MANUAL

# RUBBER-LINED PROCESS EQUIPMENT AND PIPING

DEP 30.48.60.10-Gen.

December 1997
(DEP Circular 30/98 has been incorporated)

**DESIGN AND ENGINEERING PRACTICE**

## PREFACE

DEP (Design and Engineering Practice) publications reflect the views, at the time of publication, of:

Shell International Oil Products B.V. (SIOP)
and
Shell International Exploration and Production B.V. (SIEP)
and
Shell International Chemicals B.V. (SIC)

The Hague, The Netherlands,

and other Service Companies.

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.

The right to use DEPs is granted by SIOP, SIEP or SIC, in most cases under Service Agreements primarily with companies of the Royal Dutch/Shell Group and other companies receiving technical advice and services from SIOP, SIEP or SIC. Consequently, three categories of users of DEPs can be distinguished:

1) Operating companies having a Service Agreement with SIOP, SIEP, SIC or other Service Company. The use of DEPs by these Operating companies is subject in all respects to the terms and conditions of the relevant Service Agreement.

2) Other parties who are authorized to use DEPs subject to appropriate contractual arrangements.

3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) or 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

Subject to any particular terms and conditions as may be set forth in specific agreements with users, SIOP, SIEP and SIC disclaim any liability of whatsoever nature for any damage (including injury or death) suffered by any company or person whomsoever as a result of or in connection with the use, application or implementation of any DEP, combination of DEPs or any part thereof. The benefit of this disclaimer shall inure in all respects to SIOP, SIEP, SIC and/or any company affiliated to these companies that may issue DEPs or require the use of DEPs.

Without prejudice to any specific terms in respect of confidentiality under relevant contractual arrangements, DEPs shall not, without the prior written consent of SIOP and SIEP, be disclosed by users to any company or person whomsoever and the DEPs shall be used exclusively for the purpose for which they have been provided to the user. They shall be returned after use, including any copies which shall only be made by users with the express prior written consent of SIOP and SIEP. The copyright of DEPs vests in SIOP and SIEP. Users shall arrange for DEPs to be held in safe custody and SIOP or SIEP may at any time require information satisfactory to them in order to ascertain how users implement this requirement.

All administrative queries should be directed to the DEP Administrator in SIOP.

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.

## TABLE OF CONTENTS



## APPENDICES

## 1. INTRODUCTION

### 1.1 SCOPE

This DEP specifies requirements and gives recommendations for the application, design, qualification testing, fabrication, production testing, inspection, transportation and installation of rubber-lined process equipment, piping and flanges.

This DEP is applicable to vulcanised and non-vulcanised rubber lined process equipment and piping, both shop fabricated and field fabricated.

This DEP is a revision of the DEP of the same number dated May 1989, and has been combined with a revision of DEP 30.48.60.30-Gen. which is now withdrawn.

### 1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP and SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors and Manufacturer/Suppliers nominated by them (i.e. the distribution code is "F", as defined in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants and, where applicable, in oil and gas production facilities and supply/marketing installations.

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

The **Principa**l 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, and on behalf of, the Principal.

The **Contractor** is the party which 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 sometimes 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 word **shall** indicates a requirement.

The word **should** indicates a recommendation.

### 1.4 CROSS-REFERENCES

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

## 2. APPLICATION

### 2.1 GENERAL

Rubber linings are mainly used for protection against corrosion and/or erosion damage. In brick-lined equipment rubber is used as a membrane between the brick lining and the load-bearing structure (see DEP 30.48.60.12-Gen. and DEP 30.48.60.13-Gen.).

A wide range of rubbers and elastomers is available for lining vessels, tanks and piping. Rubbers can also be made with anti-static properties to give a low surface electrical resistance.

Hard rubbers, i.e. hardness greater than Shore D 60, can only be applied by autoclave vulcanisation, and therefore hard rubber lining is restricted to small equipment or components. Only soft rubbers can be applied on site.

Hard rubber linings can only be applied to rigid structures and they are also sensitive to large temperature fluctuations. Soft rubber linings remain elastic over a large temperature range, and consequently they can accommodate major deformation, vibrations and significant temperature changes.

With respect to safety aspects, pressure rating, etc. the regulations which apply to piping, equipment and structures are also valid for rubber-lined systems.

### 2.2 MATERIAL SELECTION

Material selection is determined by:

- service conditions (pressure, temperature, medium, etc.)
- design
- manufacturing method

The following rubber types are used for lining purposes (classification according to ASTM D 1418):

- Isoprene or natural rubber (NR)
- Synthetic isoprene rubber (IR)
- Styrene-butadiene rubber (SBR)
- Chloroprene rubber (CR)
- Butyl rubber (IIR)
- Broom-butyl rubber (BIIR)
- Chloro-butyl rubber (CIIR)
- Nitrile-butadiene rubber (NBR)
- Ethylene propylene rubber (EP, EPDM)
- Urethane rubber (UR)
- Chlorosulphonated polyethylene (CSM)**
- Fluoro elastomer (FKM)*

* Commercially available under trade name "Viton" (DuPont product)

** Commercially available under trade name "Hypalon" (DuPont product)

Depending on the degree of vulcanisation, rubbers can be classified as ‘soft’ rubber or as ‘hard’ rubber. The hardness of soft rubbers is expressed in Shore A, and the hardness of hard rubbers is expressed in Shore D (ASTM D 2240).

