

DESIGN AND INSTALLATION OF CHEMICAL-RESISTANT BRICK LINING FOR PROCESS EQUIPMENT

DEP 30.48.60.13-Gen.

April 2003

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. For the design and installation of chemical-resistant linings on concrete structures, reference is made to DEP 30.48.60.12-Gen.

Excluded from the scope of this DEP is the subject of (acid-resistant) refractory bricks and shapes, for which reference is made to DEP 44.24.90.31-Gen. 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.

This DEP does not provide detailed specifications for every possible chemical attack. Each piece of process equipment shall be looked at individually and based on these minimum requirements; details shall be agreed between the Principal, the Contractor, the Manufacturer and the Applicator.

This DEP is a revision of the DEP of the same title and number dated December 1995. A summary of changes from the previous edition is given in (1.5).

NOTE: In various places in this DEP specific brands of products are named. It is not intended to preclude the use of other products; equivalent products may be used provided the Principal so approves.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI and SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group, and to Contractors nominated by them (i.e. the distribution code is "C", as defined in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, gas plants, and, where applicable, in supply/marketing installations and exploration and production facilities. When DEPs are applied, a Management of Change (MOC) process should 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 may 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 as regards 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 with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

For the purpose of this DEP, the following definitions shall hold:

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 its design and construction. The Principal will generally specify the technical requirements. 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

The **Applicator** is the party that applies the chemical-resistant linings specified by the Contractor.

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 (12).

1.5 CHANGES FROM PREVIOUS EDITION

The previous edition of this DEP was dated December 1995. Other than editorial changes, the following are the main changes since that edition:

Old section	New Section	Change
All	All	Figures and Tables moved from Appendices to text.
1.1	1.1	Scope of the DEP updated.
3.2.1	3.2.2	Coding of rubber membranes revised.
Appendix 4	Table 3-1	Maximum operating temperatures updated; statement added regarding materials typically used as membranes.
Appendix 3	Table 3-2	Porcelain tiles deleted; Reference to DEP 30.48.70.30-Gen. added.
3.2.3	3.2.3	Statement added regarding the use of polyisobutylene.
3.2.5	3.2.5	Statement added about the use of lead membranes and cold-flow behaviour.
3.3.3	3.3.3	Maximum operating temperatures lowered for synthetic resin-based mortar to bring them in line with DEP 30.48.60.12-Gen.
3.4.1	3.4.1	Thermal conductivity changed from "high" to "low".
3.4.3	-	Section on porcelain tiles deleted.
3.4.4	3.5	Section re-numbered.
3.5	3.6	Section re-numbered.
4.2	4.2	Maximum deflection due to wind revised.
4.2	4.2	Rule of thumb added for brick lining thickness.
5.3	5.3	Text revised and Figure 5-2; removed reference to Standard Drawing S 10.112.
5.4	5.4	Statement on the disadvantage of raising the temperature of steel shell during application of the brick lining added. Also added that it is common practice to maintain the vessel at or above ambient daytime air temperature.
5.5	5.5	Statement added that brick-line equipment should preferably be heated and pressurized under controlled conditions.
6.2.2	6.2.2	Statement added that only homogeneously leaded membranes shall be used.
6.2.3	6.2.3	Statement added that attention should be given to the possible cold-flow behaviour of thermoplastic membranes. Detailed installation description deleted.
6.2.4	6.2.4	Updated reference to GRP DEP 31.22.30.14-Gen.
6.3.2	6.3.2	Emphasis added on preventing inclusion of air pockets by cutoff beards.
-	9	New section added on Quality Control.
9	10	Test pressures for brick-lined equipment shall be limited to 1:1 times the design pressure.

Old section	New Section	Change
10	11	References updated and Standard Drawings deleted.
11	12	Bibliography added.

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the DEP Administrator at standards@shell.com.

