1,3[c]		5 to 12	8 to 15	
4,5 to 6,0	0,4 to 0,5	1,3 to 1,6[c]	300[a]		4 to 12	
10 to 12	0,6 to 0,8	1,0 to 1,2			4 to 6	
d	d	0,9 to 1,4		d	d	
0,5 to 1,5	0,3 to 0,4	1,7 to 7,0[c]				
1,0 to 2,5	0,35 to 0,5	1,7 to 7,0	150 to 180			
0,5 to 0,9	0,18 to 0,2	90 to 140	300[a]			
0,9 to 1,6	0,35 to 0,4	90 to 140	150 to 180			

[a] Suitable for use up to 300 °C under normal hydrothermal conditions for chemical equipment construction (with the exception of chemical ovens).

[b] Attention to be paid to chemical stresses, stress duration and cyclic temperatures stresses.

[c] If moistening occurs during operation, higher values have to be allowed depending on the water absorption of the material.

[d] The values will vary depending on the nature and/or origin of the material.

[e] The values will vary depending on the material and the type of impregnation.

4.6 Combined lining system

The combined lining system shall be capable to endure permanently the specified loads without a reduction in functionality. To achieve this, materials for the sealing and service layers have to be adjusted to each other.

a) Chemical resistance

The concentration of the agent or medium shall be taken into consideration, as well as reaction and properties of agent or medium combinations. Note that the aggressiveness of a medium does not necessarily increase with an increase in concentration.

The effects of cleaning products shall also be taken into account.

b) Resistance to mechanical loading

Mechanical loading can be static or dynamic, horizontal or vertical. The system shall be capable of accomodating such loads, as well as shear forces (e.g. caused by the stopping and starting of heavy vehicles on floor areas), and of transmitting them to the substrate.

The strength of the sealing and service layers, and the abrasion resistance of the tiles and bricks and mortars shall be taken into account when designing the system. Shrinkage stresses and stresses caused by different rates of thermal expansion shall also be considered.

c) Thermal stability

Thermal loads can be caused in tanks and vessels by hot media or by spillages of hot liquids on floors (e.g. as leaks or when pouring), by radiant heat or climatic influence, during cleaning with hot water or steam, and as a result of sudden changes in temperature.

The service layer thickness required to resist thermal loads cannot be determined until the combined lining system materials have been selected in terms of their resistance to all types of load; this will ensure that the sealing layer is not exposed to excessive thermal loading.

d) Flatness and slope

On floors the combined lining system shall have a flat surface with a slope of 2 %, at least 1,5 %, which will ensure proper drainage. Grooved surfaces may have a smaller slope.

e) Special requirements

In case of need one or more of the following exemplarily listed requirements for the combined lining must be taken into consideration by the applicator and/or supplier of the material:

1) resistance to radiation;
2) decontamination;
3) capability of dissipating electrostatic charges;
4) prevention of mechanical sparking;
5) increased skid resistance;
6) increased maintainability.

4.7 Selection criteria

4.7.1 Type and frequency of fluid loading

The requirements for the protective or sealing function of a surface protection system are linked to the type and frequency of the fluid loads to which it will be exposed. Exposure shall be graded as follows.

Grade 0: no exposure to fluids.

Grade 1: sporadic exposure to droplets of fluid (e.g. laboratory floors, floors in small units, walls).

Grade 2: frequent, short-term exposure to splashes of fluid, where the surfaces are regularly flushed (e.g. floors of closed production plants).

Grade 3: exceptional and limited exposure to fluids during operations (e.g. due to plant failure) in, for example, secondary containments.

Grade 4: constant or frequent exposure to a film of fluid, due to wetness, condensation, puddles, trickles and the like (e.g. floors in production plants, electroplating plants or pumping stations).

Grade 5: operational exposure to a constant flow of fluid involving no significant hydrostatic pressure (e.g. open gutters, trenches and their pump sumps, closed channels and pipes).

Grade 6: constant exposure of containers to fluid contents for unlimited periods (e.g. vessels, pits).

4.7.2 Thermal loading

The thermal load caused by medium effect or other sources of heat affects the effectiveness of a surface protection system in the following way:

a) Aggressiveness of medium

Elevated temperatures increase the aggressiveness of the medium by raising the levels of its chemical reactions and diffusion, and also through the accumulation of volatile substances in the headspace.

b) Thermal stress

Temperatures which deviate from the installation temperature cause thermal stress between the substrate and the surface protection system and may cause peeling, cracks, etc. This can result from the direct action of hot or cold media, or from radiant heat and extreme ambient temperature.

The maximum thermal load shall be stated in degrees Celsius (°C).

4.7.3 Changes in temperature

Changes in temperature include:

a) temperature changes at the protective surface during exposure to fluid loads of grades 3 to 5 as in 4.7.1 caused by increased/decreased medium temperatures;

b) temperature changes at otherwise constantly heated or cooled surfaces, resulting from operational circumstances, such as start-up and shutdown;

c) temperature changes, possibly involving thermal shock, which occur during cleaning operations;

d) process-related changes in the temperature of the medium under loading conditions corresponding to grade 6 (as in 4.7.1).

Temperature changes due to climatic influences are dealt with in 4.7.2.

The extent, direction, speed and frequency of temperature changes shall be taken into consideration when assessing their effect.

The following grades serve in assessing the effects of temperature changes, whereby details of the frequency and the duration of temperature changes are to be given for grades 1 to 4.

Grade 0: no temperature changes.

Grade 1: infrequent temperature changes up to 50 K.

Grade 2: infrequent temperature changes of more than 50 K.

Grade 3: frequent temperature changes up to 50 K.

Grade 4: frequent temperature changes of more than 50 K.

Grade 5: temperature changes involving thermal shock.

4.7.4 Mechanical loading

The effectiveness of a surface protection system can be impaired through exposure to mechanical loads or hydrostatic pressure during operation or assembly. The following grades shall be used to assess such loads.

Grade 0: no loads, or hydrostatic pressure up to 0,05 bar.

Grade 1: loads up to 0,2 N/mm^2 (e.g. pedestrian traffic, light transport, static loading).

Grade 2: loads up to 1 N/mm^2 (e.g. vehicles with pneumatic tires, static loading).

Grade 3: loads over 1 N/mm^2, for example

a) loads of 1 N/mm^2 to 7 N/mm^2 (e.g. vehicles with Vulkollan wheels, static loading);

b) loads over 7 N/mm^2 (e.g. vehicles with polyamide wheels, static loading).

Grade 4: impact loads, such as those resulting from setting down sharp-edged objects (e.g. barrels), and from scraping (e.g. shovel loaders).

Grade 5: hydrostatic pressure from 0,05 bar to 0,5 bar.

Grade 6: hydrostatic pressure greater than 0,5 bar.

4.7.5 Weather factors

Climatic influences may affect the durability of a surface protection system, and shall be graded as follows.

Grade 0: no climatic influences: the component is located inside a building and is not exposed to climatic influences.

Grade 1: limited climatic influences: a roof protects the component, which is exposed to limited climatic influences.

Grade 2: full climatic influences: the component is located outside, and is fully exposed to climatic influences.

4.8 Materials manufacturer

The materials manufacturer shall have suitable manufacturing and testing equipments as well as qualified personnel.

4.9 Applicator

The applicator shall have suitable application and testing equipments as well as qualified personnel to ensure the correct application of the combined lining in accordance with this standard.

4.10 Application

4.10.1 Sealing layers

Sealing layers shall be applied in accordance with EN 14879-2 and EN 14879-3 for coatings or EN 14879-4 and EN 14879-5 for linings.

Before beginning the application process, design details such as stability of steel tanks, nozzle and flange design, floor drains, connections to foundations and walls, penetrations for pipes, and expansion joints shall be specified.

If necessary, applied sealing layers may be protected against damage with a protective putty coat or a temporary covering until and during the service layer is applied.

The sealing layer shall be continuous in all areas which need protection and any penetrations shall be effectively connected.

4.10.2 Service layer

4.10.2.1 Brick lining or tiling

4.10.2.1.1 Formation of the brick bond

In the case of vertical cylindrical vessels the bricks shall generally be laid in annular layers, the vertical joints being offset in relation to each other.

The longitudinal joints shall usually be continuous in the case of horizontal cylindrical vessels.

The brick bond shall be adapted to the shape of the vessel in all other cases.

The joints in a layer shall be offset against those in the other layer in both directions when arranging several layers of bricks.

Markedly curved surfaces shall preferably be lined with shaped bricks.

The dead weight of the brick lining of overhanging surfaces shall be absorbed by the design. The adhesive strength of the mortar used may be adequate in the case of low dead weights.

Flat walls shall be constructed with an inclination ≥ 2 % if necessary.

4.10.2.1.2 Formation of joints

For the effectiveness and durability of a brick lining it is essential to fill the joints with mortar without cavities. The mortar shall adhere well to the sides of the bricks. The instructions of the manufacturer in this respect shall be observed. Joints shall generally be between 3 mm and 8 mm wide.