Hard rubbers (or Ebonites), i.e. with a hardness higher than Shore D 60, can be produced from NR or blends, e.g. NR/IR, NR/SBR and NR/IR/SBR.

## 2.3 PROPERTIES OF RUBBER

Each rubber material has a specific limit in terms of allowable service temperature and chemical resistance. The chemical resistance and temperature limits for continuous service of several rubber types are given below.

### 2.3.1 Natural rubber (NR)

Soft and hard natural rubber linings are suitable for handling most inorganic chemicals, with the exception of strong oxidising agents such as chromic and nitric acids. Natural rubber linings are also suitable for handling hydrochloric acid. Natural rubber is also resistant to most organic fluids, including alcohols and most esters. They should not be used in the presence of aliphatic or aromatic hydrocarbons, halogenated hydrocarbons, mineral oils and certain vegetable oils. The allowable service temperature range is -40 °C to +80 °C. The bond strength of NR linings on steel is excellent. The hardness is typically Shore A 55 for soft rubber and Shore D 75 for hard natural rubber.

### 2.3.2 Synthetic isoprene rubber (IR)

Isoprene rubber is a synthetic alternative form of NR, and has similar properties.

### 2.3.3 Styrene-butadiene rubber (SBR)

Styrene-butadiene rubber can be used for the containment of automotive brake fluids, alcohols and mixtures of alcohol and water. The allowable service temperature range is -30 °C to +80 °C. The hardness is in the same range as that of soft natural rubber (NR).

### 2.3.4 Chloroprene rubber (CR)

Chloroprene rubber is resistant to ozone and sunlight, and reasonably resistant to oils and chlorine. Special compounds are suitable for use with refrigerants (e.g. Freon 12 and 22). The allowable service temperature range is -30 °C to +105 °C. Hardness is approximately Shore A 60.

### 2.3.5 Butyl rubbers (IIR, BIIR, CIIR)

Butyl rubbers have excellent tolerance to hydrochloric acid. Butyl rubber is resistant to ozone and sunlight, non-flammable hydraulic fluids, animal and vegetable oils, water, alcohols, ketones and acids. Butyl rubber should not be used in the presence of free halogens, petroleum oils or halogenated or aromatic hydrocarbons. The allowable service temperature range is -30 °C to +110 °C. Hardness is in the range of Shore A 55 to A 60.

### 2.3.6 Nitrile butadiene rubber (NBR)

Nitrile butadiene rubber (also known as BuNa-N) is a copolymer of butadiene and acrylonitrile. The acrylonitrile content must be at least 35% by mole to obtain good chemical resistance. Nitrile rubbers are resistant to petroleum-based hydraulic and lubricating oils, animal and vegetable oils, acetylene, alcohols, water, alkalis and fuel oils. Nitrile rubber should not be used for phenols, ketones, acetic acids, most aromatic hydrocarbons and nitrogen derivatives. The allowable service temperature is -35 °C to +80 °C. Hardness is approximately Shore A 60.

### 2.3.7 Ethylene propylene rubbers (EPDM / EPM)

Ethylene propylene rubbers are resistant to ozone and sunlight, oxidising chemicals, non-flammable hydraulic fluids, pure aniline, fire extinguisher liquids, acids, hot water and steam. However, these rubbers are not resistant to mineral oils, petrol solvents and aromatic hydrocarbons. The allowable service temperature range is -40 °C to +150 °C. Hardness is typically in the range Shore A 40 to A 80.

### 2.3.8 Urethane rubber (UR)

Urethane rubber has excellent wear/erosion resistance and is chemically resistant to mineral oils, fuels and ozone. Urethane rubber should not be used for concentrated acids,

ketones or chlorinated hydrocarbons, and shall not be used for water above 50 °C. Otherwise, the allowable service temperature range is -40 °C to +70 °C. Hardness is typically in the range Shore A 50 to A 80.

#### 2.3.9 Chlorosulphonated polyethylene (CSM)

Chlorosulphonated polyethylene is a highly wear-resistant synthetic rubber with excellent resistance to heat, ozone sunlight, oxidising media, sodium hypochlorite and sulphuric acid. CSM rubber has also good resistance to most oils, lubricants and aliphatic hydrocarbons, but is unsuitable for use with esters and ketones. The allowable service temperature range is -35 °C to +80 °C. Hardness is approximately Shore A 60.

#### 2.3.10 Fluoro-elastomers (FKM)

Fluoro-elastomers are copolymers of hexa-fluoro-propylene and vinyldiene fluoride. They are suitable for both high-temperature and vacuum applications. These materials have excellent resistance to oils, fuels, lubricants, carbon tetrachloride, most concentrated acids and many aliphatic and aromatic hydrocarbons such as toluenes, benzene and xylene. They should not, however, be used with low molecular weight esters and ethers, ketones, certain amines and hot anhydrous hydrofluoric or chlorosulphonic acids. These materials are also resistant to ozone and sunlight and can be used in contact with many corrosive gases, e.g. bromine and chlorine. However, they are not resistant to ammonia or high-pressure steam. The allowable service temperature range is -20 °C to +230 °C. Hardness is typically in the range Shore A 60 to A 90.