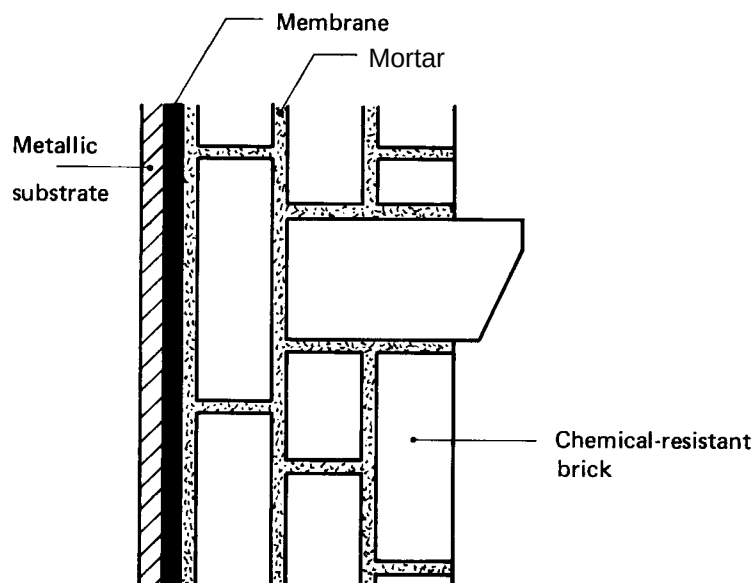
Shell staff may also post comments on this DEP on the Surface Global Network (SGN) under the Standards/DEP 30.48.60.13-Gen. folder. The DEP Administrator and DEP Author monitor these folders on a regular basis.

2. GENERAL

A chemical-resistant brick lining is used for the internal protection of process vessels, columns, tanks, etc. against corrosive attack. It is a multilayer system supported by a shell to provide rigidity and strength, and shall incorporate an impervious membrane to prevent the corrosive medium from contacting the 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. A typical brick lining composition is shown in Figure 2-1.

FIGURE 2-1 TYPICAL BRICK LINING LAYOUT AND EMBEDDING OF RING SUPPORT



A brick lining relies on each layer of brick, including every joint, being bonded to the next layer so as to form a composite structure with membrane and shell. Therefore, care shall always be taken to avoid anything that might lead to either failure of the bond between adjacent layers of brick, or to failure of the bond between the lining as a whole and the wall of the outer shell. Although bricks and mortars are permeable to some extent, the perfect chemical-resistant brick lining prevents corrosion because, in such a lining, there is complete stagnation in the pores, so that the corrosive medium cannot be refreshed and is thus rapidly exhausted.

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 may result in corrosion being sustained. As an additional protection against corrosion, a corrosion-resistant and impervious membrane is usually placed between the vessel wall and the brick lining.

The chemical-resistant brick lining should be constructed by experienced Applicators to ensure that good workmanship is achieved. A specialised brick-lining Contractor should be responsible for the complete system, i.e., the brick lining plus the membrane, including all detailed design and engineering aspects.

3. CHEMICAL-RESISTANT LINING MATERIALS

3.1 GENERAL

The various components of a chemical-resistant brick lining are specified in the following sub-sections. Optimum corrosion protection will only be achieved if proper attention is given to the installation requirements.

Table 3-1 lists the design properties of chemical resistant lining materials and Table 3-2 lists their mechanical and physical properties. For specifications and recommendations on rubber linings, see DEP 30.48.60.10-Gen. and DEP 30.10.02.13-Gen.

Table 3-1 Typical design properties of chemical-resistant lining materials¹⁾

Item	Thickness mm	Maximum operating temperature °C	Poisson's ratio	Modulus of elasticity MPa	Thermal conductivity W/(m.K)	Thermal expansion 10 ⁻⁵ /K
Carbon steel vessel wall	10	100 ²⁾	0.33		58	1.2
Hard natural rubber (80° Shore D)	5	60	0.5	3.5	0.15	20
Soft natural rubber (65° Shore A)	5	60				
Butyl rubber	5	80				
Polyisobutylene	3	70				
Glass-fibre reinforced resin	4	60 to 110	0.3	1.2 x 10 ⁴	0.35	2.0
Lead	6	70	0.3		35	
Silicate-based mortar	5 to 10	900	0.3			
Synthetic-resin-based mortar	5 to 10	110 to 140 ³⁾	0.3			
Acid-resistant brick	65 to 76 ⁴⁾		0.3			
Carbon brick (unimpregnated)	40 to 65 ⁴⁾		0.3			
Porcelain tile	20 to 40 ⁴⁾		0.25			