Wider joints shall be required:

a) if the stress calculation taking into consideration the required swelling requires the joint width;

b) if the joints (based on existing experiences) will be attacked during operation and shall probably have to be refilled subsequently;

c) if the mortar used for pointing is different from that used when laying the bricks.

Wider joints can be filled at the same time as laying the bricks or subsequently.

Except in the cases specified above, narrow joints shall be made.

They shall be filled at the same time as laying the bricks (i.e. flush laying).

Subsequent pointing requires that the joints to be kept open to the required depth and full width during laying the bricks (insertion of wedges).

The pointing depth shall be at least 15 mm. Joints about 15 mm deep can be filled in one operation; joints with a greater depth shall be filled in two or more operations.

Insufficiently deep joints or dirt on the sides of the bricks shall be carefully scraped out before introduction of the laying material. Slabs ≤ 15 mm thick shall be laid flush.

Joints are effective and durable when made according to Figure 3. The representation also applies with sufficient accuracy, if vessels with a large diameter are lined with flat slabs of suitable width.

Joints as shown in Figure 4 result, if shaped bricks with a smaller radius of curvature than that conforming to the vessel radius are installed. They shall be avoided if possible.

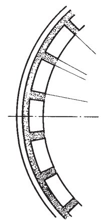


Figure 3 – Suitable joint construction

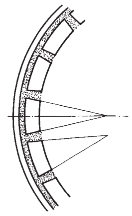


Figure 4 – Joints between not suitable bricks

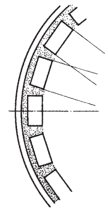


Figure 5 – Not suitable joint construction

Joints wider at the root than on the exposed side (see Figure 5) shall be avoided, if they cannot be reliably filled.

4.10.2.1.3 Flange connections

Shear stresses shall not occur between the shell and brickwork when brick-lined parts are flanged together.

4.10.2.1.4 After-treatment of the brick lining

4.10.2.1.4.1 Synthetic resin mortar as laying and/or joint material

The setting time and full hardening time are dependent on the temperature. At a temperature of about 20 °C the setting time is about one day to two days depending on the type of mortar, the full hardening time about 28 days. A usually adequate resistance to stresses exists after about eight days. If the stressing is to take place earlier or a particularly high chemical stress exists, the brick lining shall be thermally aftertreated, according to the manufacturer's instructions. The thermal after-treatment shall be undertaken by damp heat, e.g. by filling the vessel with water and slowly heating to a final temperature of 80 °C to 90 °C in the case of phenolic and furane resin mortars.

4.10.2.1.4.2 Potassium silicate mortar as laying and/or joint material

The drying time and setting time are dependent on the air humidity and temperature. During the drying and setting time of about two days to three days at about 20 °C, it shall be possible to give off the liberated water from the cement. The full hardening and resistance to stresses exists after about eight days. After setting potassium silicate mortar brick linings shall be acidified.

4.10.2.1.4.3 Cement mortar as laying and joint material

Brick linings with cement mortar shall be kept moist until adequate setting of the mortar. After-treatment following adequate setting is advisable. If the joints are filled with acid setting synthetic resin mortar in the case of brick linings with hollow joints, they shall be previously acidified.

4.10.2.1.5 Generation of pre-stresses

4.10.2.1.5.1 General information

Satisfactory interaction of the vessel shell with the brick lining shall be required for the operational reliability of the lined vessel. To ensure this, the measures according to a) to c), which are dependent on the level of the required pre-stressing (experience, calculation), may be necessary.

a) Vessels without temperature and/or pressure stress do not require special measures.

b) Vessels with a low temperature and/or pressure stress require heating of the vessel shell according to 4.10.2.1.5.2.

c) Vessels with a higher temperature and/or pressure stress require pre-stressing boiling according to 4.10.2.1.5.3.

4.10.2.1.5.2 Heating of the vessel shell (wheelwright's method)

The vessel shell is expanded from outside by a supply of heat and brick-lined in the expanded condition. The temperature difference between the brick lining materials and the vessel shell shall be as large as possible with due consideration of the permissible maximum temperatures. The supply of heat is discontinued after adequate strength of the laying and joint material is achieved, the shell shrinks on to the brick lining and produces the required pre-stress.

This method can be used for all brick lining materials. The level of the attainable pre-stresses is limited by the working temperatures.

4.10.2.1.5.3 Pre-stressing boiling

The vessel shell is expanded after completion of the brick lining. For this purpose a damp atmosphere is produced in the vessel, e.g. by filling with water, and the latter brought to a temperature and pressure preferably greater than or equal to the envisaged operating conditions. During expansion of the vessel shell the brick lining is also pulled along, which is made possible by the thermal flow properties of the different mortars. Hence pre-stressing boiling can be effectively conducted only when phenolic and furane resin mortars are used. After completion of the thermal flow the heat supply is terminated and the vessel allowed to cool. The pressure shall be gradually reduced in parallel. The shell shrinks on to the brick lining and produces the required pre-stressing. As the thermal flow capacity is dependent on the degree of cross-linking of the mortar, the pre-stressing boiling shall preferably be carried out immediately after completion of the brick lining.

A higher pre-stressing can be achieved with this method.

4.10.2.1.5.4 Operation and shutdown of brick-lined vessels

Mortar and cement shall have set or hardened sufficiently when the brick linings are stressed for the first time.

Brick-lined vessels operating by an increased temperature and/or increased pressure shall always be started and re-started slowly to prevent inadmissibly high stresses.

The same procedure shall be adopted where appropriate during cooling; quenching shall be avoided.

Brick-lined vessels not in service for a lengthy time i.e. more than three or four weeks or that are not yet in service shall be kept in a damp — in the case of potassium silicate mortars also acidic — atmosphere to prevent damage by shrinkage. This atmosphere shall preferably be achieved by at least partial filling with (acidified) water.

The brick-lined vessels shall be protected against frost.

Before changing the operating conditions it shall be checked whether the existing brick lining withstands the new stresses.

4.10.2.2 Tiling

The semi-finished products (preferably tiles and bricks) shall be laid with a stretcher bond since other types of bond are less common.

Since tiled floors normally require a slope, it is recommendable to tile at first bands along the necks and parting lines with a slope to drain as templates. Paving the areas between the bands with tiles later on, the continuous joints always have to be directed towards the slope.

Beds of resin-based mortar, water-glass mortar and bitumen shall be between 5 mm and 10 mm thick and free of cavities. Where cement mortar is used, the bed shall be at least 30 mm thick, although beds of modified cement mortar may be thinner, if proof of suitability has been provided.

Tiles and bricks shall be laid using either the 'open-joint' or the "closed-joint" technique.

With the "open-joint" tiling technique, the butt joints shall be left open to about 2/3 their depth and shall be at least 6 mm wide so that they can be closed at a later stage. Joints shall be closed either manually with a pointing trowel (sleeker), by pointing with an injection pistol or by elutriating.

With the "closed-joint" technique, it has to be provided that the mortar in the butt joints bulges out a little when the tiles are laid. The protruding mortar has to be cut off with a trowel. The surface of the joints should be smoothed out afterwards.

A special method of tiling is the floating buttering technique, in which the bedding mortar is sectional trowelled in a thin layer both on the floor and on the reverse of the tile. Only as much mortar must be applied as tiles can be laid within the pot life of the mortar. Both layers are combined by rubbing. This ensures a tight, cavity-free mortar bed.

4.10.3 General requirements

During application, climatic and operational effects shall be taken into account.

4.11 Protected objects

To protect the applied combined lining, the following requirements shall be met regarding the handling of lined objects between completion of the application process and commissioning, when in service and during subsequent maintenance.

a) The specified loads shall not be exceeded during commissioning, operation and decommissioning.

b) The specified mechanical loads shall not be exceeded during assembly and repair work.

c) Routine tests shall be performed at specified intervals to check the soundness of the combined lining and to ensure that any damage can be repaired in good time.

5 Requirements

5.1 Fluid load, chemical resistance and tightness

The combined lining shall be tight and resistant to the expected fluid load under the respective load grades defined in accordance with 4.7.1.

The selection of the sealing layer shall be made based on the specified loads under consideration of the combination with tiles and/or bricks and jointing and bedding cement or mortar.

The service layer laid on the sealing layer (semi-finished products, embedded in mortar or cement) is permanently tight against the affecting fluid only in combination with the sealing. The resistance and tightness of the sealing layer can also be proven by the test according to EN 14879-3:2006, 10.2.2.2. The useful layer may not be destroyed as a result of the fluid load; the combination of service layer and sealing layer shall be tight and resistant in any case.

The resistance and tightness of the combined lining when exposed to fluids shall be tested according to EN 14879-3:2006, 10.2.3.1.

5.2 Thermal loading

The combined lining shall be resistant to the expected thermal load due to the effect of the media or other sources of heat (e.g. heat radiation).

The combined lining shall be resistant to all temperature loads up to + 80 °C. The minimum thickness of the tile and/or brick layer shall be 40 mm in case of frequent load above + 80 °C.

