

DEP SPECIFICATION

**DESIGN AND INSTALLATION OF CHEMICAL-RESISTANT
BRICK LINING FOR PROCESS EQUIPMENT
(BASED ON EN 14879-PARTS 1, 4 AND 6)**

DEP 30.48.60.13-Gen.

September 2012

DESIGN AND ENGINEERING PRACTICE



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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the design, installation, testing and inspection of chemical-resistant brick linings for process equipment in combination with sealer layers (if required) according to EN 14879 Parts 1, 4 and 6. For the design and installation of chemical-resistant protection systems on concrete structures, reference is made to DEP 30.48.60.12-Gen.

All clauses of EN 14879-parts 1, 4 and 6 not modified by this DEP Specification remain valid as written. This DEP Specification is not applicable for use in North America, but should be used as basis for developing a project specification.

For rubber linings, reference is made to DEP 30.48.60.10-Gen. For the use of paint systems and similar protecting systems or standard coatings and for the specific requirements for the preparation of steel surfaces, reference is made to DEP 30.48.00.31-Gen and EN 14879-2.

Lead sealing layers are not covered by this DEP Specification. If required the Manufacturer shall be involved for developing a project specification. For support DIN 28058 – Part 1 and Part 2 should be used.

This DEP does not provide detailed specifications for every possible chemical attack. Each piece of process equipment shall be looked at individually. The Contractor shall provide per piece of equipment, design and installation details in close consultation with the Manufacturer and the Applicator. The results shall be submitted to the Principal for review.

This DEP is a revision of the DEP of the same title and number dated April 2003. A summary of changes from the previous edition is given in (1.5).

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

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This DEP is intended for use in facilities related to oil and gas production, gas handling, oil refining, chemical processing, gasification, distribution and supply/marketing. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases, the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Terms and technical definitions are given in:

- EN 14879-1, Section 3
- EN 14879-4, Section 3
- EN 14879-6, Section 3

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets (). Other documents referenced by this DEP are listed in (11).

Informative publications are listed in the Bibliography (12).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same title and number dated April 2003. There have been significant editorial and technical changes in this edition and they are too numerous to list here. This DEP is now based on EN 14879 Parts 1, 4 and 6. DIN 28062 has been withdrawn and replaced by EN 14879–6.

1.6 COMMENTS ON THIS DEP

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For the last two options, the completed DEP Feedback Form can be attached to an email and submitted to the Administrator at standards@shell.com. Only feedback that is entered into the Feedback Form will be considered.

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

2. SELECTION CRITERIA

2.1 GENERAL

A chemical-resistant brick lining is selected for the internal protection of process equipment (e.g., vessels, columns and tanks) against corrosive attack. It is a multilayer system supported by a shell to provide rigidity and strength, and shall incorporate an impervious sealing layer to prevent the corrosive medium from contacting the internal shell, along with one or more layers of chemical-resistant bricks laid in a chemical-resistant mortar.

The brick lining acts primarily as a corrosion barrier in direct contact with the process fluid. In practice, the lining may also act as a heat barrier. In that case, DEP 44.24.90.31-Gen. shall be consulted.

A typical brick lining composition is shown in Figure 1 of EN 14879-6.

Brick linings are susceptible to crack formation because of the low tensile strength of ceramic materials, the low bond strength between the mortar and bricks, and the greater thermal expansion of the steel compared with the brick lining. Any crack in the brick lining will allow penetration of the corrosive medium through the lining, and can result in corrosion being sustained. As an additional protection against corrosion, a corrosion-resistant and impervious sealing layer is usually placed between the vessel wall and the brick lining. The Contractor shall take this into account and shall base the design and installation on the above-mentioned weak point of materials. EN 14879-4 and EN 14879-6 shall be applied for design and installation.

The chemical-resistant brick lining shall be installed by experienced Applicators to ensure that good workmanship is achieved. The Contractor shall be responsible for the complete system, i.e., the brick lining plus the sealing layer, including all detailed design, engineering aspects and installation.