### 2.4 VACUUM APPLICATIONS

The degree of vacuum to which a specific system can be exposed is dependent not only on the operating temperature and the contents, but also on system characteristics such as:

- rubber type;
- adhesion rubber/substrate;
- rubber thickness;
- geometry (e.g. diameter);
- manufacturing method.

In general, the vacuum resistance will increase with increasing rubber hardness, lining thickness and rubber/substrate adhesion, and with decreasing diameter of the vessel or piping.

### 2.5 EROSION RESISTANCE

During transport of fluids containing hard particles (e.g. sand), linings can be damaged by erosion. The rate of erosion damage is dependent on the lining material properties, the type and size of hard particles, the particle impingement angle, fluid velocity and fluid temperature.

In general, soft materials (e.g. soft rubber linings) have a better erosion resistance than hard rubber at high impingement angles (e.g. in bends, tees, etc.). Hard rubbers have a better erosion resistance at low impingement angles (less than 10 degrees, e.g. in straight sections).

## 3. MATERIALS REQUIREMENTS

### 3.1 GENERAL

As lining for equipment, piping or structures, a dimensionally stable rubber, normally with a thickness of more than 3 mm, is applied by vulcanisation.

Rubbers are elastomeric polymers having reactive sites along their molecular chain which enable cross-linking. The cross-linking process is called vulcanisation. This process is induced by heat, vulcanising agents or a combination thereof.

### 3.2 LINING MATERIALS

The final selection of the type and thickness of the rubber lining, and the method of application, shall be made in consultation with the material Supplier and the lining Contractor.

The physical and chemical properties of vulcanised rubbers vary widely depending on the type of rubber, amount and type of filler and vulcanisation agent present in the compound. Some rubbers are available both as hard rubber and as soft rubber. Hard rubbers are generally only applied by autoclaving or shop vulcanisation. For on-site rubber lining, several types of soft rubber are used.

Lack of chemical resistance will generally result in either brittle behaviour in the form of small surface cracks or swelling combined with softening.

Rubber linings are not fully gas tight, and the degree of gas-tightness will depend on gas permeability, lining thickness and temperature gradient across the lining. Gas diffusion can result in the formation of blisters or areas of disbonding. External thermal insulation may help to prevent any such blister formation and lining disbonding.

For certain services it may be important to determine whether the lining can contaminate or discolour the fluid.

### 3.3 CARBON STEEL SUBSTRATE

The carbon steel piping, equipment and flanges shall be in accordance with the design codes and/or piping class specified by the Principal.

## 4. DESIGN, MANUFACTURING AND FABRICATION REQUIREMENTS

### 4.1 DESIGN

**Amended per Circular 30/98**

Rubber lined equipment shall be in accordance with BS 6374: Part 5, DIN 28051 or DIN 28055. Air vent holes may be required to prevent air entrapment in welded joints (e.g. in vessels), see details in Appendix 2.

Important issues are:

- the lining surface shall be accessible for surface machining;
- the weld seams shall be continuous, with a smooth surface in accordance with DIN 28053.

Branches shall be flanged and the lining shall be taken over the flange face to prevent ingress of the process liquid behind the lining.

Typical flanged connections for rubber lined systems are shown in Appendix 1 and Standard Drawing S 38.085. For dimensions of piping and piping components, see Standard Drawings S 38.080, S38.081, S38.082 and S 38.083.

The radius of any contour changes shall be at least 3 mm at the lining's internal surface.

### 4.2 MANUFACTURE

#### 4.2.1 Rubber linings

The thickness of the rubber lining shall be at least 3 mm. For the containment of aggressive media and if mechanical damage of the lining is expected (e.g. by erosion), the thickness should be increased to at least 5 mm.

The physical properties of the rubber lining shall be in accordance with the specifications described in (2.3).

#### 4.2.2 Steel surface preparation

The steel surface to be lined shall be smooth, clean and free from pitting, cavities, porosity, scale or other deposits (in accordance with DIN 28053) and shall be blast-cleaned to a surface finish corresponding to SA 2.5, in accordance with ISO 8501-1.

Directly after blast cleaning of the steel substrate, the grit, dust, etc. shall be removed and a layer of adhesive primer with a dry film thickness in the range of 30 to 50 µm shall be applied.

After vulcanisation of the rubber lining, the steel parts shall be painted externally in accordance with DEP 30.48.00.31-Gen.

#### 4.2.3 Joints in rubber lining

Overlap joints (Appendix 3, Figure 1) shall be used when joining separate sheets of non-vulcanised rubber. The overlap width shall be at least four times the sheet thickness or 32 mm, whichever is the lesser. Where applicable, overlaps shall follow the direction of the liquid flow.