5.3 Temperature change loading

The combined lining shall be resistant to the expected weather-related load as well as temperature fluctuation load caused by the medium, operating conditions or cleaning processes.

The combined lining is resistant to all temperature fluctuation loads of load grades 1 to 5 according to 4.7.3 when the thickness of the tiles and/or bricks corresponds to the minimum thickness for the load grade to be applied specified in Table 6.

Table 6 — Determining the minimum thickness of the ceramic materials depending on the expected temperature change load

Load grade according to 4.7.3	Temperature change load	Minimum thickness of ceramic materials mm
1	Infrequent change up to 50 K	20
2	Infrequent change of more than 50 K	30
3	Frequent change up to 50 K	30
4	Frequent change of more than 50 K	≥ 30
5	Temperature changes involving thermal shock	> 40

5.4 Mechanical loading

The combined lining is resistant to all mechanical loads according to 4.7.4 when the minimum thickness of the semi-finished product for the respective expected loads corresponds to the specifications in Table 7.

Table 7 — Determining the minimum thickness of the ceramic material depending on the expected mechanical load

Load grade according to 4.7.4	Mechanical load	Minimum thickness of the ceramic material mm
1a	Load up to 0.2 N/mm^2; e.g. pedestrian traffic, light transport, static loading	15
2a	Load up to 1 N/mm^2; e.g. vehicles with pneumatic tires, static loading	15
3a	Load from 1 N/mm^2 to 7 N/mm^2 e.g. vehicles with Vulkollan wheels, static loading	20
3b	Load > 7 N/mm^2 e.g. vehicles with polyamide wheels, static loading	30
4a	Impact loads, such as those resulting from setting down sharp-edged objects (e.g. barrels), and from scraping (e.g. shovel loaders)	30

If mechanical loads of load grades 5 or 6 according to clause 4.7.4 are to be taken into account, the thickness of the semi-finished product shall be chosen according to constructional aspects and possible chemical load. In case of abrasive media practical experiences shall be considered.

5.5 Anti-slip protection

If the industrial safety regulations demand anti-slip protection, this shall be proven e.g. according to DIN 51130.

5.6 Crack bridging

This requirement is considered met when the crack bridging capability of the sealing layer has been proven.

The testing of coatings used as a sealing layer shall be performed according to EN 14879-3:2006, 10.2.2.6.

5.7 Adhesion strength

The combined lining shall be sufficiently firmly and functionally connected to the concrete and/or steel substrate.

Based on existing practical experience, this requirement is considered met by floor coverings executed in accordance with this standard. All other applications shall be examined individually.

5.8 Ageing behaviour

The requirement is considered met for the combined lining without testing.

5.9 Weathering behaviour

Testing the weather resistance of the combined lining may be limited to the testing of the frost resistance of the ceramic material.

The test is conducted according to 6.4.2.2.

5.10 Concrete compatibility

The combined lining shall withstand the expected alkaline load from the mortar bonded substrate and may not attack it chemically.

The sealing layer and the system used for sticking shall be concrete compatible (see also EN 14879-3:2006, 10.1.2.10 and EN 14879-5:2007, 10.1.2.10).

5.11 Behaviour in cleaning and neutralization processes

The combined lining shall be resistant to expected cleaning and neutralization processes (pH change).

The selection of the cleaning procedure shall be agreed between the manufacturer and the user. As a rule, proof of facts established by experience is the basis for assessment. Otherwise special tests shall be agreed.

5.12 Capability of dissipating static charges

In plants handling flammable, highly flammable or extremely flammable liquids a combined lining may not lead to ignition hazards as a result of electrostatic charges.

The requirements are considered met when the dissipation resistance of the joint or in the case of conductive plates on the plate does not exceed $1 \times 10^8\ \Omega$ or the insulation resistance (surface resistance) does not exceed $1 \times 10^9\ \Omega$.

In the case of non-conductive plates, the plate size may not exceed the following dimensions in order to ensure the dissipation capability through the joint material:

— for rectangular plates: 115 mm × 240 mm;

— for square plates: 150 mm × 150 mm.

The test is conducted according to 6.4.2.3.

Other requirements from other areas, e.g. explosion protection or ESD (electrostatic discharge) applications are not an object of this standard.

5.13 Behaviour in fire

The requirements for the behaviour in fire shall be determined plant-specifically according to industrial safety and building legislation requirements.

The combined lining meets the requirements of building material grade E-d2 according to EN 13501-1:2007.

6 Testing

6.1 General

The nature and scope of testing, and any necessary documentation are to be specified on a case-by-case basis. Criteria which are to be agreed include:

a) requirements;

b) permissible deviations from specified requirements for the system;

c) tests;

d) test equipment;

e) date of test;

f) test environmental conditions.

6.2 Receiving inspection of coating/lining materials

6.2.1 Inspection of materials, components and their markings

Prior to application, the supplied materials shall be checked to ensure that the consignment is complete and that the materials comply with the (ordering) details given in the contract and are free of flaws.

6.2.2 Checking storage conditions

A check shall be carried out to ensure that the materials are stored in accordance with the manufacturer's instructions.

6.3 Testing of combined lining systems during application

6.3.1 Ambient conditions

The ambient conditions (temperature, humidity, cleanliness of environment, safety considerations, etc.) shall be monitored from the time substrate preparation begins to the completion of the application process.

6.3.2 Sealing layer

The sealing layer shall be monitored throughout the application process to ensure it is intact.

The thickness of unformed materials (coatings) shall be monitored. On steel substrate the thickness of the sealing layer can be checked by magnetic methods. On concrete substrate where such a measuring method cannot be used, the consumption of the coating material shall be monitored.

If so agreed, the continuity of the sealing layer shall be checked before it is covered by the service layer. For non-conductive layers on a conductive substrate (e.g. conductive primer, trowelled conductive layer, conductive woven fabric or steel), continuity may be determined by means of spark testing. EN 14879-4 applies to spark testing by analogy.

It is not possible to perform spark testing on a conductive coating or lining.

In cases of doubt, adhesion to the substrate may also be checked, for instance, by means of peel testing.

6.3.3 Service layer

The application of the service layer shall be continuously monitored to ensure that:

- the sealing layer remains intact;
- heights and falls are as specified;
- joints are sufficiently wide;
- no cavities or holes are formed;
- joints are staggered (where there are multiple layers).

6.3.4 Documentation

Results of all tests and inspections shall be documented in an acceptance report. The sample forms given in EN 14879-3 and EN 14879-5 may be used, for example.

Reports are considered to be construction documents and are thus to be kept on file.

6.4 Suitability testing

6.4.1 General

The following tests apply exclusively to the suitability of the surface protection systems for the area of application according to Clause 4 and the load profiles according to 4.7.

Verification of suitability can be given by:

a) laboratory examinations by a testing laboratory; or

b) proof of facts established by experience of the owner or manufacturer; or

c) a combination of both a) and b).

For the verification of suitability according to a), the specimens with the respective material for the laboratory test shall be prepared in agreement with the testing laboratory. The identity of the materials shall be adequately proven to the testing laboratory by specification of physical-chemical parameters. Individual proof can also be given to the testing laboratory by certified reference objects. The following can be considered as proof of experience according to b):

— Laboratory examinations with recorded and reproducible results;

— Reference objects which are proven executed with the surface protection system the suitability of which is to be verified;

— Resistance lists the basic conditions of which are known and can be proven by laboratory tests.

6.4.2 Testing of combined linings

6.4.2.1 Fluid load test, resistance and tightness

6.4.2.1.1 General

The test is conducted according to the specified load grade with the test method specified in 6.4.2.1.3 with the test duration listed in Table 9. Usually the test will be carried out at + 23 °C. At operating temperatures which deviate from this, the test shall be made at these temperatures of the operating medium (minimum and/or maximum value). With this test the resistance of the combined lining to the thermal load caused by the effects of the liquid is considered proven.

Testing of the fluid load of a higher load grade includes the proof of resistance of the combined lining at lower load grades according to Table 8.

Table 8 — Area of validity of the fluid load tests

Verification of load grade according to 4.7.1 Grade	Includes verification of load grade according to 4.7.1 Grade
6	1 to 5
5	1 to 4
4	1 and 2
3	1 and 2
2	1

6.4.2.1.2 Test fluids

The media test shall be made with the fluid to which the combined lining shall be tight and resistant.

If fluids can be classified in fluid groups with the specified concentration limits for verification of suitability for material/media combinations (EN 14879-3:2006, Annex E and/or EN 14879-5:2007, Annexes E and F), the test with the test fluid specified there suffices.

6.4.2.1.3 Test methods

The test run consists of the following test steps:

a) testing the ceramic materials including the joint;

b) testing the ceramic materials including the joint and the bedding;

c) testing the ceramic materials including the joint, the bedding and the sealing layer.

The specimens shall consist respectively of the layers to be tested.