2.2 SELECTION CRITERIA

The selection criteria for chemical-resistant brick linings for process equipment (excluding concrete) shall be based on:

EN 14879-1	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 14879-4	Organic coating systems and linings for protection of industrial apparatus ad plants against corrosion caused by aggressive media - Part 4: Linings on metallic components.
EN 14879-6	Organic coating systems and linings for protection of industrial apparatus ad plants against corrosion caused by aggressive media - Part 6: Combined linings with tile and brick layers

Especially, the following selection criteria shall be taken into account:

- Type and frequency of fluid loading;
- Thermal loading;
- Changes in operation temperature;
- Mechanical loading;
- Weather factor (if applicable).

The selection criteria shall be as such that the most economical and maintenance-free brick lining and sealer layer (if required) shall be obtained. The Contractor shall prove the most economical and maintenance-free system, and submit for review to the Principal.

The selection of the chemical resistant protection system shall be based on the criteria as mentioned:

- EN 14879-1
- EN 14879-4
- EN 14879-6

The requirements of the process equipment surfaces shall comply with DEP 30.48.00.31-Gen.

3. CHEMICAL-RESISTANT LINING MATERIALS

3.1 GENERAL

The various components of a chemical-resistant brick lining are specified in EN 14879-4 and EN 14879-6. The design properties of chemical resistant lining materials shall also be verified on the basis of the material specifications of the Manufacturers. For specifications on rubber linings, see DEP 30.48.60.10-Gen. and DEP 30.10.02.13-Gen.

Materials typically used as sealing layer are indicated in EN 14879-4.

3.2 SEALING LAYER

3.2.1 General

A continuous and impervious sealing layer shall be used. If no suitable impervious sealing layer is available, a brick lining may only be selected provided that there is convincing evidence that a crack-free lining can be applied and maintained, e.g., by pre-stressed brick lining.

Sealing layers shall be taken into account in heat transfer or stress calculations (5.1).

Materials used for sealing layers in process equipment are given in EN 14879-4.

For further comparison of the chemical resistance between the materials, reference may also be made to EN 14879-5.

3.2.2 Rubber sealing layers

Requirements for rubber linings and design and installation of rubber-lined process equipment, piping and concrete structures are given in DEP 30.48.60.10-Gen.

3.2.3 Thermoplastic sealing layers

Thermoplastic sealing layer materials, such as polyisobutylene (PIB), may be used for new equipment as long as the Contractor is aware that most of PIB materials are generally too rigid to accommodate irregularities in the vessel wall.

If possible, these sealing layers shall be adhesively bonded to the substrate; and the joints shall be welded (6.2.3). The selection of a suitable adhesive depends on the type and condition of the substrate and also on the operating temperature range. Cold adhesives may be used. No vulcanisation is required.

The maximum allowable operating temperature is 70 °C (160 °F).

The minimum thickness shall be 3 mm (1/8 in).

3.2.4 Thermosetting sealing layers

For specific chemical conditions, GRP (i.e., glass-fibre reinforced epoxy, vinyl-ester, polyester and furan) may be used.

The selection of type and quality of the resin shall be based on suitable commercial grades that comply with the technical requirements for the application. The recommendations of the resin Manufacturers for the use of hardeners, catalysts and accelerators shall be followed.

The minimum thickness of the GRP sealing layer shall be 3 mm (1/8 in).

3.2.5 Testing criteria for sealing layers

Detailed test criteria shall be obtained from EN 14879-4 and EN 14879-6.

3.3 CHEMICAL-RESISTANT MORTARS

3.3.1 General

Mortars shall be selected among others things on their basis of chemical resistance. The Contractor shall base his choice on EN 14879-6.

3.3.2 Silicate-based mortars

Reference is made to EN 14879-6. If contact with sulphuric acid is expected, potassium-silicate-based mortar is preferred to sodium-silicate-based mortar.

Silicate-based mortars shall not be used if $\text{pH} > 5$ (as indicated in Table 1 of EN 14879-6).