If the total lining thickness is built up of more than one layer, only the joints in the top layer shall be of the overlap bevel type, the bottom layers being flush-jointed as shown in Appendix 3, Figure 2 Joints in the different layers shall be staggered.

The relatively weak flush joint (Appendix 3, Figure 3) may be used if the rubber lining is installed to serve as a membrane underneath a chemical-resistant brick lining.

Joints between the rubber lining of a pipe and the rubber on the flange facing shall not protrude so as to restrict the bore of the pipe or to prevent efficient sealing between the flange faces.

## 4.3 FABRICATION OF LINED PIPING AND EQUIPMENT

Two techniques are used to apply the rubber lining to piping and equipment:

1) Autoclaving or shop vulcanisation;

2) In-situ vulcanisation.

### 4.3.1 Autoclaving or shop vulcanisation

After preparation of the substrate, an adhesive primer layer is applied. After sufficient evaporation of the solvent (but not longer than 96 hours), the pre-cut, non-vulcanised rubber sheets are applied. Care must be taken to position the sheets accurately without entrapment of air and with joints as described in (4.2.3).

Vulcanisation is then carried out in an autoclave, usually at a pressure of 4-6 bar and a temperature of 140 °C to 160 °C.

### 4.3.2 On-site vulcanisation, rubber lining

The steel surface shall be properly prepared and primed with a protective coating before applying the rubber lining.

During rubber lining the ambient temperature shall be between 15 °C and 25 °C, and the relative humidity shall not be higher than 75%.

To prevent premature degradation, the rubber must be stored in a cool and dry place.

On-site vulcanisation can be performed by any of the following methods:

(a) Hot-vulcanisation using steam or hot air

The vulcanisation temperature (90 °C to 100 °C) is achieved by injecting steam or hot air. The temperature is maintained for about 72 hours. Provisions should be made to drain any condensation and to prevent excessive heat loss.

(b) Hot-vulcanisation using water

The equipment is filled with water and the required vulcanisation temperature (70 °C to 90 °C) is obtained by steam injection. The vulcanisation temperature is maintained for about 100 hours.

## 4.4 CONNECTIONS

Connections in rubber-lined equipment and/or piping shall be flanged.

### 4.4.1 Flanges

The type of flanges shall be in accordance with the piping design code and/or the piping class, as specified by the Principal.

### 4.4.2 Gaskets

Rubber-lined flange surfaces can generally form a seal without the need for a gasket. However, if regular dismantling of the joint is expected, a gasket should be incorporated.

For hard rubber linings, a soft rubber gasket should be used. For soft rubber linings a hard e.g. graphite gasket should be used.

The gasket material shall suit the pressure, temperature and chemical resistance capabilities of the process equipment and piping. The minimum thickness of the gasket should be 3 mm.

## 5. QUALIFICATION TESTING

### 5.1 GENERAL

The Principal shall specify whether the Manufacturer is required to perform qualification testing.

The Principal shall specify whether the qualification testing shall be performed by, or witnessed by, an independent authorised body approved by the Principal.

The qualification testing shall be carried out on products of equal diameters. The type of product and number of tests, etc. shall be agreed with the Principal.

### 5.2 FINISHED PRODUCTS

The following qualification requirements apply to the finished products. All tests shall be carried out at ambient temperature on an inspectable pipe length or component size.

#### 5.2.1 Appearance

The internal surface of the rubber lining shall be free from blisters larger than 10 mm in diameter, dents or tool marks.

Absence of these defects shall be determined visually or by a liquid penetrant.

The rubber lining shall fit snugly on the steel housing (e.g. pipe, vessel) with no ripples caused by air entrapment.

Vent holes, if applicable, shall not be blocked by paint or other deposits.

#### 5.2.2 Physical properties of rubber

It shall be verified whether the type of rubber (see 2.3) complies with the specifications (ASTM D 3677). The manufacturer shall confirm the corrosion resistance of the selected rubber.

The physical properties of the vulcanised rubber shall comply with the values given by the manufacturer. Tensile testing shall be performed in accordance with ISO 37. These tests are carried out on separately supplied test samples. All hardness readings shall conform to the specified value within plus/minus 5°. A minimum of three readings shall be taken for each square metre of lining. For large surfaces the maximum number of readings shall be agreed upon by the manufacturer and the Principal.

#### 5.2.3 Adhesion of lining to metal substrate

To determine the degree of adhesion to the metal substrate, samples shall be prepared from the same rubber compound used for the lining and the same steel substrate.

The pre-treatment of the steel sample shall be identical to that of the surface of the equipment or piping. After the same vulcanisation procedure, the adhesion shall be determined according to method described in ASTM D 429. The minimum adhesion value shall be agreed between the manufacturer and the Principal.

#### 5.2.4 Thickness of the lining

For pipes, the thickness of the rubber lining shall be measured at both ends. For flanges, the rubber lining shall be measured at the facing of each flange. The lining thickness shall not be less than 90% of the specified thickness, or 3 mm whichever is the greater.