A cylinder filled with test fluid shall be placed on the surface of the respective sample whereby the cylinder shall be placed over a joint butt. The filling level of the cylinder shall be at least 100 mm. The test duration for the individual load grades is specified in Table 9.

6.4.2.1.4 Evaluation of the test results

The test scheme shown in Figure 6 should be used whereby the following cases shall be distinguished:

a) The test is considered passed when no test fluid has penetrated the respective specimen when exposed to liquid according to 6.4.2.1.3. Exposure of another specimen to fluid including the following layer may be omitted in this case.

b) If test fluid reaches the rear of the respective specimen but the specimen is not destroyed, a specimen including the following layer shall be tested subsequently.

c) If the specimen is destroyed by exposure to the test fluid, testing of another specimen including the following layer can be omitted because the complete combined lining is considered unsuitable in this case. There is destruction of the specimen when the ceramic material or the jointing and/or the bedding mortar or cement or the sealing layer has peeled away or dissolved at the interfaces.

Table 9 — Test duration of the fluid load, resistance and tightness of combined linings

Load grade according to 4.7.1	**Grade**						
	1	**2**	**3**	**4**	**5**		**6**
Designation	**sporadic droplets**	**frequent splashing**	**event of fault**	**constant wetness**	**constant flow**		**constant filling**
Example	e.g. laboratory floors, floors in small plants, walls	e.g. floors in closed production plants	secondary containments	e.g. floors in production plants, galvanic plants, pump stations	open gutters, trenches and appropriate pump sumps	closed gutters, trenches, pipes and ditches	containers
Test duration	suitable, no test required		14 days or 72 h[a]	14 days	14 days	28 days	90 days

[a] In plants in which infrastructural measures ensure that the maximum loading duration does not exceed 72 h.

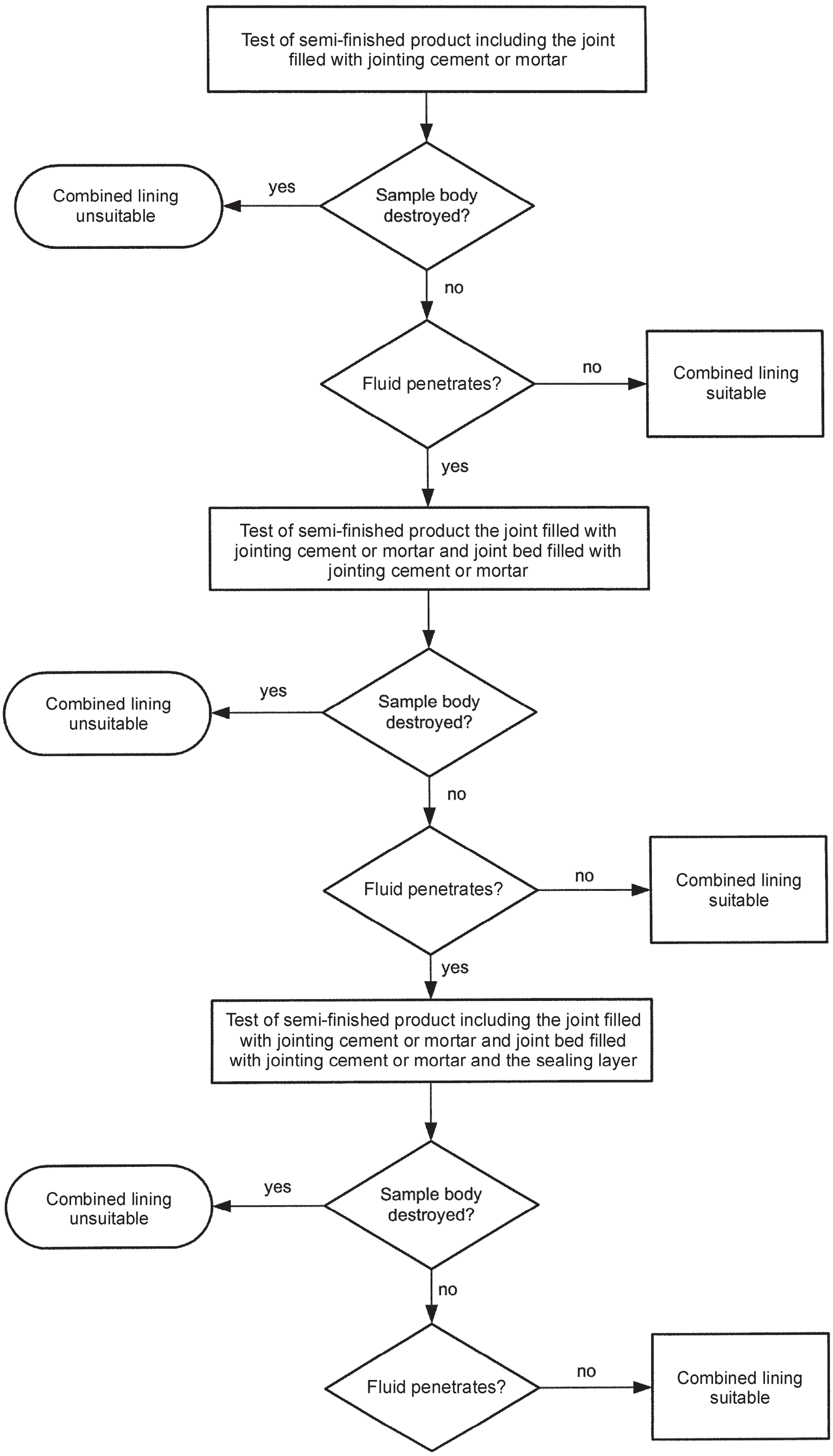


Figure 6 — Flow chart of the fluid load, resistance and tightness of a combined lining

6.4.2.2 Weathering behaviour

The resistance to frost of the plate material shall be proven according to EN ISO 10545-12. The plates may not exhibit any damage (cracks, flaking).

6.4.2.3 Dissipation capability

6.4.2.3.1 General

The dissipation capability should be tested according to Annex C and the insulation resistance (surface resistance) according to IEC 60167 immediately after 24 h conditioning of the samples in normal climate 23/50-2 according to EN ISO 291 and after seven days storage at 70 °C with a DC voltage of 100 V.

If the measured values after storage at 70 °C are higher than the initial values, further tests regarding the durability of the dissipation capability are necessary.

6.4.2.3.2 Measuring the dissipation resistance

6.4.2.3.2.1 Homogeneously conductive tile layers

For homogeneously conductive tile layers in which the dissipation takes place through the tiles and the mortar bed, the dissipation resistance shall be measured according to Annex C with the combined lining applied on a pre-cast concrete paving flag with a circular electrode according to Annex C but without protection ring put on a tile of the combined lining, whereby a ground connection shall be made to the specimen as a counter-electrode.

6.4.2.3.2.2 Combined linings with non-conductive tiles

In combined linings with non-conductive tiles, the complete structure including the grounding band described by the manufacturer shall be applied on a pavement slab according to EN 14879-3:2006, 10.2.2.1.1.1. The grounding band shall be integrated in the layer prescribed by the manufacturer on one of the narrow sides of the specimen. The dissipation resistance is measured by a circular electrode according to Annex C but without protective ring whereby it shall be placed as far as possible away from the integrated grounding band on a cross joint.

6.4.2.3.2.3 Test run

The dissipation resistance is to be tested with a DC voltage of about 100 V as an electrical resistance between a circular electrode with a measuring area of 20 cm^2 without protection ring and grounding placed on the combined lining.

The combined lining shall be rubbed down and cleaned with a dry cloth at the place to be tested and a damp piece of blotting paper or conductive foamed plastic/rubber placed on it of 50 mm in diameter on which the measuring electrode should be placed. The conductive layer shall be constituted in such way that the testing electrode has adequate contact to the surface.

6.4.2.3.3 Measuring the insulation resistance (surface resistance)

The insulation resistance (surface resistance) is measured according to IEC 60167 with 100 V DC voltages.

Annex A
(informative)

Selection criteria for surface protection systems

A.1 Load profiles and suitable surface protection systems for floors and walls

Table A.1 sets out load profiles for elements which are exposed to no or only slight climatic influences. They are only exposed to fluid loads of grades 1 and 2, and their surface temperatures do not increase greatly nor are they subject to great temperature fluctuations. The surface protection systems used in those cases need only provide moderate protection.

Examples of these elements are:

- floors in storerooms for solid bulk materials or liquid chemicals in laboratory batches;
- floors in laboratories, control rooms and the like;
- floors in production areas with closed operation;
- walls in production and storage areas;
- ceilings in production and storage areas.

