BRITISH STANDARD

BS 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

The European Standard EN 14879-4:2007 has the status of a British Standard

ICS 25.220.60

BSI
British Standards

National foreword

This British Standard is the UK implementation of EN 14879-4:2007.

The UK participation in its preparation was entrusted to Technical Committee ISE/16, Protective coatings and linings of metal pipes and 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.

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 August 2007

ISBN 978 0 580 55810 8

Amendments issued since publication

Amd. No.	Date	Comments

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 14879-4

August 2007

ICS 25.220.60

English Version

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

Systèmes de revêtements organiques de peinture et autres revêtements rapportés pour la protection des appareils et installations industriels contre la corrosion par des milieux agressifs - Partie 4: Revêtements rapportés pour composants métalliques

Beschichtungen und Auskleidungen aus organischen Werkstoffen zum Schutz von industriellen Anlagen gegen Korrosion durch aggressive Medien - Teil 4: Auskleidungen für Bauteile aus metallischen Werkstoffen

This European Standard was approved by CEN on 24 June 2007.

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

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

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

Ref. No. EN 14879-4:2007: E

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Foreword

This document (EN 14879-4:2007) has been prepared by Technical Committee CEN/BT/Task Force 130 “Organic coating systems and linings for protection of industrial apparatus and plants against corrosion caused by aggressive media”, 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 February 2008, and conflicting national standards shall be withdrawn at the latest by February 2008.

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 lining 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 United Kingdom.

1 Scope

This document describes the requirements for and methods of testing of organic linings which are applied to metallic process engineering equipment that will come in contact with chemical substances. The requirements specified here may be used for the purposes of quality control (e.g. as agreed between the contract partners[1)]).

The standard applies to linings 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) from harmful substances;

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

— to achieve a particular surface quality.

This standard applies to vessels, apparatus, piping parts and other components for process plants made of metallic substrate materials which are in contact with media and are provided with a surface protection made of

a) prefabricated, natural or synthetic rubber based sheeting (subsequently named rubber lining), to be applied in the workshop or on site;

b) prefabricated, phenol formaldehyde or epoxy resin based sheeting (subsequently named duroplastic lining), to be applied in the workshop only;

c) prefabricated, thermoplastic products (e.g. foils, sheeting, plates, pipes) (subsequently named thermoplastic lining), to be applied in the workshop or on site.

The standard specifies the requirements, acceptance inspection, packaging, transport, storage and installation of organic linings for metallic materials.

The tests described in this standard are intended for verification of the suitability of sheeting used for linings and for acceptance inspection to be carried out on the products during or after application of the lining or as part of routine inspections to determine any changes effected in the lining during service.

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 59, *Glass reinforced plastics — Measurement of hardness by means of a Barcol impressor*

EN 228, *Automotive fuels — Unleaded petrol — Requirements and test methods*

EN 590, *Automotive fuels — Diesel — Requirements and test methods*

EN 12814 (series), *Testing of welded joints of thermoplastics semi-finished products*

prEN 13122, *Hot gas welding of semifinished products of thermoplastic materials*

EN 14728, *Imperfections in thermoplastic welds — Classification*

1) For the purposes of this standard, the contract partners are the lining material manufacturer, the component manufacturer, the person(s) responsible for applying the lining, and the client ordering the linings.

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 ISO 291, *Plastics - Standard atmospheres for conditioning and testing (ISO 291:2005)*

EN ISO 868, *Plastics and ebonite - Determination of indentation hardness by means of a durometer (Shore hardness) (ISO 868:2003)*

EN ISO 2039-1, *Plastics — Determination of hardness — Part 1: Ball indentation method (ISO 2039-1:2001)*

EN ISO 4624:2003, *Paints and varnishes — Pull-off test for adhesion (ISO 4624:2002)*

EN ISO 8503-1, *Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates — Part 1: Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast-cleaned surfaces (ISO 8503-1:1988)*

EN ISO 8503-2, *Preparation of steel substrates before application of paints and related products — Surface roughness characteristics of blast-cleaned steel substrates — Part 2: Method for the grading of surface profile of abrasive blast-cleaned steel - Comparator procedure (ISO 8503-2:1988)*

EN ISO 12944-4, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 4: Types of surface and surface preparation (ISO 12944-4:1998)*

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*

ISO 813, *Rubber, vulcanized or thermoplastic — Determination of adhesion to a rigid substrate — 90 degree peel method*

ISO 1817, *Rubber vulcanised — Determination of the effect of liquids*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 14879-1:2005 and the following apply.

3.1
loose lining
loose shirt lining
lining partly fixed mechanically but not glued to the surface

4 General

4.1 Materials

4.1.1 Metallic substrates and semi-finished products

In accordance with EN 14879-1.

4.1.2 Linings

4.1.2.1 General

The lining materials used shall be suitable for the respective chemical, thermal, mechanical and other stresses to be expected in service. The requirements for the lining shall be subject to agreement between the user/customer and the manufacturer. Verification of suitability shall be performed in accordance with Clause 9.

The linings shall be tight and free from pores. For the purpose of this standard, pores are interconnected depth-penetrating cannular cavities (voids). The linings shall show no visible imperfections such as blisters, inclusions or impurities, which are likely to reduce their protective properties.

4.1.2.2 Rubber linings

A distinction shall be made between soft and hard rubber linings.

a) Soft rubber linings

Non-vulcanised and vulcanised semi-finished rubber based products shall be used as lining materials. The nominal lining thickness should be 4 mm. Other thickness has to be agreed and referenced in the standard designation.

The following types of soft rubber materials are commonly used (symbols in accordance with ISO 1629):

Symbol	Name
NR	Natural rubber
IR	Isoprene rubber, synthetic
CR	Chloroprene rubber
IIR	Isobutene-isoprene rubber (butyl rubber)
BIIR	Bromo-isobutene-isoprene rubber (Bromobutyl rubber)
CIIR	Chloro-isobutene-isoprene rubber (Chlorobutyl rubber)
CSM	Chlorosulfonylpolyethylene (Hypalon)
SBR	Styrene-butadiene rubber
NBR	Acrylonitrile-butadiene rubber (nitrile rubber)

b) Hard rubber linings

Non-vulcanised semi-finished rubber based products shall be used as lining materials. The nominal lining thickness shall be at least 3 mm. Other thickness has to be agreed and referenced in the standard designation.

The following types of hard rubber materials are preferably used (symbols in accordance with ISO 1629):

Symbol	Name
NR	Natural rubber
IR	Isoprene rubber, synthetic
SBR	Styrene-butadiene rubber
NBR	Acrylonitrile-butadiene rubber (nitrile rubber)

4.1.2.3 Duroplastic linings

Duroplastic linings shall be made of non-cross linked materials in the form of sheeting. The nominal lining thickness shall be at least 3 mm. Other thickness has to be agreed and referenced in the standard designation.

The following types of resin based lining materials are commonly used (symbols in accordance with EN ISO 1043-1):

Symbol	Name
PF	Phenol-formaldehyde resin
EP	Epoxy resin

4.1.2.4 Thermoplastic linings

Prefabricated thermoplastic products shall be used as lining materials. Preferably, the lining thickness should be 3 mm. Other thickness has to be agreed and referenced in the standard designation.

The following thermoplastics are commonly used (symbols in accordance with EN ISO 1043-1):

Symbol	Name
PVC-U	Unplasticised poly(vinyl chloride)
PVC-P	Plasticised poly(vinyl chloride)
PP	Polypropylene
PTFE	Polytetrafluoroethylene
MFA/PFA	Perfluoro alkoxy alkane resins
FEP	Perfluoro(ethylene-propylene) plastic
E/CTFE	Ethylene/chlorotrifluoroethylene
PVDF	Poly(vinylidene fluoride)
PIB	Polyisobutene
PEEK	Polyetheretherketone

4.1.2.5 Composite thermoplastic/rubber lining

In accordance with 4.1.2.2 and 4.1.2.4.

The nominal thickness of the composite lining shall be at least 4 mm. Bonding between the individual materials shall be permanent. Other thickness has to be agreed and referenced in the standard designation.

4.1.2.6 Specific requirements for lining materials

4.1.2.6.1 Resistance to the service fluid

The performance of the lining shall not be impaired when it is subjected to stresses due to contact with the service fluid. Since linings are usually subjected to a variety of stresses, additional measures such as thermal insulation or a combination of different protective layers, e.g. brick lining, may be necessary to ensure their proper performance.

