TECHNICAL SPECIFICATION

CHEMICAL-RESISTANT (CERAMIC) LINING MATERIALS

DEP 30.48.60.33-Gen.

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DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

PREFACE

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The Hague, The Netherlands,

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

The objective is to set the recommended standard for good design and engineering practice applied by Group companies operating an oil refinery, gas handling installation, chemical plant, oil and gas production facility, or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual operating companies to adapt the information set forth in DEPs to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use DEPs they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will expect them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the DEPs. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal or its technical advisor.

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NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

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APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP provides requirements for chemical-resistant lining materials for application in both process equipment and concrete structures. It is a revision of the previous DEP of the same number dated December 1980.

It principally covers the ceramic types of lining materials (e.g., bricks, tiles and mortars) and their underlying membranes, but also covers non-ceramic linings such as synthetic resin-based systems.

Chemical resistant ceramic linings are used to protect concrete elements (such as floors and gutters) and steel process equipment (including connecting piping systems) against chemical attack. A combination of a ceramic lining and a membrane is mostly used for this purpose. The ceramic lining serves to protect the membrane against chemical, mechanical and/or thermal loads (e.g. scaffolding, steam cleaning). The membrane is to prevent penetration of chemicals to the underlying concrete or steel surface.

It is not the intention to provide in this DEP detailed material specifications for various cases of chemical attack. Each case shall be looked at individually and, based on these minimum requirements, details shall be worked out and agreed between Principal, Contractor, Manufacturer and Applicator, leading to a durable protection of concrete structures and steel process equipment against chemical attack under the particular conditions. The specified properties shall be tested in accordance with internationally accepted standards, or local standards if they exist. For convenience, specific standards are mentioned in various cases.

A summary of the mechanical and physical properties required for the various materials is given in Appendix 1.

For a comparison of the chemical resistance between the materials, reference is made to Appendix 2 and DEP 30.10.02.13-Gen.

The design and installation of chemical resistant linings for concrete structures is covered in DEP 30.48.60.12-Gen.

The design and installation of chemical resistant brick linings for process equipment is covered in DEP 30.48.60.13-Gen. and DEP 30.48.60.23-Gen.

Excluded from the scope of this DEP are rubber lining materials, for which reference is made to DEP 30.48.60.10-Gen. and DEP 30.48.60.30-Gen. **Also excluded** from the scope of this DEP are refractory bricks and shapes, for which reference is made to DEP 44.24.90.31-Gen.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIPM, the distribution of this document is confined to companies forming part of or managed by 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, supply/marketing installations and exploration and production facilities**.**

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, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this document 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 document as closely as possible.

1.3 DEFINITIONS

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

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

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction and commissioning for 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 which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which 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 the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.4 CROSS-REFERENCES

Where cross-references are made, the number of the section or sub-section referred to is shown in brackets.

All publications referred to in this document are listed in (7).

2. MATERIALS FOR MEMBRANES

2.1 GENERAL

Membranes shall be continuous, vapour tight and resistant to the chemicals to which they may become exposed.

It is stressed that the optimum properties of the membranes are achieved only when installed in accordance with the appropriate installation specifications.

2.2 ASPHALTIC BITUMEN

Asphaltic bitumen membranes not subject to mechanical load shall be made of blown bitumen, "Mexphalte " R 115/5, without filler. The dry-layer thickness shall be at least 6 mm.

Asphaltic bitumen membranes designed to sustain mechanical loads in service shall be prepared as follows:

A filler shall be made by mixing 80 parts by weight of river sand (passing a sieve opening of 2 mm or finer) and 20 parts by weight of fine quartz powder, of which at least 75% should pass a sieve opening of 75 micron or finer.

12 to 13 parts by weight of "Mexphalte" 20/30 shall be added to 100 parts of filler, the components shall then be heated to 200 °C and properly mixed.

The dry-layer thickness of this filled membrane shall be at least 20 mm.