Silicate-based mortars have only slight resistance to erosion, especially from flowing hot water, steam or alkalis. Washing out of mortar from the joints may occur. For these services, the use of other types of mortar, mainly synthetic resin-based mortars, shall be considered.

A properly mixed fresh mortar reacts readily and cures even when air is excluded.

Silicate mortars can be used up to about 900 °C (1652 °F).

Halogen-free silicate-based mortars are the present industrial standard. Halogen-containing, silicate-based mortars are not allowed anymore. The Contractor shall request the Manufacturer to verify the properties.

3.3.3 Synthetic resin-based mortars

3.3.3.1 General

Synthetic resin-based mortars are commonly used for the construction of acid-resistant brick linings. They cure as a result of a chemical reaction between the synthetic resin and a curing agent. They adhere very well to a rubber sealing layer. Various types of synthetic resin-based mortars are described in more detail below.

3.3.3.2 Phenol-furfuraldehyde resin

Modified phenolic-resin-based mortars have been developed to cover a wider range than pure phenol-formaldehyde resin or furane resin mortars. They provide excellent resistance to both acidic and alkaline conditions and have good resistance to mildly oxidizing solutions.

These mortars, when properly applied, are erosion resistant and free of pores. They can be used both as a sealing layer and for embedding and sealing the joints between bricks or tiles.

These mortars consist of phenol-formaldehyde resin and furane derivatives with inert filler. They are supplied as two components: a liquid resin solution and an inert powder (both of which also contain part of the reactive agent). The liquid solution and inert powder shall be thoroughly mixed together.

If resistance to hydrofluoric acid is required, only graphite shall be used as filler.

Generally, for optimal chemical resistance, curing shall be conducted for one week at 15 °C (59 °F) to 20 °C (68 °F). The Contractor shall ensure that mortars are fully cured. The Manufacturer shall define the time lapse between application and curing. In order to give the mortar its full chemical resistance, it shall be given a heat treatment at 80 °C (176 °F) for 24 h after it has fully cured.

The maximum operating temperature of these mortars is 140 °C (284 °F). The Contractor shall request the Manufacturer to verify the properties.

3.3.3.3 Furane resin

Furane resin-based mortars have similar properties to mortars based on phenol resin. They are erosion resistant and free of pores.

These mortars are supplied as two components (a powder and a liquid) and the mortar has excellent adhesive qualities. It cures at 15 °C (59 °F) to 20 °C (68 °F) in about 3 days. Optimum chemical resistance can be obtained by heating at 80 °C (176 °F) for at least 16 h after application.

Furane resin-based mortars have good chemical resistance and, with graphite filler, resistance against hydrofluoric acid can also be obtained.

The maximum operating temperature of furane resin-based mortar is approximately 140 °C (284 °F). The Contractor shall request the Manufacturer verify and ensure the properties and required application.

3.3.3.4 Polyester resin

Polyester resin-based mortars have a good chemical and erosion resistance. The pot life of polyester resin-based mortars is rather short and influenced significantly by the temperature. The Contractor shall provide, therefore, a detailed method statement for application.

Mortars based on (unsaturated) polyester resin are supplied in two or more components, i.e., liquid resin, catalyst, accelerator, filler, etc., which shall be mixed together. The mortar is self-curing between 15 °C (59 °F) to 20 °C (68 °F), and at this temperature, a complete cure can be obtained in 24 hours. However, for optimum chemical resistance, a longer curing period is recommended.

The addition of inert fillers such as graphite may extend its resistance even to hydrofluoric acid, while resistance against alkalis may also increase.

The maximum operating temperature limit of polyester resin-based mortars is 120 °C (248 °F). The Contractor shall request the Manufacturer to verify and ensure the properties and required application.

3.3.3.5 Epoxy resin

Epoxy resin-based mortars have very good chemical resistance. If filler such as graphite is added, resistance to hydrofluoric acid is also obtained. Epoxy resin-based mortars also have very good adhesion. Apart from proper surface cleaning, the substrate needs no further pre-treatment.