For lined equipment, a minimum of three measurements per square metre shall be taken. For large surfaces, the number of readings shall be agreed between the manufacturer and the Principal. For the thickness measurements an electromagnetic measuring device should be used.

#### 5.2.5 Chemical and Physical properties

The physical properties of the lining shall comply with the values given by the manufacturer.

Test method ASTM D 3677 shall be used to measure chemical composition via infrared spectrophotometry.

The hardness of the rubber as measured according to ASTM D 2240 shall conform to the specified value, with a tolerance of plus/minus 5°. A minimum of three readings per square meter shall be taken.

### 5.2.6 Holiday test

To check the quality of the lining system, a high-voltage spark test shall be performed. Spark testing shall not be done with direct-current apparatus; only apparatus with pulsed voltage shall be used. The testing voltage depends not only on the thickness of the rubber but also on its composition.

The voltage to be used is determined by the following:

Voltage = 6 (1 + thickness in mm) kV with a maximum of 30 kV.

For high carbon black filled rubbers the voltage shall be approximately 3 kV per mm thickness (exact voltage to be determined on a test sample). It is not possible to inspect anti-static linings with this test. If the Principal agrees, the "wet sponge test" using a low-voltage holiday detector, shall be used.

Holiday tests shall be performed in accordance with BS 6374-5 or DIN 55670.

### 5.2.7 Hydrostatic pressure test

Rubber-lined equipment and piping shall be hydrostatically tested at a pressure equal to the test pressure specified by the appropriate design code, at the maximum allowable service temperature for the particular lining. These conditions shall be maintained for a period of at least 1 hour. At the end of the test, the lining shall be visually inspected. There shall be no blisters or cracks and the lining shall pass the high-voltage spark test (5.2.6).

### 5.2.8 Vacuum testing

If vacuum service is specified by the Principal, the equipment and piping shall be tested at 130 mbar absolute at ambient temperature for a period of 1 hour. No buckling or collapse of the lining shall occur during this test.

## 6. PRODUCTION INSPECTION AND TESTING

### 6.1 GENERAL

The Principal shall specify whether inspections and tests are required in addition to those specified below.

### 6.2 SHOP INSPECTIONS AND TESTS

#### 6.2.1 Visual inspection

All equipment and piping shall be visually inspected in accordance with (5.2.1)

#### 6.2.2 Thickness of the lining

The thickness of the lining of all pipes and fittings shall be inspected in accordance with (5.2.4).

#### 6.2.3 Holiday test

All equipment, pipes and fittings shall be holiday tested in accordance with (5.2.6).

#### 6.2.4 Hydrostatic pressure test

All lined process equipment and 10% of the pipes and fittings shall be subjected to a hydrostatic pressure test in accordance with (5.2.7) and subsequently visually inspected (5.2.1) and holiday tested (5.2.6)

### 6.3 REPAIR

Lined equipment and piping shall not be repaired by welding, since this will cause damage to the lining.

Repair of damaged rubber linings shall only be carried out by the Contractor after consultation and in agreement with the Principal. Repairs may be carried out on-site or at the contractor's works, using an autoclave for vulcanisation, as described in (4.3.1). The repaired area shall be checked for adhesion, thickness, hardness and integrity, as described in (5). The quality of the repairs shall be checked by a qualified Contractor.

The total extent of repairs in equipment shall not be more than 100 $cm^2$ per square metre of lined surface. No lining repairs shall be performed on piping, flange facings or equipment nozzles.

If damage occurs to a component of an installed piping system, the damaged component shall be replaced. The option may be considered of returning damaged piping to the Manufacturer for relining. Leakage at flanged connections shall be remedied by the following measures in the given order of preference:

- Re-torquing of flange bolts to the specified values. Care shall be taken that these values are not exceeded;
- Fitting of a new gasket using the specified bolting torque;
- Replacement of the pipe spool having the suspect flange face.

#### 6.3.1 Repair procedures

The damaged rubber shall be cut away, the exposed edges of the lining bevelled and the surface roughened. Depending on the size of the damage and the service conditions, repairs of equipment shall be made as follows:

- Damage in non-critical services:

  For vessel linings not in direct contact with the process fluid, a vulcanised rubber sheet, cut to size to the area to be repaired, shall be glued with an appropriate adhesive. A hot-air device may be used to make the sheet sufficiently flexible for handling.

Alternatively, if the chemical resistance is not weakened thereby, repairs may be carried out with cements based on synthetic resins such as epoxy or phenol formaldehyde.

- Minor damage in critical services:

  For vessel linings in direct contact with the process fluid, a non-vulcanised rubber sheet, cut to size to cover the area to be repaired, shall be glued with an appropriate adhesive. Subsequently heat, equivalent to the normal vulcanising conditions, shall be applied by pressing a heating element against the rubber. Areas to be repaired should not be greater than the heating surface of this element.

  Alternatively, if the chemical resistance is not weakened thereby, repairs may be carried out with a glass-fibre reinforced epoxy resin system cured with hot air in order to achieve optimum properties, or with an epoxy or a phenol formaldehyde-based cement.