Table A.1 — Load profiles and suitable surface protection for floors and walls

Chemicals as in Table 4	Grade of fluid load (as in 4.7.1)	Temperature, in °C	Grade of temperature change (as in 4.7.3)	Grade of mechanical load (as in 4.7.4)	Grade of climatic influences (as in 4.7.5)	Type of surface protection		
						Coating	Lining	Combined lining
I and II	1	20	1	1	0 to 1	R	—	A
I and II	1	50	1	1	0 to 1	R	—	A
I and II	1	70	1 and 2	1	0 to 1	A	—	R
I and II	2	20	1	1	0 to 1	R	—	A
I and II	2	50	3	1	0 to 1	A	—	R
I and II	2	70	3	1	0 to 1	A	—	R
I and II	2	70	4	1	0 to 1	N	—	R
I and II	1	20	1	2	0 to 1	R	—	A
I and II	2	20	3	2	0 to 1	A	—	R
I and II	1	50	1	2	0 to 1	A	—	R
I and II	2	50	1 and 3	2	0 to 1	A	—	R
I and II	2	50	3	2	0 to 1	A	—	R
I and II	1	70	1 and 2	2	0 to 1	A	—	R
I and II	2	70	3 and 4	2	0 to 1	N	—	R
I and II	1	20 to 70	1 to 4	3	0 to 1	A	—	R
I and II	1	20 to 70	1 to 4	4	0 to 1	A	—	R
I and II	2	20 to 70	5	1 to 4	0 to 1	A	—	R
Key to symbols: R: recommended surface protection. A: suitable alternative surface protection, depending on the durability of the system. N: not recommended as surface protection. —: not applicable.								

A.2 Load profiles and suitable surface protection systems for collecting basins

Table A.2 gives load profiles for elements located inside or outside and which may, in the case of operational failure, be required to take up considerable amounts of fluids for a limited time.

Examples of such elements are:

— collecting basins and areas near storage tanks;

— storage areas for small drums and pallets;

— barrel stores.

Table A.2 — Load profiles and suitable surface protection for collecting basins

Chemicals as in Table 4	Grade of fluid load (as in 4.7.1)	Temperature, in °C	Grade of temperature change (as in 4.7.3)	Grade of mechanical load (as in 4.7.4)	Grade of climatic influences (as in 4.7.5)	Type of surface protection		
						Coating	Lining	Combined lining
I	3	20	1	0	0 to 2	R	A	A
I	3	20	1	0	0 to 2	A	A	R
I	3	50	1	0	0 to 2	R	A	A
II	3	50	1	0	0 to 2	A	A	R
I and II	3	70	1 and 2	0	0 to 2	A	A	R
I	3	20	1	1	0 to 2	R	A	A
II	3	20	1	1	0 to 2	A	N	R
I	3	50	1	1	0 to 2	R	A	A
II	3	50	1	1	0 to 2	A	N	R
I and II	3	70	1 and 2	1	0 to 2	A	A	R
I	3	20	1	2	0 to 2	A	N	R
II	3	20	1	2	0 to 2	A	N	R
I	3	50	1	2	0 to 2	A	N	R
II	3	50	1	2	0 to 2	A	N	R
I and II	3	70	1 and 2	2	0 to 2	A	N	R
I	3	20	1	3	0 to 2	A	N	R
II	3	20	1	3	0 to 2	A	N	R
I	3	50	1	3	0 to 2	A	N	R
II	3	50	1	3	0 to 2	A	N	R
I and II	3	70	1 and 2	3	0 to 2	A	N	R
I and II	3	20	1	4	0 to 2	N	N	R
I and II	3	50	1	4	0 to 2	N	N	R
I and II	3	70	1 and 2	4	0 to 2	N	N	R
I and II	3	20 to 70	5	0 to 1	0 to 2	A	A	R
I and II	3	20 to 70	5	2 to 4	0 to 2	N	N	R

Key to symbols:
R: recommended surface protection.
A: suitable alternative surface protection, depending on the durability of the system.
N: not recommended as surface protection.

A.3 Load profiles and suitable protection for production plant floors

Table A.3 gives load profiles for elements located inside or outside, and which are designed for exposure to fluids occurring as wetness, puddles, trickles, condensation, etc. These elements require long-term protection and sealing. Examples of typical elements are:

— production area floors where open plant operation involves considerable leakage and dripping;

— floors in pumping areas;

— floors in filling areas.

Table A.3 — Load profiles and suitable surface protection for production plant floors

Chemicals as in Table 4	Grade of fluid load (as in 4.7.1)	Temperature, in °C	Grade of temperature change (as in 4.7.3)	Grade of mechanical load (as in 4.7.4)	Grade of climatic influences (as in 4.7.5)	Type of surface protection		
						Coating	Lining	Combined lining
I and II	4	20	1	1	0 to 2	A	N	R
I and II	4	50	1	1	0 to 2	A	N	R
I and II	4	50	3	1	0 to 2	A	N	R
I and II	4	70	1 and 2	1	0 to 2	A	N	R
I and II	4	70	3 and 4	1	0 to 2	N	N	R
I and II	4	20	1	2	0 to 2	A	N	R
I and II	4	50	1	2	0 to 2	A	N	R
I and II	4	50	3	2	0 to 2	A	N	R
I and II	4	70	1 and 2	2	0 to 2	A	N	R
I and II	4	70	3 and 4	2	0 to 2	N	N	R
I and II	4	20 to 70	1 to 4	3	0 to 2	N	N	R
I and II	4	20 to 70	1 to 4	4	0 to 2	N	N	R
I and II	4	20 to 70	5	1 to 4	0 to 2	N	N	R

Key to symbols:
R: recommended surface protection.
A: suitable alternative surface protection, depending on the durability of the system.
N: not recommended as surface protection.

A.4 Load profiles and suitable protection for collecting basins, gutters, channels, pipes, etc.

Table A.4 gives load profiles for elements located inside or outside, and which are designed for exposure to flowing fluids. Long-term surface protection and sealing are required for such elements. Such elements are typically exposed to media at a hydrostatic pressure of up to 0,05 bar.

Table A.4 — Load profiles and suitable surface protection for elements exposed to flowing fluids

Chemicals as in Table 4	Grade of fluid load (as in 4.7.1)	Temperature, in °C	Grade of temperature change (as in 4.7.3)	Grade of mechanical load (as in 4.7.4)	Grade of climatic influences (as in 4.7.5)	Type of surface protection		
						Coating	Lining	Combined lining
I and II	5	20	1	0	0 to 2	A	A	R
I and II	5	50	1	0	0 to 2	A	A	R
I and II	5	50	3	0	0 to 2	A	A	R
I and II	5	70	1 and 2	0	0 to 2	A	A	R
I and II	5	70	3 and 4	0	0 to 2	N	A	R
I and II	5	20	1	1	0 to 2	A	A	R
I and II	5	50	1	1	0 to 2	A	A	R
I and II	5	50	3	1	0 to 2	A	A	R
I and II	5	70	1 and 2	1	0 to 2	A	A	R
I and II	5	70	3 and 4	1	0 to 2	N	A	R
I and II	5	20	1	2	0 to 2	A	N	R
I and II	5	50	1	2	0 to 2	A	N	R
I and II	5	50	3	2	0 to 2	A	N	R
I and II	5	70	1 and 2	2	0 to 2	A	N	R
I and II	5	70	3 and 4	2	0 to 2	N	N	R
I and II	5	20 to 70	1 to 4	3	0 to 2	N	N	R
I and II	5	20 to 70	1 to 4	4	0 to 2	N	N	R
I and II	5	20 to 70	5	1 to 4	0 to 2	A	A	R

Key to symbols:
R: recommended surface protection.
A: possible alternative surface protection, depending on the durability of the system.
N: not recommended as surface protection.

A.5 Load profiles and suitable protection for containers

Table A.5 gives load profiles for containers with continual, long-term exposure to fluids, and also to hydrostatic pressure and mechanical loading. Examples of such containers are:

- sewage tanks;
- neutralisation basins;
- process tanks;
- sedimentation tanks;
- settling tanks.

Table A.5 — Load profiles and suitable surface protection for containers exposed to long-term hydrostatic pressure and mechanical loading

Chemicals as in Table 4	Grade of fluid load (as in 4.7.1)	Temperature, in °C	Grade of temperature change (as in 4.7.3)	Grade of mechanical load (as in 4.7.4)	Grade of climatic influences (as in 4.7.5)	Type of surface protection		
						Coating	Lining	Combined lining
I	6	20	1	0	0 to 2	R	R	A
I	6	50	1	0	0 to 2	A	R	A
I	6	50	3	0	0 to 2	A	R	A
II	6	50	1	0	0 to 2	A	A	A
II	6	50	3	0	0 to 2	A	A	R
II	6	70	1 to 4	0	0 to 2	A	A	R
I and II	6	20	1	5	0 to 2	R	R	A
I	6	50	1	5	0 to 2	A	R	A
I	6	50	3	5	0 to 2	A	R	A
II	6	50	1	5	0 to 2	A	A	R
II	6	50	3	5	0 to 2	A	A	R
II	6	70	1 to 4	5	0 to 2	A	A	R
I and II	6	20	1	6	0 to 2	A	R	R
I	6	50	1	6	0 to 2	A	R	R
I	6	50	3	6	0 to 2	A	R	R
II	6	50	1	6	0 to 2	A	A	R
II	6	50	3	6	0 to 2	A	A	R
I and II	6	70	1 to 4	6	0 to 2	A	A	R
I and II	6	20 to 70	5	0; 5; 6	0 to 2	A	A	R

Key to symbols:
R: recommended surface protection.
A: possible alternative surface protection, depending on the durability of the system.
N: not recommended as surface protection.