4.1.2.6.2 Physical properties

The values required for the physical properties of the selected lining material, e.g. density, tensile strength, elongation at fracture, modulus of elasticity, softening point and hardness, shall be specified as appropriate for the intended application and be verified as part of the quality control.

4.1.2.6.3 Characteristics of lining material

Semi-finished products to be used for linings shall meet the requirements agreed upon (see 4.1.2.1).

Multilayer materials shall be fully bonded interfacial and there shall be sufficient adherence between the individual layers.

4.1.2.6.4 Thickness of semi-finished products to be used for lining

The thickness of semi-finished products to be applied as linings shall be equal to the agreed nominal thickness and the permitted deviation shall be ± 10 %.

4.1.2.6.5 Adhesion system

Adequate and long time adhesion of the lining to the substrate over the entire area shall be ensured. The adhesion system to be applied shall therefore be selected in consideration of the requirement for the lining material, except for linings applied without adhesion system, e.g. by "loose shirt" technique.

4.1.2.6.6 Additional requirements for the lining material

Other relevant requirements for the lining material, e.g. physiological safety, resistance against fluid based tension tear resistance, resistance to radiation, electrical conductivity and decontamination properties, shall be subject to agreement, if necessary.

4.2 Selection criteria

4.2.1 General

The stress to be encountered by a protective lining shall be known before the requirements for it can be specified. For the scope or this standard, the stress types detailed in 4.2.2 to 4.2.8 are the most relevant. Where necessary, grades have been used to describe different levels of stress.

4.2.2 Aggressive substances

Aggressive substances or water pollutants may occur as solids or fluids. Their aggressive action on metallic material usually occurs when they are in a liquid state (e.g. aqueous solutions or condensates). The substances may occur in their pure state, or as mixtures and may attack the metallic material at varying intervals.

These substances shall be designated using the Geneva nomenclature, IUPAC[2)] nomenclature or CAS[3)] number. They may also be designated by trivial names which have become established in the literature. Concentrations and any changes to these shall be given as a percentage by mass or volume, or as g/l, g/kg, mol/l etc. The pH value shall also be given for aqueous solutions.

All constituents, including traces and impurities, shall be named, even if they do not attack metallic materials. Successive exposure shall be represented accordingly.

Table 1 lists chemicals which are commonly used, having the properties mentioned above.

2) International Union of Pure and Applied Chemistry.

3) Chemical Abstract Service.

Table 1 — Classification of frequently (commonly) used chemicals

Type of chemical	Examples	
I. Inorganic chemicals		
Inorganic, non-oxidizing acids	HCl H_2SO_4 H_3PO_4	Hydrochloric acid Sulfuric acid, up to 70 % Phosphoric acid
Inorganic, oxidizing acids	HNO_3 H_2SO_4 CrO_3, H_2CrO_4 $HClO_3$	Nitric acid Sulfuric acid, over 70 % Chromic acid Chloric acid
Inorganic acids, dissolving SiO_2	HF H_2SiF_6 HBF_4	Hydrofluoric acid Hexafluorosilicic acid (containing HF) Tetrafluoroboric acid (containing HF)
Salts	$NaCl$ $FeSO_4$ Na_2CO_3	Sodium chloride Iron (II) sulfate Sodium carbonate
Bases	$NaOH$ KOH CaO, $Ca(OH)_2$ NH_4OH	Sodium hydroxide Potassium hydroxide Calcium oxide Calcium hydroxide Ammonia solution (Ammonium hydroxide solution)
Oxidizing bases	$NaOCl$	Sodium hypochlorite
II. Organic chemicals		
Organic acids	$HCOOH$ CH_3COOH $CH_2ClCOOH$ $(COOH)_2$ $CH_3CHOHCOOH$	Formic acid Acetic acid Chloroacetic acid Oxalic acid Lactic acid
Aliphatic hydrocarbons	C_6H_{14} C_8H_{18}	Hexane Octane
Aromatic hydrocarbons	C_6H_6 $C_6H_5CH_3$ $C_6H_4(CH_3)_2$	Benzene Toluene Xylene
Alcohols	CH_3OH C_2H_5OH C_4H_9OH CH_2OHCH_2OH	Methanol Ethanol Butanol Ethanediol
Aldehydes, Ketones, esters	CH_2O CH_3COCH_3 $C_2H_5COCH_3$ $CH_3COOC_2H_5$	Formaldehyde Acetone Methyl ethyl ketone (2.butanone) Ethyl acetate
Aliphatic halogenated hydrocarbons	CH_2Cl_2 C_2HCl_3 $C_2Cl_3F_3$	Dichloromethane Trichloroethylene Trichlorotrifluoroethane
Aromatic halogenated hydrocarbons	C_6H_5Cl $ClC_6H_4CF_3$	Chlorobenzene Chlorobenzotrifluoride
Aliphatic amines	CH_3NH_2 $(C_2H_5)_3N$ $NH_2C_2H_4NH_2$	Methylamine Triethylamine Ethylene diamine
Aromatic amines	$C_6H_5NH_2$ C_5H_5N	Aniline Pyridine
Phenols	C_6H_5OH $CH_3C_6H_4OH$	Phenol Cresol
Fats, oils		Vegetable and animal fats and oils

4.2.3 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: constant or frequent exposure to a film of fluid, due to condensation and the like (e.g. gas ducts, stacks).

Grade 2: operational exposure to a constant flow of fluid involving no significant hydrostatic pressure (e.g. pipes).

Grade 3: constant exposure of containers to fluid contents for unlimited periods (e.g. vessels).

4.2.4 Thermal loading

Temperature influences the effectiveness of a surface protection system in the following ways.

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 may 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 °C.

4.2.5 Changes in temperature

Changes in temperature include

a) temperature changes at the protective surface during exposure to fluid loads of grades 1 to 2 as in 4.2.3 involving changed medium temperatures;

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

c) process-related changes in the temperature of the medium under loading conditions corresponding to grade 3 (as in 4.2.3).

Temperature changes due to climatic influences are dealt with in 4.2.7.

The source, degree, 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 of not more than 50 K.

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

Grade 3: frequent temperature changes of not more than 50 K.

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

Grade 5: temperature changes involving thermal shock (assessment not possible with this standard).

4.2.6 Mechanical loading

The effectiveness of a surface protection system may be impaired through exposure to mechanical loads or hydrostatic pressure during operation or assembly.

4.2.7 Climatic influences

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.

4.2.8 Additional requirements

Additional requirements may derive from special applications, and are not fully covered by this standard. They may refer to water protection, explosion protection, fire behaviour, decontamination, health and safety (particularly in the case of foodstuffs and drinking water), non-slip surfaces and smoothness.

4.3 Load profile

The loads described in 4.2.2 to 4.2.8 shall be recorded, together with the grades selected, using the form reproduced in Annex A.

4.4 Design of component

The structural design of metallic components shall be in accordance with EN 14879-1.

For the design and the size of surfaces and components to be lined it is necessary to previously specify

a) lining material,

b) lining process,

c) site at which the lining shall be applied.

This will result in different requirements for the design of the component which are subject to agreement between the manufacturer of the component and the lining manufacturer.

4.5 Manufacture of the lining

4.5.1 Environmental conditions

The environmental and climatic conditions shall be in accordance with the manufacturer's instructions.

The temperatures of the surface to be protected and of the semi-finished product shall not be allowed to drop below the dew point during the lining process. In order to ensure this, the surface temperature shall be at least 3 °C above the dew point.

4.5.2 Surface condition and preparation of the substrate

The surface condition of the components to be lined shall meet the requirements defined in EN 14879-1.

The surface to be protected shall be subjected to abrasive blast-cleaning.

After blast-cleaning the remaining traces of blast-cleaning abrasives shall be removed and the abrasive blasted metallic surfaces shall be suitably treated to prevent rusting, e.g. by applying a primer or adhesive coating.

NOTE For repairs on small surface areas, preparation of the substrate can be carried out by grinding provided that the required surface roughness is achieved.

Ferritic steel:

Abrasive blasting of the whole surface to be lined in accordance with EN ISO 12944-4: standard preparation grade at least Sa 2½; roughness in accordance with EN ISO 8503-1 and EN ISO 8503-2: medium (G) R_z: 25 µm up to 80 µm.