- NOTES:
- 1) The given data should be considered as directional and should not be regarded as a basis for requisitions and/or purchasing.
 - 2) When a ceramic brick lining functions as a heat barrier, the minimum thickness is determined either by the maximum permissible membrane temperature, or by the steel wall temperature (maximum 100 °C), or by the maximum temperature gradient of the bricks (5.2).
 - 3) Maximum temperature may vary per type/product.
 - 4) Typical value, indicative only.

Materials typically used as membrane are:

- butyl rubber (IIR);
- fibre reinforced thermoset resins, e.g., epoxy, vinyl ester, polyester, furan and phenolic.

Table 3-2 Typical values for mechanical and physical properties

For convenience, the table below gives a summary (copied from DIN 28062) of the various materials mentioned in this DEP.

Property	Units	Acid-resistant bricks & tiles		Carbon bricks		Graphite bricks		Silicate- based mortars	Synthetic-resin-based mortars	
		Red acid-resistant	Chem.-Techn. Stoneware	Un-impregnated	Impregnated	Un-impregnated	Impregnated		Phenolic & furane	Polyester & epoxy
Bulk density	kg/m ³	1900 to 2500	2200 to 2500	1400 to 1600	1600 to 1800	1600 to 1700	1700 to 1900	1800 to 2000	1400 to 2100	1500 to 2100
Water absorption	%	4 to 10	0 to 3.0	18 to 22	0	17 to 19	0 to 10	6 to 10	0.3 to 3.0	0.1 to 0.5
Apparent porosity	max.%			18	0	20	0	12	1	1
Acid resistance	%	2.5 to 8	0.3 to 0.8	0.5 max.	0 to 10	0.5 max.	0.5 max.			
Coefficient of thermal expansion	10 ⁻⁵ /K	0.5 to 0.6	0.4 to 0.55	0.3 to 0.5	0.35 to 0.5	0.18 to 2	0.35 to 0.4	1.0 to 1.2	2.0	4.0
Specific heat	J/(kg.K)	800 to 840	750 to 840	670 to 1090	800 to 1170	670 to 1090	800 to 1170			
Thermal conductivity	W/(m.K)	0.9 to 1.3 at 300 °C	1.3 to 1.6	1.7 to 7.0	1.7 to 7.0	90 to 140	90 to 140	1.63	1.6	1.1
Compressive strength	MPa	50 to 150	100 to 500	20 to 40	90 to 110	25 to 40	80 to 100		60	60
Tensile strength	MPa			6	12	5	15		8	8
Flexural strength	MPa	10 to 20	30 to 90	25 to 35	25 to 35	10 to 20	25 to 35		15 to 29	25 to 60
Modulus of elasticity	GPa	20 to 40	45 to 60	10 to 25	10 to 25	5 to 9	9 to 16	8	8	8

NOTE: Porcelain tiles are now rarely used in the petrochemical industry. An alternative option for a brick lining in process equipment is glass-lining, as specified in DEP 30.48.70.30-Gen.

3.2 MEMBRANES

3.2.1 General

Membranes, or protective interlayers, are of prime importance for the operation and service life of a brick lining. A membrane need not necessarily be completely resistant by itself, provided the brick lining acts as a diffusion/temperature barrier and also prevents free transport and circulation of the corrosive medium to the membrane. This reduces the chance of the membrane being attacked.

A continuous and impervious membrane should be used. If no suitable impervious membrane is available, a brick lining should only be selected provided that there is convincing evidence that a crack-free lining can be applied and maintained, e.g., by pre-stressing the brick lining.

Membranes must be taken into consideration in heat transfer or stress calculations (5.1).

Materials used for membranes in process equipment are listed in Table 3-3, together with an indication of their chemical resistance to some service environments. Rubbers (3.2.2) and polyisobutylene (3.2.3) are best suited for use as membranes because they adhere well to the synthetic-resin-based cement and permit a high elastic elongation.