Annex B
(normative)

Overview of verification of suitability for combined linings

Table B.1 — Necessity of proof for the requirement

Requirement		**Load grade according to Clause 4**						
		Grade						
		1 sporadic droplets	2 frequent splashing	3 event of fault	4 constant wetness	5 constant flow		6 constant filling
	Section	e.g. laboratory floors, floors in technical rooms, walls	e.g. floors in closed production plants	secondary containments	e.g. floors in production plants, electroplating plants, pump stations	open gutters, trenches and appropriate pump sumps	closed gutters, trenches, pipes and ditches	containers
Fluid load, chemical resistance and tightness	5.1	+	+	A	C	A	A	A
Thermal load	5.2	+	+	+	+	+	+	+
Temperature change load	5.3	+	+	+	+	+	+	+
Mechanical load	5.4	+	+	+	+	+	+	+
Anti-slip protection	5.5	B	B	B	B	-	-	-
Crack bridging (concrete substrate)	5.6	-	-	C	B/C	C	C	C
Adhesion strength/Anchoring strength	5.7	+	+	A	+	A	A	A
Aging behaviour	5.8	+	+	+	+	+	+	+
Weathering behaviour	5.9	B	B	B	B	B	B	B
Concrete compatibility (concrete substrate)	5.10	D	D	D	D	D	D	D
Behaviour in cleaning and neutralization processes	5.11	B	B	B	B	B	B	B
Dissipation capability	5.12	B	B	B	B	B	B	B
Behaviour in fire	5.13	+	+	+	+	+	+	+

A Proof always necessary
B Proof only on demand
C Proof only for certain materials, media, versions or applications
D Covered by other proof
\+ Suitable without additional proof
\- Not applicable

Annex C
(normative)

Testing the dissipation capability

C.1 General

C.1.1 Dissipation resistance

The dissipation resistance shall be measured between a circular electrode of 50 mm diameter on the top of a sample and the grounding band integrated in the conductive layer.

C.1.2 Ground dissipating resistance

The ground dissipating resistance shall be measured between a circular electrode of 50 mm in diameter placed on the surface protection system and ground.

C.2 Testing the dissipation resistance of test samples

C.2.1 Instruments

— Resistance measuring instrument according to IEC 60093 with 100 V (DC).

— Climate cabinet for conditioning the samples.

— Circular measuring electrode of 50 mm diameter without protection ring.

— Blotting paper or conductive rubber foil according to 7.7 of IEC 60093:1980 with 50 mm diameter.

C.2.2 Test procedure

The test samples shall be conditioned for 24 h in normal climate EN ISO 291 23/50-2 prior to testing.

The measurement shall be made at (23 ± 2) °C.

A blotting paper moistened with tap water or a foil of conductive rubber with a diameter of 50 mm should be placed on the surface of the sample body as a contact agent, the electrode placed flush and pressed down during the measurement with a force of about 10 N.

The resistance shall be measured between the electrode and the ground connection whereby the measuring positions shall be selected so that they are as far as possible away from the ground connection.

C.2.3 Test report

The following shall be specified in the test report:

a) type of surface protection system;

b) material;

c) manufacturer;

d) colour;

e) thickness of surface protection system;

f) dissipation resistance, single and mean value;

g) conditioning conditions;

h) date of the test.

C.3 Measuring the ground dissipation resistance on the laid surface protection system

C.3.1 Instruments

Use instruments described in C.2.1 as well as a measuring instrument for temperature and relative humidity.

C.3.2 Preparation

The surface protection system shall be rubbed down with a dry cloth at the measuring point prior to testing.

C.3.3 Test procedure

The measurements may be carried out one week after applying the surface protection system at the earliest. The measurements may only be made on areas on which you can walk or drive (except container linings). In case of non-conductive tiles or bricks the measurements shall be executed on the conductive joints.

The blotting paper moistened with tap water or the conductive rubber or the conductive foam plastic shall be placed on the prepared measuring point, the electrode placed flush and pressed down during the measurement with a force of about 10 N.

The ground dissipation resistance is measured between the electrode and the ground potential of the system.

The number of measurements shall be selected according to Table C.1.

Table C.1 — Number of measurements of the ground dissipation resistance

Area of the laid surface protection system m²	Number of measurements
below 10 m²	1 measurement/1 m²
10 to 100 m²	10 to 20 measurements
above 100 m²	10 measurements/100 m²

Ground dissipation resistance: at ambient temperature, the following maximum measured values are permitted:

— up to 50 % relative humidity: 1×10^8 Ω;

— above 50 % to 70 % relative humidity: 1×10^7 Ω;

— above 70 % relative humidity: 1×10^6 Ω.

C.3.4 Test report

The following shall be specified in the test report:

a) Type of surface protection system;

b) Material;

c) Manufacturer;

d) Colour;

e) Thickness of the surface protection system;

f) Application date;

g) Location and position of the surface protection system;

h) Temperature and relative humidity;

i) Number of measuring points;

j) Ground dissipation resistance for every measuring point, in ohms (Ω);

k) Scale drawing with the measuring points and the corresponding measuring results;

l) Substrate data;

m) Deviations from this standard;

n) Date of the test.

Annex D
(normative)

Test methods for tolerances and limit deviations

D.1 Scope and purpose

EN 14879-6 stipulates the concentricity and flatness tolerances for brick-lined vessels and apparatus made of steel and non-ferrous metals, referred to as "vessels" in the remainder of this annex. Details on possibilities for testing the specified permissible dimensional deviations are not given in the normative part of this standard as their representation and explanation exceeds its scope.

The reason for the adherence to the permissible deviations required in this standard lies in the very low resistance of a brick lining to bending stress. For reasons of safety, no claims shall be made with respect to this resistance. It is known that at parts of a vessel which are not circular or not adequately level, deformation and resultant stresses occur due to hydrostatic or internal process-related pressure and/or temperature, which generally have no significant effect on the bearing capacity of the casing. This does not apply to the permissible stressing of the brick lining of such vessels.

In order to prevent damage to the brick lining, care shall be taken to ensure that additional stress resulting from production-dependent deviations of the completed vessel shape from the design shape remains as small as possible. For instance, in brick-lined storage or collecting vessels which have stood empty and cold and which are filled with a hot material within a short time, thermally-conditioned internal pressure of the brick lining on the steel casing can occur which can reach a considerable height depending on the thickness ratio of the brick lining to the casing and the size of the vessel diameter. This is of particular concern for vessels with flat bases.

D.2 Tolerances and limit deviations

D.2.1 Cylindrical vessel

D.2.1.1 Cylindrical part

After completion of fabrication, the radii in the cylindrical part of the brick-lined vessel may not deviate by more than ± 0,4 % from the mean value, a maximum of ± 15 mm for diameters exceeding 7 500 mm.

Such a deviation, with gradual assimilation to the standard circle, shall extend over at least 1/16 of the circumference, or over 1 500 mm in the case of diameters exceeding 7 500 mm. The maximum deviation of + 0,4 % or - 0,4 % may not occur on a shorter distance than 1/16 respectively maximum 1 500 mm of the circumference. The distance between planes of measuring shall be between 1 000 mm and 2 500 mm. Measurements are necessary at minimum two levels. Measuring points must be beyond welding areas.

If for instance a dimensional deviation of + 0,4 % of the mean radius occurs at test point 2 of a test circle, then the dimensional deviation at the immediately adjacent test points (test point 1 or test point 3 or 1/16 division) may not equal - 0,4 %; it shall be equal to or greater than 0 (see Figure D.1).