Austenitic steel:

Abrasive blasting of the whole surface to be lined similar to EN ISO 12944-4 (with mineral abrasives); roughness in accordance with EN ISO 8503-1 and EN ISO 8503-2: medium (G) R_z: 25 µm up to 60 µm.

Type and composition of the abrasive shall be such as to exclude the formation of local elements.

Non-ferrous metals:

Preparation shall be performed in accordance with the instructions of the lining manufacturer.

4.5.3 Preparation and application of pre-cut parts of the semi-finished products

The semi-finished products shall be subject to preparatory treatment in accordance with the manufacturer's instructions.

If necessary, thermoplastic semi-finished products shall be hot formed so as to fit the size and the shape of the component to be lined.

After treatment the pre-cut lining parts shall be applied to the surfaces to be protected in such manner, that the formation of air pockets and any inclusion of foreign matter are prevented.

4.5.4 Lining joints

4.5.4.1 General

Jointing of semi-finished pre-cut parts shall be performed

— by reactive bonding for rubber and duroplastic linings,

— by welding for thermoplastic linings.

Jointing usually leads to an increase of the lining thickness in the joint area. Where such an increase in thickness is not permitted in certain areas, this shall be agreed between the lining manufacturer and the customer and shall be marked in the relevant drawing.

4.5.4.2 Bonded joints

To ensure an adequately large contact area for bonded joints, the edges of the lining segments shall usually be cut at an angle of 15° to 30°.

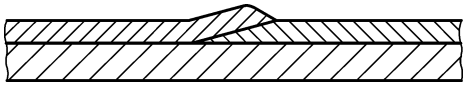


Figure 1 — Bonded joint, type A

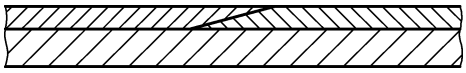


Figure 2 — Bonded joint, type B

The joint design shall be in accordance with Figure 1 or Figure 2. In specific cases, a wider overlap or covering of the joint by applying a cover strip may be agreed upon.

4.5.4.3 Welded joints

Welded joints shall be made in accordance with prEN 13122. The most common welding processes are:

— hot gas welding with torch separate from filler rod

— hot gas string-bead welding

— hot gas extrusion welding

— butt heat-fusion welding

The most common types of welded joints are:

a) Single-V butt joint as shown in Figure 3.

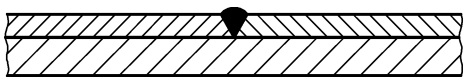


Figure 3 — Single-V butt joint

b) Single-V butt joint with cover strip as shown in Figure 4.

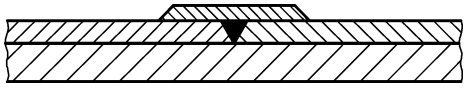


Figure 4 — Single-V butt joint with cover strip

c) Hot-tool butt joint as shown in Figure 5. This type of welded joint can only be produced prior to application of the lining.

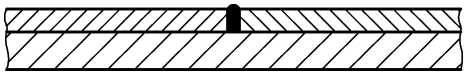


Figure 5 — Hot-tool butt joint

d) Hot-tool butt joint with cover strip as shown in Figure 6. This type of welded joint can only be produced prior to application of the lining.

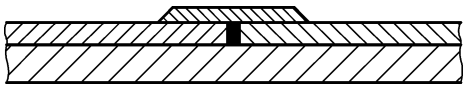


Figure 6 — Hot-tool butt joint with cover strip

e) Fillet weld at the transition of cylindrical vessel part to head or bottom as shown in Figure 7.

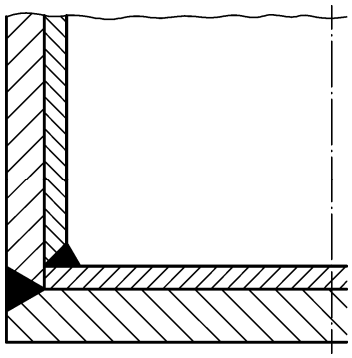


Figure 7 — Fillet weld on cylindrical shell to head or bottom

f) Fillet weld on set-in nozzles as shown in Figure 8.

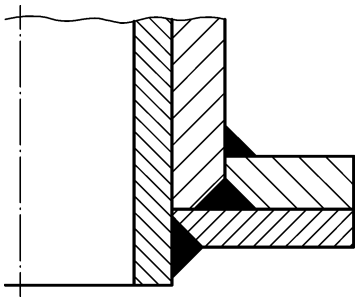


Figure 8 — Fillet weld on nozzles

g) Butt joint and/or lapped joint for linings made of PTFE materials.

4.5.5 Thermal post treatment

4.5.5.1 Rubber and duroplastic linings

To ensure that the desired properties (e.g. chemical, thermal and mechanical resistance) of the lining material and a durable bond between lining and substrate are achieved, cross linking of the lining materials is necessary, usually by vulcanisation under increased temperature and pressure. For vulcanised or cold vulcanising (also: self-vulcanising) rubber sheeting any subsequent heat treatment is not necessary. For cold vulcanising rubber sheeting the time of cross linking is depending on the temperatures used.

4.5.5.2 Thermoplastic linings

For thermoplastic linings, the necessity as well as the type and method of any subsequent heat treatment is depending on their intended use.

4.6 Lined component

The lining of the component shall show the properties specified and agreed upon.

The thickness of the lining at any point of the lined component in contact with the medium shall not be permitted to be less than 10 % of the nominal thickness. The nominal lining thickness may, however, be exceeded up to twice its value, unless any restrictions have been specified by the customer.

For flange facings, any deviations from the nominal thickness shall be subject to agreement.

The limit deviations of the agreed hardness shall be ± 5 Shore A for soft rubber linings and ± 5 Shore D for hard rubber linings.

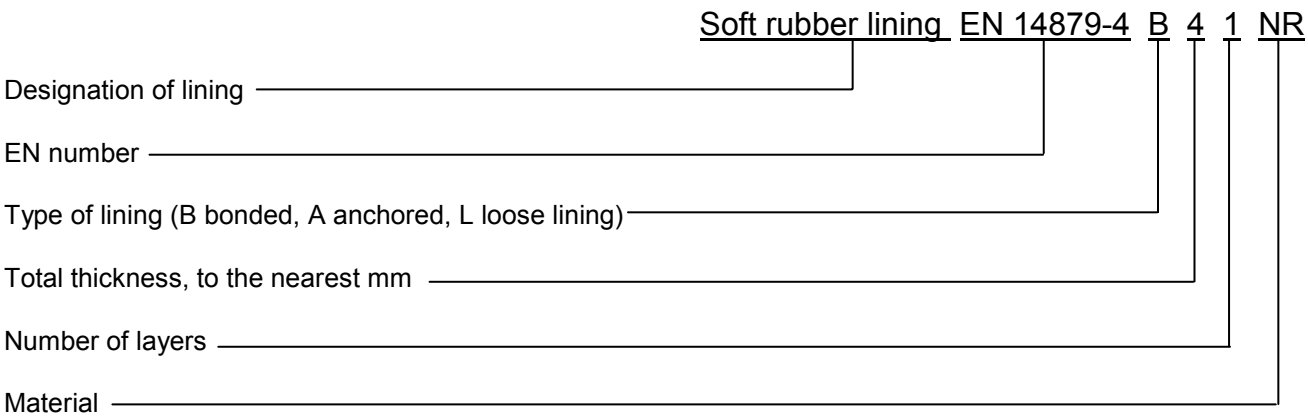
5 Repair of defects

The lining manufacturer is allowed to repair professionally any defects in the lining by using material of the same type or mortars which have proven suitable for repair.