Mortars based on epoxy resin are supplied in two or more components. Curing starts immediately after mixing, and the rate of curing is influenced by the ambient temperature.

Properties will vary according to the various curing agents used. The curing agent generally used is a cold-curing type, which limits the maximum operating temperature but facilitates processing.

In metallic process equipment, these mortars can be used as sealing layers, with an optional, glass-fibre reinforcement.

The maximum operating temperature of epoxy resin-based mortars is 60 °C (140 °F) for "cold-cured" systems. The Contractor shall request the Manufacturer verify and ensure the properties and required application.

3.4 CERAMIC LINING MATERIALS

3.4.1 General

Bricks and tiles manufactured to standard dimensions should be used whenever possible to avoid additional costs. If special shapes are used, detailed drawings shall be made to indicate their position in the lining.

Radial bricks are required if the width of the side joint at the back of the standard brick is greater than 1.5 times the joint width at the front (6.3.2).

Console bricks are sometimes used in the inner courses of bricks to support internals.

The bricks and tiles shall have a roughened surface and, to ensure good adhesion to the cement, shall not be glazed.

Mechanical and physical properties of various chemical-resistant lining materials are given in EN 14879-6 and the Contractor shall request the Manufacturer to verify and ensure the properties and required application.

Porous bricks offer low resistance to penetration of liquids and/or gases. They have low thermal conductivity and good thermal shock resistance. Porosity should be considered, particularly if crystallising liquids are present where there is a potential danger of volume change destroying the brick. Due to the low thermal conductivity, high thermal gradients can occur in the bricks. Temperature shock(s) can lead to fracture.

The erosion resistance of the bricks and tiles shall also be considered; see EN 14879- 6.

Most brick and tile materials have good resistance to organic chemicals, so their resistance to inorganic chemicals often governs the final selection.

3.4.2 Acid-resistant bricks and tiles

Silica-alumina acid-resistant bricks with a maximum apparent porosity of 5 %, as specified in EN 14879-6, are widely used in chemical-resistant brick linings. Higher apparent porosity, e.g., 12 %, will result in increased thermal shock resistance but reduced chemical resistance.

Small variations in the chemical composition of the bricks can produce significant changes in their chemical resistance and mechanical properties. For example, enhanced properties are achieved by the addition of oxides of iron, titanium, magnesium, potassium and sodium. The Al_2O_3 content, which generally varies between 15 % and 30 %, can be used to vary the acid-resistance of the bricks. In some countries, e.g., the USA and UK, less acid-resistant bricks are produced containing more than 30 % Al_2O_3 , but the Al_2O_3 content may be reduced to below 10 % where increased acid-resistance is required.

Further control of the mechanical and chemical properties of the bricks can be achieved by varying the firing times and temperatures used to control the ratio of glassy to crystalline phases in the bricks, or alternatively, by varying the structure and distribution of the grains of the constituent materials. For example, acid-resistant bricks with an apparent porosity of 5 % can resist all acids except hydrogen fluoride and alkalis up to concentrations of 20 % weight at room temperature. Carbon or graphite bricks, or porcelain tiles are required for resistance to higher concentrations of alkali. The Contractor shall request the Manufacturer verify and ensure the properties and required application.

3.4.3 Special ceramic lining materials

For very corrosive and erosive services, including use at high temperatures, it may be necessary to select special ceramic lining materials.

These ceramic lining materials are mainly based on:

- sintered alumina ($\text{Al}_2\text{O}_3 > 80 \%$); or,
- silicon carbide (SiC); or,
- silicon nitride (Si_3N_4).

3.5 CARBON AND GRAPHITE MATERIALS

Carbon bricks are made from synthetic carbon.

In non-oxidizing atmospheres, carbon and graphite can be used up to high temperatures and their chemical resistance is excellent. Carbon bricks are generally available in two qualities, either with an ash content of about 6 % or with ash content below 1 %. The latter shall be used when the process liquid contains hydrogen fluoride, fluorine-containing products or strong alkalis.