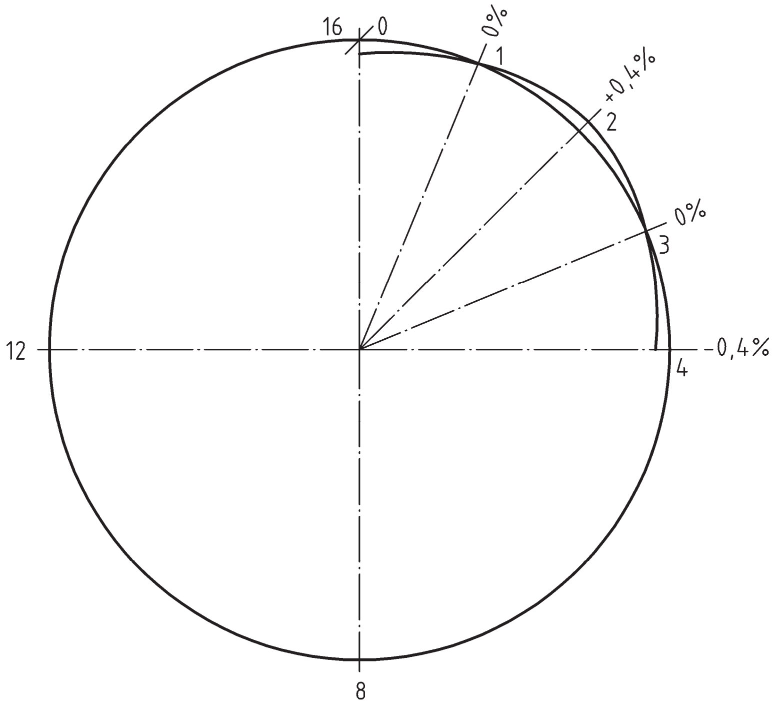
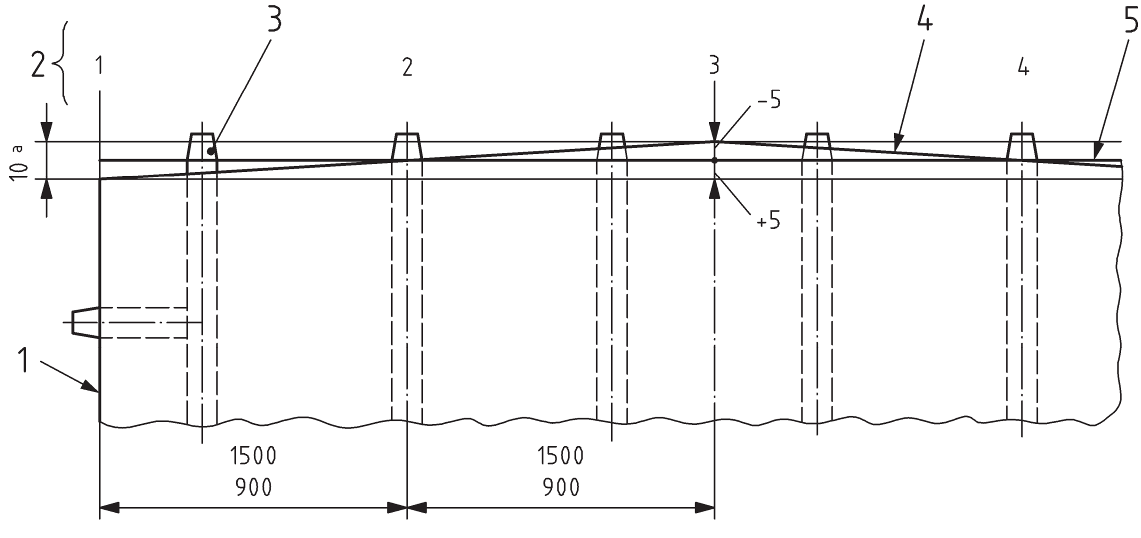


Figure D.1 — Vessel cross-section, permissible shape of the circumferential line (diagrammatic view)

Dimensions in millimetres



Key

1 End wall
2 Test point
3 Reinforcing frame
4 Actual vessel wall
5 Ideal vessel wall

[a] Straightness tolerance

Figure D.2 — Permissible range of straightness tolerances for flat-sided vessels

D.2.1.2 Conical part

The provisions for cylindrical parts shall be applied similarly to conical parts of a vessel.

D.2.1.3 Base and cover

The permissible concentricity error for bases and covers can be taken from national standards, e.g. DIN 28011, DIN 28013 and DIN 28014. For the flatness tolerances of round, flat bases, see D.2.2.3.

D.2.2 Flat-sided vessels

D.2.2.1 General

Flat-sided vessels shall be considered as those with a generally rectangular horizontal projection without re-entering angles.

D.2.2.2 Walls

The straightness tolerance[2)] for any profile lines of the vessel wall from 900 mm to 1 500 mm in length equals 10 mm. In this event, the deviations from the ideal line (allowance) from one test point to the next may not exceed half the straightness tolerance (see Figure D.2) and may only occur gradually.

D.2.2.3 Bases

The straightness tolerance[2)] on angular or round flat-ended bases for any profile line from 900 mm to 1 500 mm in length equals 10 mm. In this event, deviations from the ideal line (allowances) from one test point to the next may not exceed half the straightness tolerance and may only occur gradually.

D.3 Test methods

D.3.1 General

The following test methods are only given by way of examples. Other methods may also be used.

In each case, a front and back measurement shall be taken and recorded. The starting point of the measurements shall be stipulated and recorded.

A scale, cord (tension wire) and rod as well as a levelling instrument or construction laser may serve as aids for determining the test points.

D.3.2 Cylindrical vessel, cylindrical part

D.3.2.1 Erection

The vertical or horizontal position or correct design inclination of the vessel shall be verified, e.g. with a theodolite.

D.3.2.2 Centre point of the vessel base

The centre point of the vessel base is the centre of gravity of reference area A which is bounded by arcs described from three points on the vessel circumference with the nominal radius (see Figure D.3). In the case of an ideally circular base with precise nominal dimensions these arcs will intersect each other at one point.

---

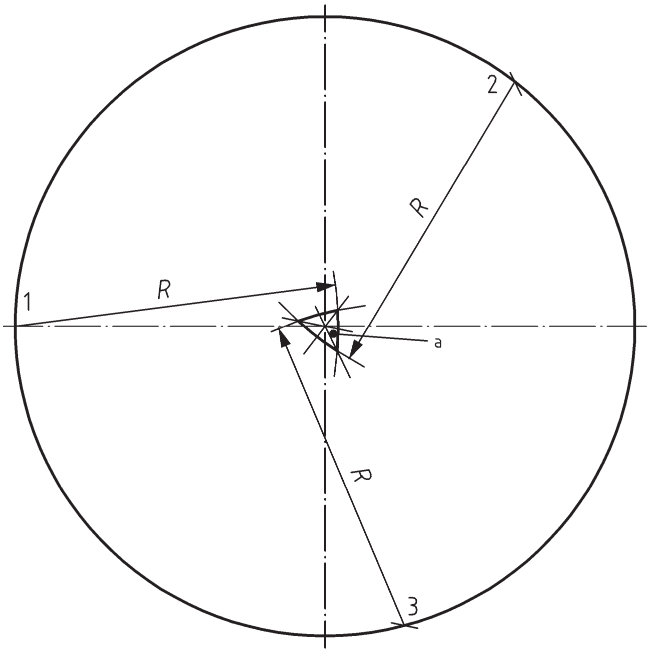
2) The straightness tolerance is defined in accordance with EN ISO 1101:2005 as the distance between two parallel lines or planes between which all points of the profile line under consideration shall lie.

D.3.2.3 Centre point of the vessel cover

The centre point of the vessel cover shall be determined as for the base; it may if required be transferred onto the cover by dropping a perpendicular. If no cover is provided, then a dummy construction shall be assembled.

D.3.2.4 Vessel axis

The vessel axis may be indicated by a wire (held in position, e.g. by magnetic clamps) or a beam of light (construction laser).



a Reference area A
Centre point = intersection of the medians

Figure D.3 — Determination of the centre point of the vessel base

D.3.2.5 Position of the test planes

The first test plane, perpendicular to the vessel axis, is situated 100 mm away from the weld seam between the base or cover and the cylindrical part of the vessel in the cylindrical trajectory in the case of flat bases or covers, or 1 000 mm away in the case of dished ends or covers. The distance between the test planes shall be between 1 000 mm and 2 500 mm (supply width of the sheet). It shall be ensured that the subsequent test planes are each situated 100 mm from the weld seams in the cylindrical trajectory. The test planes shall be marked and consecutively identified. The circumferential line of the test planes shall be provided with divisions in accordance with D.2.1.1 (see also Figure D.1).

D.3.2.6 Measurement of circularity

The distance between the vessel axis and vessel wall shall be measured in the divisions described above.

A measuring lance has proved suitable for measuring the radii. It principally comprises a telescopic tube which can be extended, latching at intervals of approx. 200 mm, with one horizontal and one vertical bubble level. At the end of the outer tube is a fixed spherical head; at the opposite end of the innermost tube is a precision measuring device with a vernier scale (Nonius).

When measuring the radii, the spherical end shall be placed at the respective division point of the test circle and — after adjusting the radius measuring instrument with the aid of the bubble levels — the precision measuring end shall be used to detect the cylinder axis (wire or light beam).

When using other measuring instruments it shall be ensured that the margin of error does not exceed 1 mm.

The mean value of the individual measurements of the test circle radii of each test plane shall be used for further evaluation.

The mean value r_m is obtained as the arithmetical mean of the individual radii r_n.

$$r_m = \frac{1}{n} \sum_{n=1}^{n} r_n \quad \text{(D.1)}$$

where

n = number of radii measured for each test plane.

The deviations Δr_i result from

$$\Delta r_i = r_i - r_m \quad \text{(D.2)}$$

i.e. from the difference between the measured individual radii and the mean value of all radii of the test plane under examination.

D.3.3 Shop-fabricated cylindrical vessel, flat base

D.3.3.1 Erection

The measures complying with D.3.2.1 and D.3.2.2 shall be carried out.