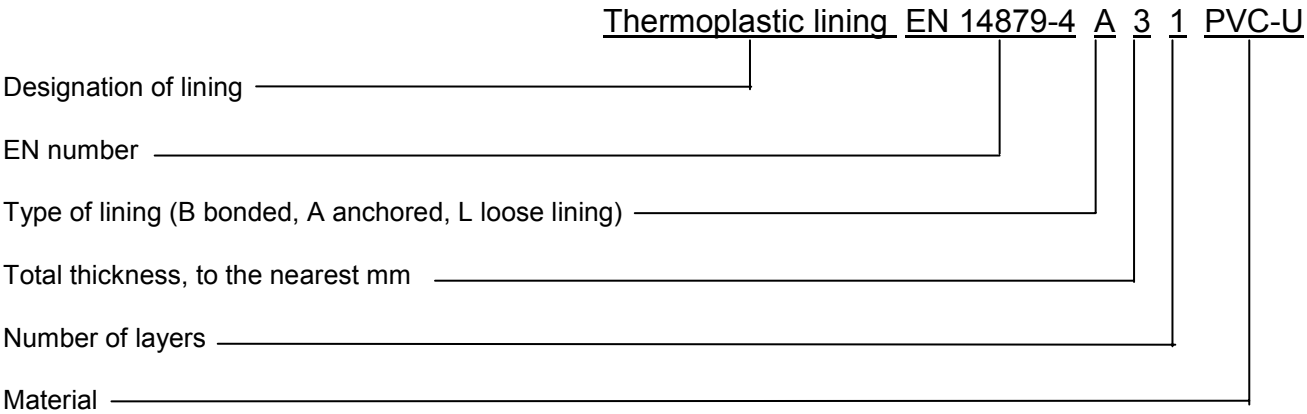
6 Designations

EXAMPLES

a) The designation of a soft rubber lining (B) of a total thickness of 4 mm, based on single layer (1) natural rubber (NR) shall read:



b) The designation of a thermoplastic lining (A) of a total thickness of 3 mm, based on single layer (1) unplasticised polyvinyl chloride (PVC-U) shall read:



7 Packaging, transport, storage and installation

7.1 General

Linings which are susceptible to impact and shock at room temperature and particularly at low temperatures shall be handled with specific care. Deformations of the substrate may cause damages in the linings.

7.2 Packaging and transport

The stresses to be expected to arise during transport shall be decisive for the type and scope of packaging. They are depending on the size, mass and rigidity of the components, the type of lifting devices used, the means of transport, necessary unloading and reloading, if applicable, as well as the conditions at the installation site.

Exposed linings on the flanges of nozzles and pipes, on edges, rims, etc. are particularly in danger of being damaged. Covering of such parts is therefore recommended.

Where necessary, reinforcements, braces or suitable transport racks shall be provided. Chains and steel ropes shall be provided with appropriate packing means so as to eliminate friction or pressing against the protective lining.

The transport of components with linings which are susceptible to low temperatures (e.g. hard rubber linings) should be avoided at temperatures below 0 °C.

After transportation the linings shall be inspected for damages.

7.3 Storage

To protect the linings from cold, heat, temperature fluctuations or UV radiation, storage in closed rooms or covering with suitable materials should be provided.

Where components are stored outdoors for longer periods of time, the transition zones between lining and substrate (e.g. flange facings) shall be provided with additional temporary protection against undercutting layer corrosion (tunnelling).

7.4 Installation

Handling during installation shall be in accordance with 7.1.

Prior to commissioning re-inspection of the lining shall be performed to detect any damages.

8 External finish of surfaces not to be lined

This is not part of this standard but the external finish of surfaces not to be lined should preferably be carried out at the lining workshop.

9 Testing

9.1 General

Depending on the case of application, the linings shall meet specific requirements. The verification of suitability shall be conducted in accordance with 9.3. The requirements shall be subject to agreement between the client and the manufacturer. The conditions defined by the approval authority have to be fulfilled.

9.2 Basic requirements

9.2.1 Resistance to the service fluid

The lining shall be tight and resistant to the loads to be expected in service. The effects of the gas/vapour phase as well as the temperature gradients shall also be taken into account, where relevant.

The verification of suitability shall be carried out in accordance with 9.3.1 and/or 9.3.2.

Fixings used for loose linings shall be resistant to the effects of the fluid or shall be provided with a permanent surface protection against its effects.

9.2.2 Cleaning and neutralizing processes

The lining shall be resistant to the cleaning agent used.

The selection of the cleaning process shall be agreed between the manufacturer and the user. Typically, proof of experience is the basis for assessment. Where necessary, tests shall be carried out on the stressed component in accordance with 9.3.2.

9.2.3 Adhesive strength

Linings shall be permanently and firmly joined to the substrate over their entire area. Testing and evaluation of the test results shall be carried out in accordance with 9.3.3 (does not apply in the case of "loose shirt" linings).

9.2.4 Capability of dissipating electrostatic charges

In process plants intended for handling flammable, highly flammable or extremely flammable liquids, the linings shall be able to dissipate electrostatic charges to avoid hazards of ignition.

The requirements are considered to be met, when

— dissipation resistance at each point of the lining does not exceed $1 \times 10^8\ \Omega$, or

— values for the volume resistance and the insulation resistance (surface resistance) do not exceed $1 \times 10^8\ \Omega$ and $1 \times 10^9\ \Omega$ respectively,

unless the hazard of ignition due to electrostatic charges can be eliminated by equivalent measures. The suitability of any such measure shall be verified by a relevant certificate.

Testing shall be carried out in accordance with 9.3.4. Additional requirements relating to the field of explosion protection are not within the scope of this standard.

9.2.5 Additional requirements

In cases, where additional requirements (e.g. abrasion resistance, resistance to thermal shock and stress corrosion cracking) are specified by agreement between the user/customer and the manufacturer, appropriate proofs of suitability shall also be agreed upon.

9.3 Testing of suitability

9.3.1 General

The tests specified below are intended, as far as necessary, for verification of the suitability of surface protection systems within the scope defined in Clause 1. Identification of the materials shall be done by indicating the physical-chemical parameters.

Verification of suitability can be established by:

a) laboratory tests carried out by a testing body, or

b) proof of experience of the user or the manufacturer, or

c) combination of both a) and b).

For verification of suitability according to a) the test specimens required for laboratory testing shall be produced with the respective material in agreement with the testing body. Proofs for individual components can also be furnished to the testing body by proven reference objects.

Proof of experience according to b) can be established by:

— laboratory tests providing results which have been recorded and are reproducible;

— reference objects with comparable load conditions which have been produced with the same surface protection system for which suitability shall be proven;

— resistance lists containing the known boundary conditions, which can be proven by laboratory tests.

9.3.2 Testing of resistance and tightness to the service fluid

Testing shall be carried out with the fluid to which the lining shall be resistant and tight.

The tests shall be performed on steel plates with the lining applied (with joint seam), as well as using sheeting sections or rounds with a diameter of approximately 36 mm. In the case of loose linings, only sheeting sections need to be tested.

a) The immersion test shall be carried out with the liquid to which the lining shall be resistant and tight.

b) Where the lining shall be resistant and tight to various liquids, the immersion test shall be carried out with each of these liquids.

c) If specific material combinations have been specified for rubber linings, immersion tests using the test fluids of the respective media list (Annex B) will be sufficient.

d) If fluids can be classified into a media group given in the reference list (Annex C) for thermoplastic linings, immersion tests with the test liquid given in the list will be sufficient.

An appropriate test assembly which can be used for linings applied to steel plates is e.g. a test apparatus in accordance with EN 977 or a comparable test assembly in which the test plates can be clamped in such manner that both the effects of the liquid phase and the vapour phase can be tested at the same time. The ratio of the test liquid volume in cubic centimetres and the lining surface exposed to the liquid in square centimetres shall be at least 8 : 1. Testing shall be carried out at 40 °C or at the intended service temperature.

The sheeting sections and rounds may be immersed together.

Immersion shall be continued until the sheeting sections or rounds have reached mass constancy, but a least for a period of 28 days. Changes in hardness and mass shall be recorded with the measurements to be taken after 7, 14, 21, 28 days (or any multiple). Typically, the duration of the test period shall not exceed 168 days.

The tests shall be performed on sheeting sections having the minimum thickness intended for use.

The requirements are considered to be met, if mass constancy has been reached within the test period. After exposure to the test liquid, the test specimens shall show no visible changes (excepting changes in colour or gloss), when inspected visually. Assessment shall be carried out in accordance with ISO 1817.

In particular, the joint seam of the lining applied to the steel plate shall be tested. The joints shall not gape apart.

Changes in hardness shall be determined by measurement using an appropriate method (e.g. Shore A, Shore D, Barcol in accordance with EN 59). The measurements shall be carried out 1 h after removal of the test liquid and after 24 h conditioning in normal climate 23/50-2 in accordance with EN ISO 291.

The determined change in hardness shall be assessed in consideration of the intended case of application.

Thermoplastic linings shall be tested. For test methods see for example the standard series ISO 4433.