Shell Pipe Primer shall be used if a primer is required under a membrane of asphaltic bitumen.

NOTE: Mexphalte and Shell Pipe Primer are Shell products. Alternate materials may be used subject to approval of the Principal.

2.3 THERMOPLASTICS

Almost all of the thermoplastic membranes are based on polyisobutylene. They may be used for membranes on concrete surfaces, depending on the required chemical and temperature resistance. For alternatives the Principal shall be consulted.

The polyisobutylene sheet shall meet the following requirements:

colour	: black	
thickness	: minimum 1.5	mm
density	: minimum 1.4	kg/dm^3
tensile strength	: minimum 2	N/mm^2
elongation	: minimum 300	%

2.4 THERMOSETTING MATERIALS

Resins, based on epoxy, polyurethane, furane, phenol, polyester and acrylic may be used for membranes on metallic and concrete surfaces, depending on the required chemical and temperature resistance.

Properties are dependent on the type of resin, type of filler or pigment, curing agent, curing method and the possible use of fibrous reinforcements (e.g. glass fibre). The Manufacturer shall state the composition.

In the case of membranes, no additional fillers or pigments etc. shall be used, except for those cases where a resin-based membrane is used as a final (concrete) surface finish.

2.5 LEAD

Lead may be used as a material for membranes in process equipment, in which case they should be homogeneous lead membranes. The material shall be in accordance with DIN 28062 type 3.1.

3. CHEMICAL RESISTANT CEMENTS

3.1 HYDRAULIC CEMENTS

These hydraulic cements , based on Portland clinkers, blast furnace slags or high Alumina raw materials, shall be in accordance with DEP 34.19.20.31-Gen. or internationally accepted standards:

3.2 SILICATE BASED CEMENTS

Sodium silicate, potassium silicate and silica cements shall be in accordance with DIN 28062 type 2.2.

3.3 SYNTHETIC RESIN BASED CEMENTS

These cements shall be in accordance with DIN 28062 type 2.3.

The main types are filled phenolic, furane, polyester and epoxy resin-based cements.

Furane based resins shall contain less than 1% of free furfural.

3.4 (EPOXY) PAINT SYSTEMS

Paint systems are applied where aggressive products are incidentally present, e.g. on concrete constructions in plants, chimneys, and on dry or wet floors, where chemicals may be spilled.

The properties are dependent on the type of resin, type of filler or pigment, curing agent, curing method and the possible use of fibrous reinforcements (e.g. glass fibre). The Manufacturer shall state the composition and the Principal shall be consulted .

Paint systems shall not be used for protection against continuous chemical attack, not even for mildly aggressive conditions.

4. CERAMIC AND CARBONACEOUS MATERIALS

4.1 GENERAL

Bricks and tiles shall have such a surface that optimum adhesion to the cements is obtained.

Because of the special nature of chemical resistant linings, many manufacturers have specialised in the development and engineering of dedicated ceramic and carbonaceous products and shapes in order to suit the required application. These developments resulted mostly in special catalogues, which contain a wide variety of bricks and tiles and shapes, which may vary per manufacturer, and can be consulted.

4.2 ACID RESISTANT BRICKS AND TILES

The main constituents of acid-resistant bricks and tiles are SiO_2 and Al_2O_3

Their properties are determined by:

- chemical composition (i.e. SiO_2 and Al_2O_3 and addition of special components);

  NOTE: Usually the Al_2O_3 content is between 15 and 30% by weight, but if kept below 10% by weight an improved chemical resistance will be achieved. Conversely, the chemical resistance will decrease at an Al_2O_3 content higher than 30% by weight .

- type of mineral constituents (i.e. crystalline and glassy phase);
- structure and distribution of the grains;
- porosity,
- firing/bonding temperatures.

Acid-resistant bricks and tiles (including 'Glover' bricks) shall be in accordance with DIN 28062 type 1.1.2.