D.3.3.2 Division

The base shall be provided with divisions corresponding to the casing divisions in D.2.1.1.

D.3.3.3 Position of the test points

The test grid results from the points of intersection of the beams resulting from D.3.3.2 and concentric circles drawn at a distance of between 900 mm and 1 500 mm from each other. For smaller vessels at least three test points shall be used per diameter, one at the centre point and two at the edges.

In the case of a sloping base it is advisable to establish a rectangular grid using the specified test methods.

D.3.3.4 Measuring the flatness of the base

The deviations of the values determined at the test points result from the difference between the measured gauge dimensions and the mean value of all gauge dimensions.

The mean value of all gauge dimensions is:

$$h_m = \frac{1}{n} \sum_{n=1}^{n} h_n \quad \text{(D.3)}$$

which yields the deviation:

$$\Delta h_i = h_i - h_m \quad \text{(D.4)}$$

D.3.4 Flat-sided vessels, angular horizontal projection (Determination of the flatness of the faces)

D.3.4.1 Erection

The vertical or horizontal position or correct design inclination of the vessel shall be verified, e.g. using a theodolite, levelling instrument or laser gear.

D.3.4.2 Test lines

A number of horizontal transverse guides complying with D.3.4.3 shall be attached to the exterior sides of the top of the vessel.

The transverse guides shall be horizontally connected by tension wires at a distance of a = 200 mm from the vessel wall in the longitudinal direction. The tension wires shall be located in a vertical plane above each other.

D.3.4.3 Position of the test planes

The vertical test planes (1, 2, 3, ..., n) shall be situated at intervals b of between 900 mm and 1 500 mm. The second, fourth, sixth, etc. vertical test plane shall coincide with a reinforcing frame. The first (= end wall), third, fifth, etc. vertical test plane shall be situated between two reinforcing frames (see Figure D.2 and Figure D.4). The test planes I, II, etc. shall also be located accordingly. There shall be at least two horizontal test planes (A, B, C, ...) (at the top edge and at the base). The distance c between test planes shall be between 900 mm and 1 500 mm.

D.3.4.4 Measuring the flatness of the walls

The gauge dimension from the tension wires to the vessel wall shall be taken at the test points (see Figure D.4).

The ideal vessel wall distance is yielded as the arithmetical mean of the measured gauge dimensions for each test plane. The deviations result from the difference between the measured gauge dimension and the mean value of all gauge dimensions.

The mean value of all gauge dimensions for each test plane is:

$$a_{\mathrm{m}} = \frac{1}{n} \sum_{n=1}^{n} a_{\mathrm{n}} \qquad \text{(D.5)}$$

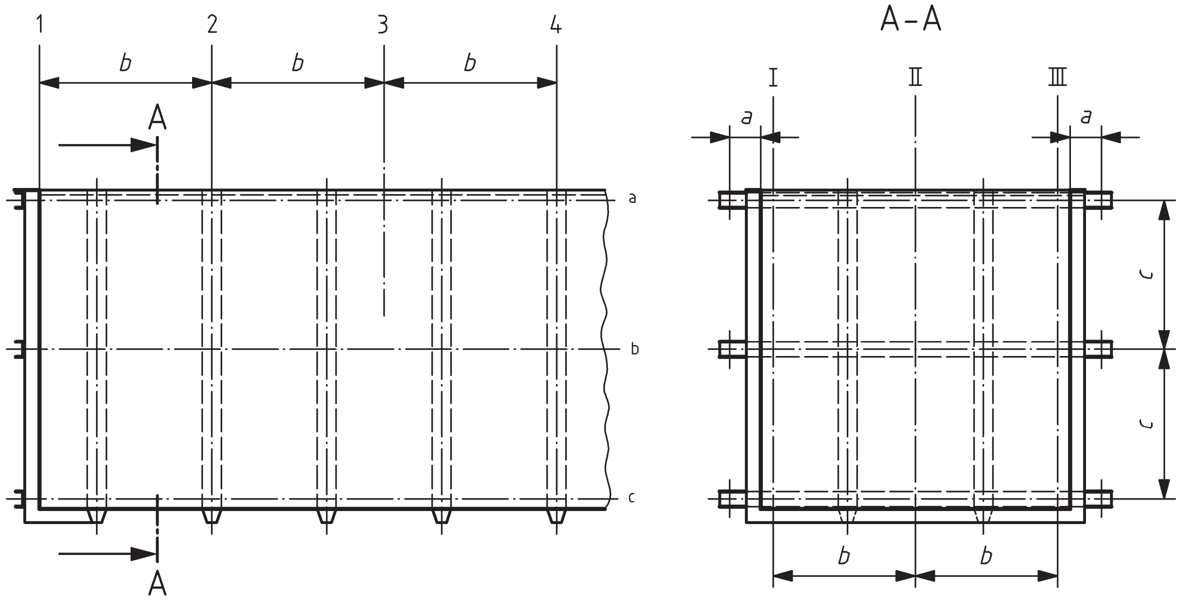
which yields a deviation of:

$$\Delta a_{\mathrm{i}} = a_{\mathrm{i}} - a_{\mathrm{m}} \qquad \text{(D.6)}$$

D.3.4.5 Measuring the flatness of the angular base

The vertical planes 1, 2, etc. in Figure D.4 shall be transferred onto the vessel base. The flatness of the base shall be measured, e.g. with the aid of a levelling instrument or laser gear, at the points at which these planes intersect the vertical planes I, II, etc., which according to D.3.4.3 are located as vertical test planes in the width of the vessel. The deviations are calculated as the difference between the respective measured gauge dimension and the mean value of all gauge dimensions, using the formulae given in D.3.3.4 and D.3.4.4.

Proceed similarly for sloping bases.



a Plane A
b Plane B
c Plane C

Figure D.4 — Measurement of the flat-sided angular vessel

Annex E
(informative)

A-deviations

A- deviation: National deviation due to regulations, the alteration of which is for the time being outside the competence of the CEN/ CENELEC Member.

This European Standard does not fall under any Directive of the EU.

In the relevant CEN/CENELEC countries these A-deviations are valid instead of the provisions of the European Standard until they have been removed.

Comments on prEN 14789-6 – National legislative/administrative deviations:

In Germany construction products for stationary plants for the storage, filling and loading/unloading of water-hazardous substances require national technical verification with respect to section 1 No. 2 Wasserbauprüfverordnung ("Model Water Construction Products Code").

A Verification of applicability (e.g. a allgemeine bauaufsichtliche Zulassung ("national technical approval")) is required for interior coatings and linings for containers and pipes and for coatings and linings which are used for other facilities in plants for the storage, filling and loading/unloading of water-hazardous substances.

Ceramic tiles which are used in combined linings for collecting rooms and liquid-tight areas shall fulfil the requirements of Bauregelliste A Teil 1, lfd. Nr. 15.31 ("Construction Products List A part 1, No. 15.31").

Bedding and jointing mortar/cement and other jointing materials for ceramic tiles shall fulfil the requirements of Bauregelliste A Teil 1, lfd. Nr. 15.42 ("Construction Products List A part 1, No. 15.42").

Regulations for the application of these products in Germany are given by water legislation (Verordnungen über Anlagen zum Umgang mit wassergefährdenden Stoffen ("Acts for plants for the handling of water-hazardous substances")).

Further application rules for linings for metallic facilities used for the handling of water-hazardous substances are laid down in the Technische Regeln wassergefährdender Stoffe "Technical rules water-hazardous substances" especially in

— TRwS 779 Allgemeine Technische Regelungen ("General Technical Rules"); and

— TRwS 786 Ausführung von Dichtflächen ("Execution of liquid-tight areas").

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EN 933 (all parts), *Tests for geometrical properties of aggregates*

EN 1081, *Resilient floor coverings – Determination of the electrical resistance*

EN 13238, *Reaction to fire tests for building products – Conditioning procedures and general rules for selection of substrates*

EN 13445-3, *Unfired pressure vessels – Part 3: Design*

EN ISO 1101:2005, *Geometrical Product Specifications (GPS) – Geometrical tolerancing – Tolerances of form, orientation, location and run-out (ISO 1101:2004)*

DIN 28011, *Torispherical heads*

DIN 28013, *Ellipsoidal heads*

DIN 28080, *Saddle supports for horizontal apparatus – Dimensions*

DIN 28081-1, *Tubular supports for vessels – Dimensions*

DIN 28081-2, *Vessel supports made of steel sections; dimensions, material and design*

DIN 28082-1, *Skirts for apparatus; part 1: With simple bottom ring; dimensions*

DIN 28082-2, *Skirts for apparatus – Part 2: Bottom ring with bracket supports or twin ring with webs; dimensions*

DIN 28083-1, *Bracket supports; dimensions and maximum loads*

DIN 28084 (all parts), *Support rings and ring supports on apparatus*

DIN 51130, *Testing of floor coverings – Determination of the anti-slip properties – Workrooms and fields of activities with slip danger, walking method – Ramp test*

Directive 97/23/EC of the European Parliament and of the Council of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment.

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