The weld seams shall meet the requirements in accordance with the series of standards EN 12814.

9.3.3 Testing of adhesive strength

The adhesive strength of soft rubber linings shall be determined on unexposed test specimens in accordance with 9.4.5.2.2 (based on ISO 813). The resistance to peeling shall be at least 3 N/mm up to a service temperature of 60 °C. At higher service temperatures, verification shall be performed by using test specimens which were exposed to the media.

Testing of hard rubber linings shall be carried out using the pull-off method in accordance with EN ISO 4624. The adhesive strength shall be at least 6 N/mm^2 up to a service temperature of 60 °C. At higher service temperatures, verification shall be performed by using test specimens which were exposed to the media.

For thermoplastic linings the minimum values of adhesive strength shall be specified for each individual case.

9.3.4 Testing of capability to dissipate electrostatic charges

Testing shall be carried out on steel plates with the applied lining having the greatest thickness intended for use. Prior to measurement, the test specimens shall be conditioned at least 24 h in normal climate 23/50-2. Treatment of the specimens with organic solvents prior to the measurement shall be excluded.

Testing of the dissipation resistance is carried out with a voltage of 100 V DC in accordance with Annex D.

The insulation resistance (surface resistance) is measured in accordance with IEC 60167 with a voltage of 100 V DC.

9.4 Acceptance inspection

9.4.1 General

The type, scope and date of the tests required for acceptance inspection and their documentation shall be agreed between the lining manufacturer and the customer.

Testing of the components shall only be carried out by competent test personnel. The areas to be tested shall be appropriately lighted and shall be accessible. The lining surface to be tested shall be sufficiently dry and clean. The surface temperature should be + 10 °C to + 30 °C.

The test programme to be carried out shall be specifically adapted to the material properties of the lining.

Where destructive acceptance tests have to be carried out, work samples shall be manufactured for that purpose.

The test equipment used shall be calibrated and shall be in perfect functional condition.

For any given property to be tested, the number of measurements required depends on the size of the area under testing and on the test method used. Prior to testing, variations in lining properties and admissible scattering of measured values shall be specified on the basis of relevant standards or by agreement between the parties concerned. The same applies for the specification of statistical procedures for any statistical evaluation intended.

A test report shall be prepared in accordance with 9.4.9.

9.4.2 Visual inspection

The visual inspection is used to assess the general condition and quality of the lining. It should be conducted prior to all other tests over the entire area of the lining. For conductive lining materials in particular, visual inspection is the only suitable method to identify any defects.

The visual examination shall be carried out with sufficient light, if necessary with the aid of a lamp, without magnifying lens. The lining shall be checked for visible imperfections, e.g. blistering, inclusions, discontinuities, cracks or mechanical damage.

Particular attention shall be given to edges, corners, flange facings and joints.

Both bonded and welded joints shall be specifically examined for open seams, insufficient overlapping or inadmissible material excess in seam areas, cracks and notches.

The assessment of welded joints shall be performed in accordance with EN 14728.

Imperfections in the linings or joints shall be suitably marked and shall be subjected to additional testing.

The assessment of welded joints in fluoroplastics such as PFA, FEP, PTFE shall be performed analogously.

9.4.3 Measurement of lining thickness

9.4.3.1 General

The purpose of measuring the lining thickness is to establish the actual overall thickness of the lining and any deviations from the design value, with an adequate degree of accuracy, by taking measurements at particularly critical points.

Typically, the overall thickness of the lining is measured even in those cases where it consists of different composite layers (e.g. soft rubber/hard rubber, soft rubber/thermoplastics). Where the thickness of individual layers has to be measured, this can only be carried out during application, before the subsequent layer is applied.

The lining thickness shall be measured using one of the non-destructive methods specified below. The method shall be selected in accordance with the characteristics of the substrate as well as the specified maximum and minimum thickness of both substrate and lining.

In the case of ferromagnetic substrates, the magnetic methods specified in EN ISO 2178 may be used.

9.4.3.2 Adhesive force method

With this method, the lining thickness is determined by measuring the magnetic attraction between the substrate and a permanent magnet placed on the surface of the lining. The thicker the lining is, the lower the magnetic flux is, i.e. the magnetic attraction.

9.4.3.3 Magnetic induction method

Here, a probe with one or two magnetic poles, depending on the type of measuring device, is placed on the lining. Any changes effected in the magnetic field are measured by their inductive reaction generated in a live coil. The thicker the lining, the lower is the inductive reaction.

9.4.3.4 Eddy current method

The eddy current method specified in EN ISO 2360 may be used for non-ferromagnetic metallic materials which are not suitable for magnetic test methods. The principle is to induce eddy currents in the substrate and to measure the reaction generated in the probe.

9.4.3.5 Factors influencing the measurement value

The factors described below may falsify the measurement results and shall be given due consideration during testing, in accordance with the instructions of the manufacturer of the measuring device.

— Effects of temperature

  With the increase of temperature, the electromagnetic inductance of metallic materials decreases and the polarizability of organic materials are enhanced. Both effects have an influence on the measured value.

— Placing of the sensor

  The measuring probe should be placed perpendicularly and gently on the surface of the lining. Particular care shall be taken with soft materials, where the load pressure of the sensor shall be kept to the minimum possible.

— Spacing

Measurements within a certain marginal distance of the probe from edges, holes, bores or changes in profile produce errors in measurement. The minimum distance from such areas shall be 20 mm.

— Surface curvature

Curvatures of the surface can have an influence on the measured values. To obtain correct measurements, the minimum radii are usually specified by the manufacturers of measuring devices. In cases of doubt, it may be necessary to calibrate the measuring device using a reference sample with the same radius of curvature.

— Surface roughness

Since single measurements become less reliable as surface roughness increases, an above-average number of measurements shall be taken on rough linings.

— Ferromagnetic or conductive fillers and intermediate layers

Measurements may be considerably influenced where fillers or intermediate layers are ferromagnetic or conductive. In such cases, correction factors determined on a reference sample with the same lining system shall be used for assessment purposes.

9.4.4 Testing of Hardness

9.4.4.1 General

The purpose of measuring the hardness of new linings or repair work is to verify compliance with specifications, while measurements are carried out on used linings in order to establish any changes in performance as a result of the stresses occurring in service.

The hardness of thermoplastic lining materials is a characteristic value of the product itself. The hardness of duroplastic linings and rubber linings is a function of the degree of cross linking.

The hardness of a lining shall be established by measuring its resistance to indentation by a defined specimen, the test method used being non-destructive. The hardness is a function of the temperature. Any subsequent mechanical treatment of the lining may also affect the results.

The lining surface to be tested shall be smooth and free from visible defects, e.g. scratches or pores.

9.4.4.2 Shore A and Shore D hardness testing

These methods shall be used to determine the hardness of rubber and thermoplastic linings. Testing of Shore A hardness is suitable for soft rubber linings and Shore D for hard rubber and thermoplastic linings. Testing shall be carried out in accordance with EN ISO 868. Where testing is carried out manually, scattering of the measured values has to be taken into account.

9.4.4.3 Barcol hardness testing

This method is suitable for determining the hardness of resin linings. Testing shall be carried in accordance with EN 59.

9.4.4.4 Ball indentation hardness testing

This method is suitable for determining the hardness of phenol formaldehyde materials and thermoplastics. Testing shall be carried out in accordance with EN ISO 2039-1.

9.4.5 Testing of Adhesion

9.4.5.1 General

For the testing of adhesion, various aspects have to be considered and therefore different methods of testing are applicable.

— In the case of rigid linings, sound testing in accordance with 9.4.5.2.1 may be used to detect air pockets.

— The adhesion of linings to the substrate or between layers may be determined by means of the pull-off test in accordance with 9.4.5.2.3 for rigid linings or the separation test (peel test) in accordance with 9.4.5.2.2 for soft linings.

Basically, the non-destructive sound testing method is to be preferred, where applicable. Destructive testing should preferably be carried out on representative production test plates and is to be carried out on the actual component only when there is reason to believe that adhesion is inadequate.

Due to the variety of material factors which can influence ultrasonic testing, these test methods can provide unreliable results when used for determining lack of adhesion. Therefore they cannot be recommended for routine inspections as being the actual state of the art.