Unless otherwise specified acid-resistant bricks and tiles with an apparent porosity of 5% maximum, which are resistant against all acids except hydrofluoric acid (HF), shall be used. Additionally this type of brick has a good resistance to solutions of alkalis up to 20% by weight at room temperature, but will not withstand stronger concentrations, especially under hot conditions. For such conditions, carbon or graphite bricks should be used.

In order to provide thermal shock resistance, acid-resistant bricks with a higher apparent porosity 12% maximum and less chemical resistance, such as red or blue acid-resistant bricks may be used. The use of these bricks is subject to approval of the Principal.

4.3 CARBON AND GRAPHITE BRICKS AND TILES.

Unless otherwise specified, bricks to be used shall be unimpregnated carbon or graphite bricks in accordance with DIN 28062 type 1.2.1. or type 1.2.2 respectively.

Carbon bricks with an ash content below 1% shall be used when the process liquid contains HF or strong alkalis.

Requirements for impregnated bricks and tiles and impregnated/unimpregnated graphite bricks and tiles shall be stated in the purchase order and shall be approved by the Principal.

NOTE: Carbon bricks are porous, but they can be made liquid-tight by impregnating them with synthetic resins during the manufacturing process. Impregnation does not significantly change the thermal conductivity of the material, but it does improve its strength.

4.4 SPECIAL CERAMIC LINING MATERIALS

These special ceramic bricks and cements are usually based on:

- unglazed porcelain
- sintered Alumina (Al_2O_3 > 80%)
- Silicon-Carbide (SiC)
- Silicon-Nitride (Si_3N_4)

Requirements for these products shall be in accordance with DIN 28062 and shall be stated in the purchase order, after consultation with the Principal.

5. SAMPLING, TESTING AND INSPECTION

The Manufacturer shall maintain quality control/test records. He shall submit a record of inspection and testing together with a statement of compliance with this DEP.

The type of membranes and (synthetic resin) cements for mortars selected shall be indicated in the requisition sheets. The Manufacturer shall be prepared to supply certificates including a reference or lot number for the materials and samples for test and reference purposes. These specifications shall not be changed without approval from the Principal.

All bricks and tiles shall have a regular texture throughout, without laminations, cavities or cracks and shall have consistent dimensions and shapes.

The number of items (bricks or tiles) to be tested shall be determined in accordance with a (standardized) sampling plan and the required acceptable quality level (AQL) agreed upon between parties. The AQL and sampling plan should reflect the criticality of the intended service. For example, in many cases a tighter AQL/sampling plan would be more suitable for process equipment than for concrete structures.

5.1 TESTING OF PROPERTIES

The selected bricks and tiles shall be tested for the following properties:

- Bulk density;
- Water absorption;
- Cold crushing strength, at ambient temperature;
- Acid resistance, (once per order);
- Content of fluxes, (once per order);

Refer to DEP 64.24.32.30-Gen, Table 3-1 ("Reference Table for Testing") for appropriate ISO, ASTM, DIN and JIS testing standards.

The acceptance criteria for the above tests shall be based on the manufacturer's data and shall be agreed in the order.

5.2 VISUAL INSPECTION OF MANUFACTURING DEFECTS

The textural properties of selected bricks or tiles shall be inspected in accordance with BS 1902, methods 311 and 313. The dimensions shall be inspected in accordance with (5.3).

The measurements determine the permissible laminations, cracks, craters and other surface defects of bricks and tiles. The following description should be used as guidance:

Laminations	None
Texture	No grain segregation at corners and edges. No presence of extraneous particulate matter. External evidence of a strong, well bonded and uniform texture
Surface defects and cracks	To be specified in the order.
Edge and corner damage	No more than two on any working face, with a maximum of three in total. The acceptable value shall be specified in the order.

