

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE

MANUAL

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

PTS 30.48.60.13

DECEMBER 2010



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This revision of PTS **30.48.60.13 - Design and Installation of Chemical-Resistant Brick Lining for Process Equipment (December 2010, Revision 0)** has been updated to incorporate PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards.

The previous version of this PTS **30.48.60.13 (April 2003)** will be removed from PTS binder / e-repository from herein onwards.

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PREFACE

PETRONAS Technical Standards (PTS) publications reflect the views, at the time of publication, of PETRONAS OPU/Divisions.

They are based on the experience acquired during the involvement with the design, construction, operation and maintenance of processing units and facilities. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

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1. INTRODUCTION

1.1 SCOPE

This PTS 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 PTS 30.48.60.12.

Excluded from the scope of this PTS is the subject of (acid-resistant) refractory bricks and shapes, for which reference is made to PTS 44.24.90.31. For rubber linings, reference is made to PTS 30.48.60.10. 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 PTS 30.48.00.31-P.

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

NOTE: In various places in this PTS 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 PETRONAS, the distribution of this PTS is confined to companies forming part of PETRONAS, and to Contractors nominated by them.

This PTS is intended for use in oil refineries, chemical plants, gas plants, and, where applicable, in supply/marketing installations and exploration and production facilities. When PTSs 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 PTS 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 PTS 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 PTS as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

For the purpose of this PTS, 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 PTS are made, the referenced section number is shown in brackets. Other documents referenced by this PTS are listed in (11).

Informative publications are listed in (12).

1.5 CHANGES FROM PREVIOUS EDITION

The previous edition of this PTS was dated April 2003. Other than editorial changes, the following are the main changes since that edition:

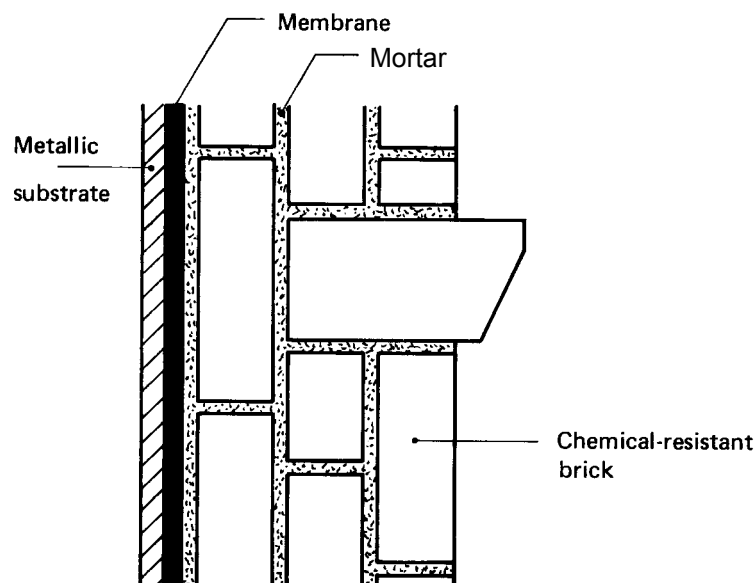
Section	Change
3.1	Reference updated to BS EN 14879-6. Table 3.2 updated to reflect BS EN 14879-6.
4.2	Reference updated to BS EN 14879-6
6.2.2	Reference updated to DIN 28058-1.
11	Reference to DIN 28060 removed. Reference updated to DIN 28058-1. Added reference to BS EN 14879-6.

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 PTS 30.48.60.10 and PTS 30.10.02.13.

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 BS EN 14879-6) of the various materials mentioned in this PTS.