The results of destructive testing can in some cases be influenced by the temperature and the drying stage of the lining. Therefore, the ambient humidity shall be given along with the test temperature in the test report, particularly for rigid linings.

9.4.5.2 Procedure

9.4.5.2.1 Sound testing (for air pockets)

Sound testing is suitable for linings which are sufficiently rigid. Blisters may be detected by lightly tapping the surface of the lining with a fingernail or small metallic object. In case of blisters or less adhesion, a hollow sound will appear instead of a solid tap.

Alternatively or in addition, a blunt object (plastic or metal test hammer) may be used to carefully tap the surface of the lining.

9.4.5.2.2 Testing of flexible linings for resistance to peeling

The separation test may be used to determine the resistance of the lining to peeling or to establish its overall adhesion. In the case of multilayer linings, both the complete lining and the individual layers can be tested to determine these two properties.

A test strip, preferably 30 mm wide and 200 mm long, shall be carefully incised in the lining, down to the substrate or to the layer not subject to testing. A piece of the test strip 30 to 40 mm long shall be lifted up at its front end and clamped in a peeling device with an integrated spring balance. The test piece shall be peeled at right angles to the bonded face, at a rate of about 3 mm/s (maintained as constant as possible), until a maximum of 100 mm is removed.

During peeling, the spring balance shall be observed, and the smallest and largest tensile forces recorded, disregarding the first and last 20 mm of peeled test piece.

The resistance to peeling shall be given in N per 1 mm of the test piece width.

The separation features (i.e. location of failure area and appearance of the surfaces thus separated) shall be assessed in accordance with ISO 813 and given in the test report. In the case of an inhomogeneous appearance of the peeled surface, the proportions of the parts of the surface that differ in appearance shall be expressed as percentages of the total area.

9.4.5.2.3 Pull-off test

Testing shall be carried out in accordance with EN ISO 4624. This test is applicable to rigid linings only.

The area to be tested shall be equal to that of the test plunger face, and defined by an incision in the lining made with a drill bit.

The test piece shall be subjected to steadily increased loading and the tensile load at failure shall be recorded and given in the test report. The fracture surface shall be assessed in accordance with 9.2 of EN ISO 4624:2003, and the type of failure reported.

Suitable test equipment are small mobile instruments which function either manually or hydraulically and permit the tensile load to be steadily increased.

9.4.6 High-voltage testing for tightness

9.4.6.1 General

This test is intended to detect through pores and cracks which extend to the substrate as well as other imperfections. Its application is suitable for electrically insulating linings which are applied to conductive substrates. Where the lining is intact the voltage applied only produces a disruptive breakdown when the breakdown voltage has been reached. Defects in the lining will produce a breakdown at a lower voltage.

High-voltage testing is not to be applied to linings which have too low volume or surface resistance such as linings capable of dissipating electrostatic charges. Such linings shall be marked by stamping to the effect that they are not suitable for high-voltage testing or shall be supplied with documents stating the same.

High-voltage testing for the detection of pores and cracks may particularly require a thorough cleaning and/or drying of linings which had already been in service.

9.4.6.2 High-voltage test equipment

Only high voltage test equipment with the following properties shall be used:

— indication of breakdown by reliable optical and acoustical signal;

— precise and easily controllable setting of the test voltage;

— electric charge of the lining shall not be generated;

— dielectric breakdown strength of the lining shall not be affected adversely;

— safety of personnel handling the equipment shall be ensured.

The following high-voltage test equipment is generally used:

— AC test equipment is suitable for materials with very high breakdown strength and where fillers do not tend to dielectric polarisation. This equipment does not allow for exact limitation of the height and duration of peak voltages;

— test equipment with constant direct current (DC) may induce electric charges and permanent changes in the electric properties of the lining thus producing erroneous results and are not recommended;

— test equipment with pulsed DC is suitable for all fields of application.

9.4.6.3 Test voltage

The test voltage height to be used is dependent on the thickness and the specific electric resistance of the lining material. It shall be specified and selected by the lining manufacturer for the specific test equipment and lining material so as to ensure reliable fault detection without the risk of electric breakdown in the lining which would result in its damage.

Repeated high-voltage testing may reduce the breakdown strength of the materials. For periodic inspection, this has to be taken account of by a reduction of the test voltage. For the testing of linings which have already been in service, the possibility of further tests and the test voltage to be used shall be subject to specific agreement.

9.4.6.4 Procedure

Overall contact of the test electrode with the surface area of the lining shall be ensured during testing.

The electrode shall be swept smoothly over the surface of the lining with a speed of 20 cm/s to 40 cm/s. The test electrode shall not be allowed to stay at any single point, as this could lead to a reduction of the break-down strength and even the destruction of the lining.

9.4.7 Testing of capability to dissipate electrostatic charges (special test)

This test is intended for determining the resistance to earth, i. e. the electric resistance of the completely applied lining, to be measured between the electrodes placed on the lining surface and the earth.

Testing is carried out in accordance with Annex D.

9.4.8 Destructive testing of weld seams (special test)

This test shall be carried out using samples of lining materials only, i.e. without substrate.

Preferably, the short-time weld test and the technological bending test in accordance with the series EN 12814 shall be performed to determine the assessment criteria.

9.4.9 Test report

A test report shall be prepared. Depending on the scope of testing performed, it should contain the following information:

— number of this standard;

— description of component or lining to be tested;

— date of testing and name of inspector;

— type and scope of testing (e.g. acceptance inspection, inspection of repair work, production test or routine inspection);

— type and design of lining system;

— general condition of the lining at the time of testing (e.g. new, clean/re-cleaned, dry/re-dried, visible, accessible);

— test temperature (including lining surface temperature and ambient temperature, where relevant);

— relative humidity (including difference to dew point, where relevant);

— test equipment used;

— test voltage used for high-voltage testing;

— measured values/reference values;

— number and location of discontinuities/defects;

— special observations and assessments made during testing.

Example for a test report see Annex E.

Annex A
(informative)

The note in the margin on page 1 prohibiting reproduction of any part of the standard does not apply to the following specimen form.

Specimen form

Load profile as in EN 14879-4 for linings on metallic components

The form is to be completed separately for each part.

Plant _____

Structure to be protected

O Tank O Reaction vessel O Container O Others

Part to be protected

O Floor O Wall O Ceiling O Pipe O Sump

Application

O Storage O Filling O Loading/Unloading O Production O Treatment O Use

Load

1. Chemicals (use a separate sheet if necessary, see Table 1 for examples): _____

_____

_____

_____

_____

_____

_____

_____

_____

_____

2. Grade of fluid load (4.2.3) _____

_____

_____

_____

3. Steam/Condensate: O yes O no

Gas O yes O no

4. Grade of thermal load (4.2.4) _____

_____

_____

5. Grade of temperature change (4.2.5) _____

_____

6. Grade of mechanical loading (4.2.6) _____

_____

7. Grade of exposure to climatic influences (4.2.7) _____

_____

_____

8. Additional requirements: _____

_____

_____

_____

_____

_____

_____

Signature: _____ **Date:**_____

Annex B
(normative)

Material combinations to which the media lists for rubber linings are applicable

B.1 Hard rubber linings (media list I)

Where a hard rubber lining is made of natural or synthetic isoprene rubber, styrene butadiene rubber or a combination of these rubber types (NR, IR, NR/IR, NR/SBR, IR/SBR or NR/IR/SBR) with a maximum content of 50 % SBR related to the total rubber content, the minimum rubber content shall be 40 % as related to the complete recipe. Hard rubber dust, carbon black or other inert fillers shall be used as additives. Vulcanisation of the completed rubber linings may be carried out under pressure or also by hot water vulcanisation, which, however, is subject to the limitations indicated in media list I.

B.2 Soft rubber linings

B.2.1 Butyl rubber, halogenated butyl rubber (media list II)

A soft rubber lining made of butyl (IIR) or halogenated butyl rubber (CIIR or BIIR) may be blended with maximum 10 % of other rubbers as related to the total rubber content. The minimum rubber content shall be 40 %, as related to the complete compound recipe. The completed, chemically resistant lining may be produced by vulcanisation using vapour or hot air, by cold bonding of pre-vulcanised or fully vulcanised sheeting or of self-vulcanising sheeting.