5.3 DIMENSIONAL TOLERANCES

DIMENSIONAL TOLERANCES:		
Length	+/- 1%	
Width	+/- 1.5%	with a minimum of +/- 1.5 mm
Thickness		+/- 1.5 mm
Taper		+/- 1.5 mm
Warpage (See Note)		+/- 1 mm for diagonal <= 350 mm +/- 1.5 mm for diagonal > 350 mm
Assemblies	The mortar joints of assembled shapes shall not be larger than 3 mm. Shapes of one set shall be clearly marked with a set number, followed by a sequential number. The tolerances for the main dimensions shall be stated on the drawing(s) or purchasing documents.	

NOTE: Warpage is expressed as the largest deviation from a straight line across the diagonal of a brick face

6. PACKAGING AND STORAGE

The chemical-resistant lining materials shall be packed and transported in a manner which will ensure arrival at their destination in a satisfactory condition.

The packaging shall be clearly and indelibly labelled, indicating the name, brand and quantity of the contents.

Care shall be taken that the cements are transported and stored in accordance with manufacturer's instructions. These instructions shall include precautions for safe handling. The cements should not be stored longer than the period indicated by the manufacturer, generally about 6 months. After this period their use shall be permitted only when a new and complete recheck has indicated that the products are in accordance with the original specification.

Cements from different manufacturers shall not be mixed.

7. REFERENCES

In this DEP reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Non-metallic materials selection and application	DEP 30.10.02.13-Gen.
Design and installation of rubber-lined process equipment, piping and concrete structures	DEP 30.48.60.10-Gen.
Design and installation of chemical-resistant linings for concrete structures	DEP 30.48.60.12-Gen.
* Design and calculation of chemical-resistant brick linings for process equipment	DEP 30.48.60.13-Gen.
* Installation of chemical-resistant brick linings for process equipment	DEP 30.48.60.23-Gen.

NOTE: It is planned to combine both these DEPs as DEP 30.48.60.13-Gen.

Requirements for rubber linings for process equipment and piping	DEP 30.48.60.30-Gen.
Reinforced concrete foundations and structures	DEP 34.19.20.31-Gen.
Refractory bricks and shapes	DEP 44.24.90.31-Gen.
Insulating and dense refractory concrete linings	DEP 64.24.32.30-Gen.

BRITISH STANDARDS

Refractory Materials; Measurement of dimensions and shape of refractory bricks and blocks (method 1902-311)	BS 1902 section 3.11
Refractory Materials; Measurement of corner and edge defects and other surface imperfections of refractory bricks and blocks (attributive properties) (method 1902-313)	BS 1902 section 3.13

Issued by:
British Standards Institution
2 Park Street
London W1A 2BS, England.

GERMAN STANDARDS

Chemical equipment; building materials for brick-lining, classification, properties, testing	DIN 28062

Issued by:
Beuth Verlag Gmbh
Burggrafenstrasse 4-10, 1000 Berlin 30,
Germany.

APPENDICES

APPENDIX 1 TYPICAL VALUES FOR MECHANICAL AND PHYSICAL PROPERTIES OF CHEMICAL-RESISTANT LINING MATERIALS

	Units	Acid-resistant bricks and tiles		Porcelain tiles (unglazed)	Carbon bricks		Graphite bricks		Silicate-based cements	Synthetic-resin-based cements	
		Glover type	Red acid-resistant		Unimpreg-nated	Impreg-nated	Unimpreg-nated	Impreg-nated		Phenolic and furane	Polyester and epoxy
Apparent specific gravity (density)	kg/m^3	2100-2400	2100-2400	2200-2400	1500-1600	1750-1850	1600-1700	1800-1900	2000-2100	1400-2100	1500-2100
Water absorption	%	1.0	5.0	0.05 max.	12-18	0	14-16	0	1-3	0.3-3.0	0.1-0.5
Apparent porosity, max.	%	5.0	12.0	0.1	18	0	20	0	12	1	1
Acid resistance	%	0.5 max.	1.5 max.	0.5 max.	0.5 max.						
Coefficient of thermal expansion	K^{-1}	0.5×10^{-5}	0.5×10^{-5}	0.4×10^{-5}	0.5×10^{-5}	0.5×10^{-5}	0.2×10^{-5}	0.4×10^{-5}	1.2×10^{-5}	2.0×10^{-5}	4.0×10^{-5}
Specific heat	J/(kg.K)	750-840	800-840	800	670-1090	800-1170	670-1090	800-1170			
Thermal conductivity	W/(m.K)	1.1	1.0	1.4	2.3	2.3	116-145	116-145	1.16	1.6	1.1
Compressive strength	N/mm^2	75	110	300	40	75	40	70	50	60	60
Tensile strength	N/mm^2	20	6	35	6	12	5	15	4	8	8
Flexural strength	N/mm^2	25-65	20	60	20	35	15	40		15-29	25-60
Modulus of elasticity	N/mm^2	55 000	55 000	80 000	12 000	20 000	7000	13 000	11 000	8000	8000