- Major damage in critical services:

  Most rubber lining manufacturers have a method utilising a hot water vulcanising or self-vulcanising type of rubber for repairing large areas in contact with the process fluid. Such rubber compounds have modified accelerator systems so that vulcanising at 90 °C or at ambient temperature is possible.

### 6.3.2 Re-lining

If the rubber lining of existing equipment has to be replaced, the old lining should be removed by one of the following methods:

**- Heating**

This method involves external heating of the rubber lined equipment so that the bond with the metal substrate is weakened. This is followed by mechanical removal of the rubber. The following options may be used:

- Molten salt, temperature about 500 °C;
- Whirl-bed, temperature about 500 °C;
- Cooking at 360 °C, but, for environmental reasons this method shall only be applied if the flue gases produced during cooking are cleaned before venting to atmosphere.

**- Burning off**

Most rubbers can be burnt off, but this has the following disadvantages:

- Metal structures may distort due to the heat generated.
- Noxious or toxic fumes may be generated.

For environmental reasons, burning off may be done only if the flue gases produced are cleaned before venting to atmosphere.

**- Mechanical**

An alternative method for lined systems where the rubber-to-metal adhesion is still strong, is to cut through the rubber and tear off the lining.

**- High-pressure water jet**

Large areas of soft rubber can be removed using high pressure water jet blasting (up to 2500 bar). It is a very effective method for removing both the rubber liner, primer and adhesive.

**- Cryogenic**

Hard rubber can be removed from small lined equipment or components by cooling the rubber with liquid nitrogen (-190 °C). For both graphite-filled rubber and soft rubbers this method cannot be applied.

After removal of the old lining, the metal should be prepared as described in (4.2.2). However, if severe corrosion of the metal substrate has occurred, relining should not be performed.

## 7. INSTALLATION

### 7.1 GENERAL

The installation of rubber-lined piping and equipment is similar to that of normal flanged steel piping and equipment with respect to supporting, thermal expansion, etc. Welded supports shall not be applied.

### 7.2 FLANGED CONNECTIONS

Flange facings shall be cleaned and greased with colloidal graphite prior to installation.

### 7.3 BOLTING

Flange bolts shall be tightened with a torque wrench, using greased bolts and nuts, in the sequence and to the torque values as specified by the Manufacturer of the rubber-lined piping or equipment.

### 7.4 WELDING

No welding shall be performed on lined piping or equipment. Lined piping or equipment shall not be used as a welding earth, as this can cause damage to the lining.

### 7.5 VENTING SYSTEM

Care shall be taken that the vent holes (4.1) do not become blocked by paint or other deposits. Regular inspection of the vent holes should be made. Sharp tools shall not be used to clean the vent holes. If lined piping or equipment is insulated, vent hole extensions shall be used.

### 7.6 MARKING

The lined equipment or piping system shall be marked to identify it as lined, in order to prevent inadvertent damage of the lining, e.g. by welding.

## 8. MAINTENANCE

### 8.1 MAINTENANCE AND REPAIR

Rubber linings should be thoroughly inspected at the end of the first year of service. If their condition is satisfactory, further inspections may be carried out at longer intervals.

Visual inspection and hardness testing shall be performed. If blisters or other evidence of failure are discovered, then high-voltage spark testing should be performed as described in (5.2.6).

Vent holes shall be kept free from paint or other deposits; sharp tools shall not be used for this purpose. The vent holes and flange bolt torque shall be checked regularly.

Blocked equipment and piping should be cleaned with low-pressure water only; rods or steam jets shall not be used.

Rubber-lined piping and equipment shall be dismantled from an existing system only at temperatures below 40 C to prevent retraction of the rubber flange face. Immediately after disconnection, a flange protector shall be installed on each flange face.

Prior to any repairs the damaged part and adjacent lining should be thoroughly neutralised, cleaned and dried. Then, repairs shall be performed as specified in (6.3).

## 9. HANDLING AND STORAGE

### 9.1 MARKING

All equipment and piping shall be permanently marked with the Manufacturer's name or trade name, the type and rating of the lining, the nominal diameter, and the equipment or pipe spool number.

The marking shall remain legible under normal handling and installation conditions.

Markings shall be made so as not to impair the integrity of the equipment, or fitting.

### 9.2 PACKAGING

Lined equipment and piping shall be packed in a manner which will ensure their arrival at the destination in an undamaged and clean condition. Flanges and manholes shall be protected with suitable cover plates securely attached. The plates shall be such that they also prevent stretching of the flared lining ends.

### 9.3 HANDLING

The objects shall be handled with care and hoisting shall be done using non-metallic slings. In particular, branches, openings and flange facings are vulnerable and shall be protected adequately. The protective cover plate mounted on flanges shall be left in place until installation. If the plates have to be removed for testing or inspection, they shall be re-installed immediately thereafter.

Hard rubber-lined equipment and piping shall not be transported if the ambient temperature is below 0 °C for hard rubber up to Shore D 75, or below 5 °C for rubber harder than Shore D 75.

Soft rubber-lined equipment and piping shall not be transported at ambient temperatures lower than -30 °C.