B.2.2 Chloroprene rubber (media list III)

A soft rubber lining made of chloroprene rubber (CR) may be blended with maximum 10 % of other rubbers, as related to the total rubber content, or with butyl or halogenated butyl rubber of any mixing ratio. The minimum rubber content shall be 40 %, as related to the complete compound recipe. The completed, chemically resistant lining may be produced by vulcanisation using vapour or hot air, by vulcanisation with a medium or by cold bonding of self-vulcanising sheeting.

B.3 Test media for the media lists

B.3.1 General

For verification of basic material suitability, immersion tests in accordance with 9.3.2 shall be carried out using the test media listed in Table B.1.

The test temperature shall be 40 °C.

Table B.1 — Test media

	Material combinations (types or rubber)	Test medium
Media list I	NR, IR, NR/IR, NR/SBR, IR/SBR, NR/IR/SBR	Sulphuric acid solution 60 % Sodium hydroxide solution 50 %
Media list II	IIR, CIIR, BIIR (< 10 % of other rubber types relative to the total rubber content)	Sulphuric acid solution 70 % Sodium hydroxide solution 50 %
Media list III	CR (< 10 % of other rubber types or any amount of butyl rubber relative to the total rubber content)	Sulphuric acid solution 60 % Sodium hydroxide solution 50 %

B.3.2 Media lists

The following media lists include aqueous, technically pure, but water pollutant liquids which may be stored up to a temperature of 40 °C, provided that no limitations are specified in the list. Where no limitation of the concentration is indicated, any possible concentration shall be permitted.

Table B.2 — Media list I (for hard rubber linings)

Group	Liquids
1	Aqueous solutions of non-oxidizing inorganic salts (pH 6-8)
2	Inorganic lyes and alkaline inorganic salts in aqueous solution (pH > 8), with the exception of ammonia solutions and oxidizing salt solutions (e.g. hypochlorite)
3	Aqueous solutions of acidic non-oxidizing inorganic salts (pH < 6)
4a	Hydrochloric acid ≤ 35 %
4b	Hydrochloric acid ≤ 37 % up to 30 °C maximum storage temperature
5	Sulphuric acid ≤ 50 % Sulphuric acid ≤ 60 %[a]
6	Phosphoric acid
7	Hexafluorosilicic acid ≤ 30 % Hexafluorosilicic acid of any concentration[a]
8	Chlorine water, max. 0,5 % free Cl_2
9	Chlorine bleaching (NaOCl and KOCl active chlorine ≤ 80 g Cl_2/l), up to 30 °C maximum storage temperature
10	Ammonia solutions ≤ 25 %, up to 25 °C maximum storage temperature
11	Formic acid ≤ 10 % as well as aqueous formate solutions
12	Acetic acid ≤ 10 % as well as aqueous acetate solutions
13	Monovalent and polyvalent alcohol and their aqueous solutions, unless they are classified as flammable, highly flammable or extremely flammable

[a] To be used only for pressure vulcanising, not for hot water vulcanising.

Table B.3 — Media list II (for butyl rubber, halogenated butyl rubber)

Group	Liquids
1	Aqueous solutions of non-oxidizing inorganic salts (pH 6-8)
2	Inorganic lye as well as alkaline inorganic salts in aqueous solution (pH > 8), with the exception of ammonia solutions and oxidizing salt solutions (e.g. hypochlorite)
3	Aqueous solutions of acidic non-oxidizing inorganic salts (pH < 6)
4	Hydrochloric acid ≤ 30 %, up to 25 °C maximum storage temperature
5	Sulphuric acid ≤ 70 %
6	Phosphoric acid
7a	Hexafluorosilicic acid ≤ 30 %
7b	Hexafluorosilicic acid ≤ 40 %, up to 30 °C maximum storage temperature
8	Hydrofluoric acid ≤ 10 %
9	Ammonia solutions ≤ 25 %, up to 25 °C maximum storage temperature

Table B.4 — Media list II (for chloroprene rubber)

Group	Liquids
1	Aqueous solutions of non-oxidizing inorganic salts (pH 6-8)
2	Inorganic lye as well as alkaline inorganic salts in aqueous solution (pH > 8), with the exception of ammonia solutions and oxidizing salt solutions (e.g. hypochlorite)
3	Aqueous solutions of acidic non-oxidizing inorganic salts (pH < 6)
4	Sulphuric acid ≤ 60 %
5	Phosphoric acid
6	Hexafluorosilicic acid ≤ 40 %, up to 30 °C maximum storage temperature
7	Hydrofluoric acid ≤ 10 %
8	Ammonia solutions ≤ 25 %, up to 25 °C maximum storage temperature

Annex C
(normative)

Test fluid groups for verification of suitability for material/media combinations

Table C.1 applies to thermoplastic linings.

Table C.1 — Test fluid groups for verification of suitability for material/media combinations

No	Group	Test fluid
1[a]	Petrol according to EN 228 with a maximum alcohol content of 5 %	47.5 vol.-% toluene, 30.4 vol.-% isooctane (2,2,4-trimethylpentane) 17.1 vol.-% n-heptane 3.0 vol.-% methanol 2.0 vol.-% tert. butanol
1a[a]	Petrol according to EN 228 with a maximum alcohol content of 20 % (including 1)	42.3 vol.-% toluene, 25.3 vol.-% isooctane (2,2,4-trimethylpentane) 12.7 vol.-% diisobutylene 4.2 vol.-% ethanol 15.0 vol.-% methanol 0.5 vol.-% water
2[b]	Aviation fuels	a) Aviation fuel 100 LL b) 50 vol.-% toluene, 30 vol.-% isooctane (2,2,4-trimethylpentane) 15 vol.-% diisobutylene 5 vol.-% ethanol c) Aviation turbine fuel Jet-A1 with additives (Nato-Code F-34)
3	Heating fuel oil EL unused combustion engine oils, unused vehicle gear oils, aliphatic and aromatic hydrocarbons with an aromatic content of ≤ 20 wt.-% and a flash point of > 55 °C	80 vol.-% Diesel fuel according to EN 590 20 vol.-% 1-methylnaphthalene
3a[c]	Diesel fuel according to EN 590 with a maximum content of 5 % Biodiesel (including 3)	76 vol.-% Diesel fuel according to EN 590 19 vol.-% 1-methylnaphthalene 5 vol.-% Rape-oil fatty acid methyl ester (RME)
3b[c]	Diesel fuel according to EN 590 with a maximum content of 20 % Biodiesel (including 3 and 3a)	64 vol.-% Diesel fuel according to EN 590 16 vol.-% 1-methylnaphthalene 20 vol.-% Rape-oil fatty acid methyl ester (RME)
4	Raw oils	10.0 wt.-% Iso-octane 10.0 wt.-% toluene 20.0 wt.-% heating fuel oil EL 10.0 wt.-% 1-methyl naphthalene (min. 96 %) 47.7 wt.-% heating fuel oil S 0.2 wt.-% thiophene (99 %) 0.3 wt.-% dibenzene sulfide 0.5 wt.-% dibutyl disulfide (97 %) 1.0 wt.-% naphthalic acid mixture (acid factor 230) 0.1 wt.-% phenol 0.2 wt.-% pyridine Mixed with 2.0 wt.-% water
5[d]	All hydrocarbons including benzene and benzene mixtures	30 vol.-% benzene, 30 vol.-% toluene, 30 vol.-% xylene, 10 vol.-% methyl naphthalene

Table C.1 (*continued*)