APPENDIX 2 COMPARISON OF THE CHEMICAL RESISTANCE OF VARIOUS MATERIALS AT 20 °C

	Water			Ammonia liquid 25%	Hydrochloric acid 35%	Sulphuric acid 98%	Nitric acid 25%	Hydrofluoric acid 50%	Alkalis	Sulphates	Chlorides	Other salts	Hydrocarbons			Mineral oils	Alcohols	Ketones	Phenols	Esters
	Sea	Brackish	Potable										Aliphatic	Aromatic	Chlorinated					
Concrete based on:																				
Portland cement	–	(+)	+	+	–	–	–	–	+	–	–	–	+	+	+	+	+	+	–	(+)
Portland blast-furnace cement	+	+	+	+	–	–	–	–	+	–	(+)	(+)	+	+	+	+	+	+	–	(+)
High-alumina cement	+	+	+	–	–	–	–	–	–	+	(+)	+	+	+	+	+	+	+	–	(+)
Sulphate-resisting Portland cement	+	+	+	+	–	–	–	–	+	+	(+)	+	+	+	+	+	+	+	–	(+)
Protective membranes																				
Asphaltic bitumen	+	+	+	+	+up to 30%	+up to 50%	–	+[1]	(+)	+	+	+	–	–	–	–	+	–	–	–
Polyisobutylene sheet	+	+	+	+	+	(+)	+	+	+	+	+	+	+	–	–	–	+	(+)	–	–
Cold-cured epoxy	+	+	+	+	+	–	+	+[1]	+	+	+	+	+	+	+	+	+	–	–	+
Cements based on:																				
Phenol-furfuraldehyde resin	+	+	+	+	+	+	–	+[1]	(+)	+	+	+	+	+	+	+	+	+	+	+
Phenol-formaldehyde resin	+	+	+	+	+	–	–	+[1]	+	+	+	+	+	+	+	+	+	+	+	+
Furane resin	+	+	+	+	+	–	–	+[1]	+	+	+	+	+	+	+	+	+	+	+	+
Epoxy resin	+	+	+	+	+	–	(+)	–	+	+	+	+	+	+	–	+	+	(+)	–	+
Polyester resin	+	+	+	+	+	–	(+)	(+)[1]	(+)	+	+	+	+	+	(+)	+	+	(+)	–	+
Sodium silicate [2]	–	–	–	–	+	(+)	+	–	–	(+)	+	(+)[3]	+	+	+	+	+	+	+	+
Potassium silicate [2]	–	–	–	–	+	+	+	–	–	+	(+)	(+)[3]	+	+	+	+	+	+	+	+

\+ : Resistant
(+) : Resistant to a limited extent
– : Not resistant

NOTES:
1. The filler shall also be resistant
2. Has a porosity of 7-16% and should never be used as a membrane
3. Sodium and potassium silicate cements are not resistant to ammonium fluoride and sodium bicarbonate

This table should be used only as a guide
Applications should be selected in consultation with the material specialist