### 9.4 STORAGE

Lined equipment, pipe spools and fittings shall be stored with an identification label showing the Manufacturer, type of lining, size, length, recommended bolting torque, design pressure and design temperature.

Rubber-lined equipment and piping shall not be stored at ambient temperatures below -20 °C for hard rubber, or below -40 °C for soft rubber.

Equipment and piping shall be stored so that damage to the rubber lining is avoided. Equipment and piping shall be stored with their protective cover plates installed.

Care shall be taken that the vent holes do not become blocked during storage.

## 10. DOCUMENTATION

The applicable dimensions and tolerances of equipment and piping shall be stated on the Manufacturer's drawings.

The Manufacturer shall keep a traceable record of all materials and products and of the quality controls performed, and shall maintain this record for at least five years from the date of manufacture. These records shall be sufficient to demonstrate compliance with the purchase order and the Manufacturer's standards.

If specified in the purchase order, the Manufacturer shall submit inspection certificates in accordance with ISO 10474, type 3.1.B. This certification shall also state the maximum service ratings for temperature, pressure and vacuum.

## 11. 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.

**Amended per Circular 30/98**

### SHELL STANDARDS

| | |
|---|---|
| Index to DEP publications and standard specifications | DEP 00.00.05.05-Gen. |
| Design 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 |
| Painting and coating of new equipment | DEP 30.48.00.31-Gen. |

### STANDARD DRAWINGS

| | |
|---|---|
| Branch pieces, wafer type, for rubber-lined piping systems | S 38.080 |
| Make-up pieces (spacers) for rubber-lined piping systems | S 38.081 |
| Overall dimensions of flanged fittings for rubber lining | S 38.082 |
| Overall dimensions of flanged fittings for rubber lining | S 38.083 |
| Flanges, flat face with recess for rubber-lined systems | S 38.085 |

### AMERICAN STANDARDS

| | |
|---|---|
| Rubber property - Adhesion to rigid substrates | ASTM D 429 |
| Rubber and rubber lattices - Nomenclature | ASTM D 1418 |
| Rubber property - Durometer hardness | ASTM D 2240 |
| Rubber - Identification by infrared spectrophotometry | ASTM D 3677 |

*Issued by:*
*American Society for Testing and Materials*
*1916 Race Street*
*Philadelphia, Pa 19103*
*USA.*

### BRITISH STANDARD

| | |
|---|---|
| Lining of equipment with polymeric materials, for the process industries - specification for lining with rubbers | BS 6374: Part 5 |

*Issued by:*

*British Standards Institution*
*2 Park Street, London, W1A 2BS,*
*United Kingdom*

**GERMAN STANDARDS**

| | |
|---|---|
| Chemical apparatus: Design of metal parts to be protected by coatings and lining with organic materials | DIN 28051 |
| Chemical apparatus: Coating and lining with organic materials; Metallic substrates and semi-finished products | DIN 28053 |
| Chemical apparatus: Lining of organic material for metallic components: Requirements and testing | DIN 28055 |
| Paints, varnishes and similar coating materials; Method for testing paint coatings for pores and cracks, using high voltage | DIN 55670 |

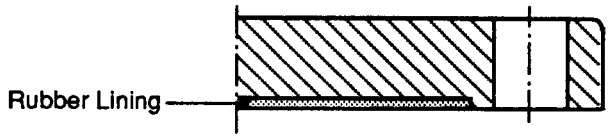
*Issued by:*
*Beuth Verlag GmbH*
*Burggrafenstrasse 4-10*
*1000 Berlin 30*
*Germany*

**INTERNATIONAL STANDARDS**

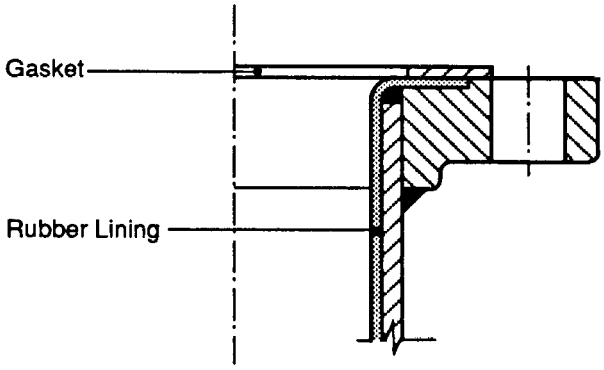
| | |
|---|---|
| Rubber, vulcanised or thermoplastic - determination of tensile stress-strain properties | ISO 37 |
| Preparation of steel substrate before application of paint related products | ISO 8501-1 |
| Steel and steel products - Inspection documents | ISO 10474 |

*Issued by:*
*International Organisation for Standardisation*
*1, Rue de Varembé*
*CH-1211 Geneva 20*
*Switzerland.*
*Copies can also be obtained from national standards organisations.*