No	Group	Test fluid
5a[e]	All hydrocarbons as well as used combustion engine oils and used vehicle gear oils with the exception of raw oils, benzene and benzene mixtures	60 vol.-% toluene, 30 vol.-% xylol, 10 vol.-% methyl naphthalene
5b	— Used combustion engine oils and — used vehicle gear oils with a flash point > 55 °C	80.0 wt.-% motor oil based on mineral oil 10.0 wt.-% toluene 9.9 wt.-% water 0.1 wt.-% anionic tenside sodium dodecylsulfate
6a	Aliphatic halogen hydrocarbons ≥ C_2	trichlorethylene
6b	Aromatic halogen hydrocarbons	monochlorobenzene
7	All alcohols and glycol ethers (including 7a)	methanol
7a	Single and multiple value alcohols (up to max. 48 vol.-% methanol), glycol ether (including 7b)	48 vol.-% methanol, 48 vol.-% isopropanol, 4 vol.-% water
7b	Alcohol ≥ C_2	48 vol.-% ethanol 48 vol.-% isopropanol 04 vol.-% water
8[f]	All organic esters and ketone (including 8a and 8b)	50 vol.-% ethyl acetate 50 vol.-% methylisobutylketone
8a	Aromatic ester and ketone	50 vol.-% methyl salicylate 50 vol.-% acetophenon
8b	Biodiesel	Rape-oil fatty acid methyl ester (RME) (summer quality)
9	Aliphatic aldehydes and their aqueous solutions (incl. 9a)	50 vol.-% n-butyl aldehyde (Butanal) 50 Vol.-% n-heptaldehyde (Heptanal)
9a	Aqueous solutions of aliphatic aldehydes up to 40 %	35 - 40 % commercially available aqueous formaldehyde solution
10	Cyclic and acyclic ether (including 10a)	tetrahydrofurane (THF)
10a	Acyclic ether	diethyl ether
11	Amines and their salts (in aqueous solution)	35 vol.-% triethanolamine 30 vol.-% n-butylamine 35 vol.-% N, N-dimethylaniline
12[g]	Organic acids (carboxylic acids, except formic acid) and their salts (in aqueous solution)	50 vol.-% acetic acid 50 vol.-% propionic acid
12a[g]	Aqueous solutions of organic acids (carboxylic acids) to 10 % as well as their salts (in aqueous solution)	10 weight-% aqueous acetic acid
13[g]	Mineral acids up to 20 % as well as acetic hydrolysing inorganic salts in aqueous solution (pH < 6), except hydrofluoric acid and oxidizing acids and their salts	Sulphuric acid (20 %) Hydrochloric acid (20 %) should be used for testing inside linings of containers
14[g]	Inorganic lies as well as alkaline hydrolysing inorganic salts in aqueous solution (pH > 8), except ammonia solutions and oxidizing salt solutions (e.g. hypochlorite)	Sodium hydroxide (20 %) Sodium hydroxide (1 %) should be used additionally for testing inside linings of containers
15[g]	Aqueous solutions of inorganic non-oxidizing salts with a pH value between 6 and 8	aqueous sodium chloride solution (20 %)
16	Aqueous solutions of organic tensides	3 % solution of sodium laurylether sulphate $[C_{12}H_{25}\text{-}O\text{-}[(CH_2)_n\text{-}O]_m\text{-}SO_3]Na$ and sodium chloride in water 2 % of a fluid consisting of about 99 wt. % of a fat alcohol polyglycol ether $R\text{-}O(CH_2CH_2O)_nH$ (ethoxylation factor $n \approx 8$; as a mean value) in addition to small quantities of polymerised ethylene oxide (≤ 1 wt. %) 95 % water

Table C.1 (*continued*)

[a] Proof of suitability for group 1 is considered provided if tests with the test fluids of groups 5a or 5 and 7a or 7 have been passed.

[b] The tests shall be made with all test fluids. The suitability is only considered proven for this medium when testing only takes place with one test fluid.

[c] If the tests with groups 3 and 8 or 8b have been passed, the suitability for groups 3a and 3b applies additionally.

[d] Suitability for groups 2, 3, 3a, 4, 5a and 5b applies additionally providing the test with test fluid of group 5 has been passed.

[e] Suitability for groups 2, 3, 3a and 5b applies additionally providing the test with test fluid of group 5a has been passed.

[f] A test shall be made with the pure substance for acetone for load grade 6.

[g] Proceed as follows regarding practical testing if higher concentrations are to be permitted than specified in the groups:

a) If the tests with groups 12 and 12a have been passed, the suitability for all concentrations of organic acids (carboxylic acids) in aqueous solution, except for formic acid > 10 % applies additionally.

b) For mineral acids of group 13 testing should take place within the scope of the suitability test on the one hand with the appropriate test fluid of the group and on the other hand with the maximum concentration desired by the applicant. As a result, this mineral acid is covered up to the tested maximum concentration but all other mineral acids belonging to the group only up to the concentration limit of the test fluid of the group.

c) Proof of suitability for group 15 is also considered provided if the tests with the test fluids of groups 13 and 14 have a positive outcome.

Annex D
(normative)

Testing the dissipating capability

D.1 Principle

D.1.1 Dissipation resistance

The dissipation resistance shall be measured on test specimens between a circular electrode of 50 mm diameter on the upper surface of a specimen and the earthing strip integrated in the conductive layer.

D.1.2 Dissipation resistance to earth

The dissipation resistance to earth shall be measured between a circular electrode of 50 mm diameter placed on the lining and the ground.

D.2 Testing of dissipation resistance of test samples

D.2.1 Test equipment

— Resistance measuring device in accordance with IEC 60093 with 100 V DC;

— Climate cabinet for conditioning of the specimens;

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

— Blotting paper or conductive rubber foil in accordance with 7.7 of IEC 60093:1980, with 50 mm diameter.

D.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 °C ± 2 °C.

A blotting paper moistened with tap water or a foil of flexible conductive rubber with a diameter of 50 mm should be placed on the surface of the specimen 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 band whereby the measuring positions shall be selected so that they are as far as possible away from the ground connection band.

D.2.3 Test report

The test report shall include the following information:

— number of this standard;

— type of lining;

— material;

— manufacturer;

— colour;

— thickness of lining;

— dissipation resistance, single and mean value;

— conditions during conditioning;

— date of testing.

D.3 Measurement of dissipation resistance to earth on the completely applied lining

D.3.1 Test equipment

See D.2.1, as well as equipment for temperature and relative humidity.

D.3.2 Preparation of the lining

Prior to testing, the lining shall be rubbed down with a dry cloth at the measuring point.

D.3.3 Procedure

Measurements can be carried out 4 weeks after the lining has been applied, at the earliest.

The blotting paper moistened with tap water or the flexible conductive rubber foil 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.

The number of measurements shall be selected in accordance with Table D.1.

Table D.1 — Number of measurements of dissipation resistance to earth

Area of the applied lining	Number of measurements
< 10 m^2	1 measurement/1 m^2
10 m^2 to 100 m^2	10 to 20 measurements
> 100 m^2	10 measurements/100 m^2

D.3.4 Test report

The test report shall include the following information:

— number of this standard;

— type of lining;

— material;

— manufacturer;

— colour;

— thickness of lining;

— date of application of the lining;

— place and location of the lining;

— temperature and relative humidity;

— number of measuring points;

— dissipation resistance to earth at each measuring point, in Ohm;

— true-to-scale representation showing the measuring points and the respective results of measurement;

— description of the substrate;

— deviations from this standard;

— date of testing.

Annex E
(informative)

Sample form for acceptance inspection report

The copyright statement on page 1 prohibiting reproduction of any part of this standard does not apply to the following specimen form.

Acceptance inspection report for lined metallic parts	
Client:	Order No.:
Project:	
Type of plant part:	
Type of lining:	
Tests	Test results
A. Checks prior to application	
1. Visual check of surface	
B. In-process checks	
1. Ambient temperatures and humidity	
2. Checking application steps	
C. Checks after completion of application	
1. Ambient conditions	Ambient temperature: _____ Surface temperature: _____ Relative humidity: _____
2. Visual check	
3. Lining thickness	
Nominal value: _____ mm	Actual value: _____ mm
4. Checking for defects	
Type of equipment used:	
Test voltage: _____ kV	
D. Testing carried out on test panels	
1. Shore/Barcol hardness:	
Type of equipment used: _____	
Nominal value: _____ Shore A/Shore D/Barcol	Actual value: _____ Shore A/Shore D/Barcol
2. Adhesion test:	
Equipment used: _____	
Nominal value: _____ N/mm^2	Actual value: _____ N/mm^2
Comments:	

Test site:					
Date					

Annex F
(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 EC.

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 EN 14789-4 — 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 linings for containers and pipes and for linings which are used for other facilities in plants for the storage, filling and loading/unloading of water-hazardous substances.

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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[3] EN ISO 2360, *Non-conductive coatings on non-magnetic electrically conductive basis materials - Measurement of coating thickness - Amplitude-sensitive eddy current method (ISO 2360:2003)*

[4] EN ISO 1043-1*, Plastics — Symbols and abbreviated terms — Part 1: Basic polymers and their special characteristics (ISO 1043-1:2001)*

[5] ISO 1629, *Rubber and latices — Nomenclature*

[6] ISO 4433 (series), *Thermoplastics pipes — Resistance to liquid chemicals — Classification*

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