For further comparison of the chemical resistance between the materials, reference is made to DEP 30.10.02.13-Gen.

Table 3-3 Comparison of the Chemical resistance of various materials at 20 °C

	Hydrocarbons			Mineral oils	Alcohols	Ketones	Phenols	Alkalis	Esters	Sulphates	Chlorides	Other salts	Water			Ammonia liquid 25 %	Hydrochloric acid 35 %	Sulphuric acid 98 %	Nitric acid 25%	Hydrofluoric acid 50 %
	Aliphatic	Aromatic	Chlorinated										Sea	Brackish	Potable					
Protective membranes:																				
Hard natural rubber	(+)	-	-	-	+	-	-	(+)	(+)	+	+	+	+	+	+	+	+	+	-	+ ³⁾
Polyisobutylene sheet	+	-	-	-	+	(+)	-	+	-	+	+	+	+	+	+	+	+	+	+	+
Cold-cured epoxy	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	-	+	+ ³⁾
Cements and mortars based on:																				
Phenol-furfuraldehyde resin	+	+	+	+	+	+	+	(+)	+	+	+	+	+	+	+	+	+	+	-	+ ³⁾
Phenol-formaldehyde resin	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+ ³⁾
Furane resin	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+ ³⁾
(Fibre-reinforced) Epoxy resin	+	+	-	+	+	(+)	-	+	+	+	+	+	+	+	+	+	+	-	(+)	-
(Fibre-reinforced) Polyester resin	+	+	(+)	+	+	(+)	-	(+)	+	+	+	+	+	+	+	+	+	-	(+)	(+) ³⁾
(Fibre-reinforced) Vinylester resin	(+)	-	-	+	(+)	-	-	(+)	+	+	(+)	+	(+)	(+)	(+)	(+)	(+)	-	(+)	(+)
Sodium silicate ¹⁾	+	+	+	+	+	+	+	-	+	(+)	+	(+) ²⁾	-	-	-	-	+	(+)	+	-
Potassium silicate ¹⁾	+	+	+	+	+	+	+	-	+	+	(+)	(+) ²⁾	-	-	-	-	+	+	+	-

This table should be used only as a guide. Materials should be selected in consultation with a materials specialist.

- + = Resistant
(+) = Limited Resistance
- = Not resistant

- NOTES: 1) Has a porosity between 7 % and 16 % and shall not be used as a membrane.
2) Sodium and potassium silicate cements are not resistant to ammonium fluoride or sodium bicarbonate.
3) The filler shall also be resistant.

3.2.2 Rubber membranes

A hard rubber (typically Shore D-80, method ASTM D 2240) is generally used, but soft rubber (typically Shore A, method ASTM D 2240) or a combination of a hard rubber over a soft rubber is also possible.

The minimum thickness of a rubber membrane shall be 5 mm.

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 membranes

Thermoplastic membrane materials, such as polyisobutylene, are no longer used for new equipment because most of them are generally too rigid to accommodate irregularities in the vessel wall.

These membranes 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 are generally used. No vulcanisation is required.

The maximum allowable operating temperature is 70 °C.

The minimum thickness shall be 3 mm.

3.2.4 Thermosetting membranes

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 suppliers for the use of hardeners, catalysts and accelerators shall be followed.

The minimum thickness of the GRP membrane shall be 3 mm.

3.2.5 Lead membranes

Lead linings are still used as an impervious membrane for brick linings in sulphuric acid service, particularly for sulphuric acid concentrations over 50 %.

Due to the "cold-flow" behaviour of lead, leaded membrane shall be homogeneously applied. Only for repairs shall loose panels or sleeves, adequately connected to the existing membrane, be allowed.

A homogeneous lead lining shall be applied to the steel surface in a horizontal position. The best adhesion is obtained when the steel surface has been lightly tinned. The maximum allowable temperature depends on the corrosive environment and the composition of the precoat layer.

Where lead sheets are connected to the wall by bolts, rivets or lead caps, they will sag at relatively low temperature under their own weight and eventually tear off at the supports. In this case, the maximum allowable temperature is 70 °C.

The minimum thickness shall be 6 mm.