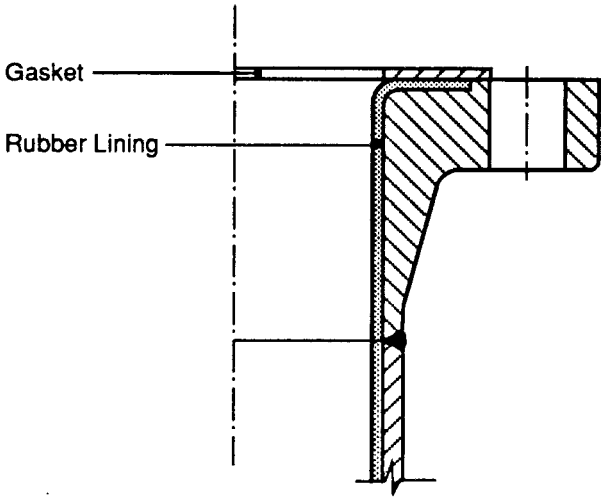
## APPENDIX 1 FLANGED CONNECTIONS FOR HARD RUBBER-LINED PIPING




BLIND FLANGE - SPECIAL FACING

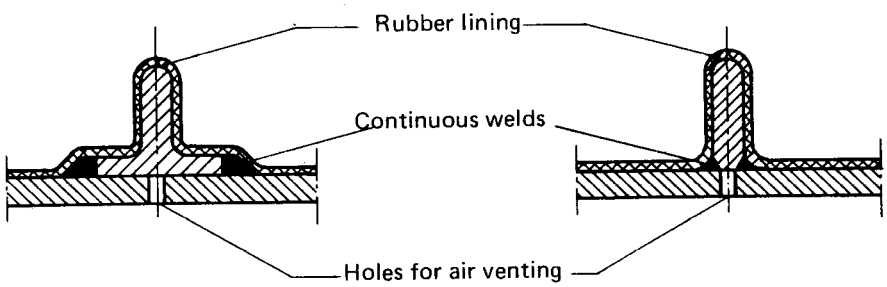



SLIP ON FLANGE - SPECIAL FACING



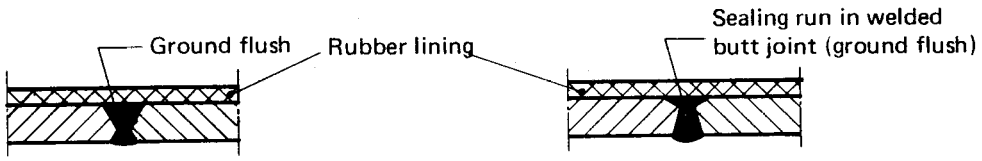

WELDING NECK FLANGE - SPECIAL FACING

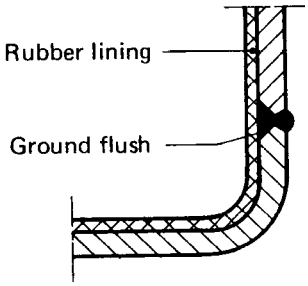
## APPENDIX 2 AIR VENT HOLES/WELDING DETAILS




NOTE: Air vent holes to be drilled at regular distances. Diameter of holes depends on dimensions of vessel, but is generally 5 mm

## WELDING DETAILS



## APPENDIX 3 JOINTS IN RUBBER LININGS

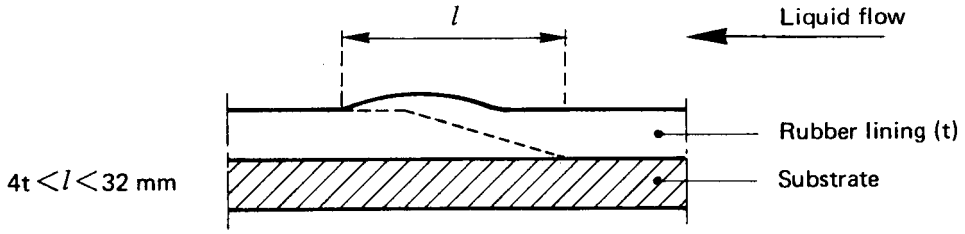



Fig. 1
OVERLAP BEVEL JOINT
(1 layer)

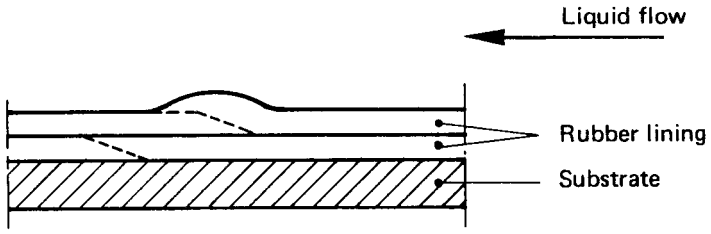



Fig. 2
OVERLAP BEVEL JOINT
(2 layers)

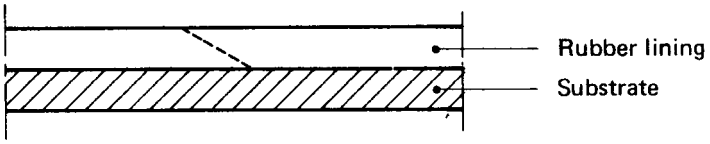



Fig. 3
FLUSH JOINT
(Brick lining not shown)