Building material	Bulk density	Water absorption	Solubility in sulphuric acid	Compression strength	Bending strength	Elasticity modulus compression	Linear expansion coefficient	Heat conductivity	Max. operating temp. ^b	Resistance to cyclic temperature stresses	Wear (abrasion)
	kg/dm ³	Wt. %	Wt. %	N/mm ²	N/mm ²	10 ⁴ N/mm ²	10 ⁻⁵ K ⁻¹	W/(m • K)	°C	Quenching	cm ³ /50 cm ²
Acid-resistant bricks, tiles and shaped components	2.0 to 2.2	2 to 8	0.5 to 1.5	50 to 120	12 to 20	3.0 to 3.5	0.5 to 0.6	0.9 to 1.3 ^c	300 ^a	5 to 12	8 to 15
Industrial chemical stone-ware	2.2 to 2.4	0.2 to 3.5	0.5 to 2.5	150 to 400	30 to 60	4.5 to 6.0	0.4 to 0.5	1.3 to 1.6 ^c			4 to 12
Cast basalt	2.8 to 2.9	0	d	450 to 550	80	10 to 12	0.6 to 0.8	1.0 to 1.2			4 to 6
Natural stone	1.8 to 3.0	d	d	d	d	d	d	0.9 to 1.4		d	d
Carbon brick non-impregnated	1.4 to 1.6	18 to 22	About 0	20 to 40	8 to 12	0.5 to 1.5	0.3 to 0.4	1.7 to 7.0 ^c	150 to 180		
Carbon brick synthetic resin- impregnated	1.6 to 1.8	0 to 10 ^e	About 0	90 to 110	25 to 35	1.0 to 2.5	0.35 to 0.5	1.7 to 7.0			
Non-impregnated electro-graphite	1.6 to 1.7	17 to 19	About 0	25 to 40	10 to 20	0.5 to 0.9	0.18 to 0.2	90 to 140		300 ^a	
Synthetic resin-impregnated electro-graphite	1.7 to 1.9	0 to 10 ^e	About 0	80 to 100	25 to 35	0.9 to 1.6	0.35 to 0.4	90 to 140	150 to 180		

Note:

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

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

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

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

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

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 PTS 30.48.70.30.

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 PTS 30.10.02.13.

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 PTS 30.48.60.10.

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.

3.2.6 Testing criteria for membranes

A summary of the main requirements for the various membrane materials is given in Table 3-4.

Table 3-4 Summary of the main requirements for membranes

Requirements	Criteria - Test Method	Membrane material		
		Rubber ¹⁾ (3.2.2), (6.2.5)	Plastics (3.2.3), (3.2.4) (6.2.3), (6.2.4)	Lead (3.2.5), (6.2.2)
Visual examination	No superficial defects	x	x	x
Adhesion	No lack of adhesion when checked by careful knocking	x	x	x
Discontinuity (holiday)	No holes when tested in accordance with ASTM D 5162	x	x	x ²⁾
Thickness ³⁾	Thickness meter	x	x	x
Hardness	Shore durometer	x		
Curing	No softening after 1 minute rubbing with acetone		x ⁴⁾	

NOTES: 1) A number of tests are described in detail in PTS 30.48.60.10.

- 2) For new lead membranes the following dye-checking method shall be used instead of holiday testing:
- Apply to the surface a 30 % to 40 % wt solution of H₂SO₄ for about 2 hours;
 - Remove the H₂SO₄ residues on the surface by washing with water;
 - Apply a water wash dyed with Congo Red (benzidine pigment), which will change blue in colour if there is a reaction with H₂SO₄ residues emerging from discontinuities.

3) Only required if the substrate is magnetic.

4) Applies only to glass-fibre reinforced epoxy-resin-based membranes.

3.3 CHEMICAL-RESISTANT MORTARS

3.3.1 General

Silicate-based mortars or synthetic-resin-based mortars are commonly used to cement the bricks. Because the suitability of these mortars and bricks depends on their chemical resistance, careful selection is required and a chemical resistance test should be conducted to confirm the resistance of the selected material (Table 3-2 and Table 3-3). Erosion resistance of the mortars should also be considered.

Hydraulic cements are occasionally used for chemical-resistant brick linings in process equipment. For additional information on these cements, see PTS 30.48.60.12.

3.3.2 Silicate-based mortars

Silicate-based mortars are two component systems. They consist of a sodium or potassium silicate solution mixed with inert fillers, e.g., quartz flour. The mortar cures as silica is deposited from the alkali silicate solutions, a process that is accelerated by the presence of a catalyst, e.g., salts of fluorosilicic acid or di-methyl-formamide.

If contact with sulphuric acid is expected, potassium-silicate-based mortar is preferred to sodium-silicate-based mortar.

NOTE: Under these conditions, the sodium sulphate formed in the sodium-silicate mortar crystallizes with an increase in volume due to the release of crystallisation water. Potassium sulphate, on the other hand, crystallises without increase of volume.

Mild alkaline media may be used at ambient temperature after careful "acidulation" of the mortar (6.4.2). Alternating acid and alkaline service is not allowed.

Silicate-based mortars have only slight resistance to erosion, especially from flowing hot water, steam or alkalis, and 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.