



Materials System Specification

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Specification for Lining of Tanks
and Vessels with Elastomeric Materials

Document Responsibility: Non-metallic Standards Committee

Saudi Aramco DeskTop Standards

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1 Scope

This specification covers the requirements for materials and procedures to be used for lining metallic tanks and vessels either at the rubber lining Contractors own workshops, at the fabricators workshop or at the construction site. The protective elastomeric lining selected shall provide the maximum chemical and mechanical resistance for the service and the operating conditions. The adhesives used shall be compatible with the selected elastomeric liner and shall meet the service physical and chemical conditions.

2 Conflicts and Deviations

- 2.1 Any conflicts between this Specification and other applicable Saudi Aramco Materials System Specifications (SAMSSs), Engineering Procedures (SAEPs), Engineering Standards (SAESs), Standard Drawings (SASDs), or industry codes and standards, and forms shall be resolved in writing by the Company or Buyer Representative through the Manager, Consulting Services Department of Saudi Aramco, Dhahran.
- 2.2 Direct all requests to deviate from this Specification in writing to the Company or Buyer Representative, who shall follow internal company procedure [SAEP-302](#) and forward such requests to the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

3 References

This Specification is based on the latest edition of the references below, unless otherwise stated.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

[SAEP-302](#)

Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement

3.2 Industry Codes and Standards

American Standards for Testing and Materials

[ASTM D2240](#)

Test Method for Rubber Property - Durometer Hardness

[ASTM D429](#)

Test Method for Rubber Property - Adhesion to Rigid Substrates

British Standards

<u>BS 903 Part A21</u>	<i>Determination of Rubber to Metal Bond Strength</i>
<u>BS 6374-5</u>	<i>Lining Equipment with Polymeric Material for the Process Industries Part 5: Lining with Rubbers</i>

International Standards Organization

<u>ISO 813</u>	<i>Physical Testing of Rubber - Determination of Rubber to Metal Bond Strength-Adhesion to Rigid Substrates 90° Peel Method</i>
<u>ISO 8501 Part 1</u>	<i>Preparation of Steel Substrates before the Application of Paint and Related Products - Visual Assessment Surface Cleanliness</i>
<u>ISO 9002</u>	<i>Quality Management Systems - Requirements</i>

Swedish Standard

<i>SIS 05 5900</i>	<i>Pictorial Surface Preparation Standards for Painting Steel Surfaces</i>
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4 Definitions

Accelerator: A substance which hastens the vulcanization of an elastomer, causing it to take place in a shorter time or at a lower temperature.

Compounding: The action of introducing various additives to raw polymer material to affect its physical properties. Additives can include curative, accelerator, secondary accelerator, retarder, plasticizer, softening agent, release aid, anti-oxidant, anti-ozonant, acid acceptors, flame-retardant, filler, pigment, etc.

Cross-Linking Agents: Chemicals that bond polymer chains together to form a thermoset rubber product.

Cure: see vulcanization.

Elastomer: A polymer with the properties of rubber. Polymers that can be formulated as elastomers are polyurethane, butyl rubber, silicones and specially treated ethylene-propylene copolymers.

Hardness: The resistance of a material surface to penetration by an indenter of specified dimensions under specified load. Hardness is typically tested on flat buttons, for curved surfaces the 'Apparent Hardness' is often quoted, as IRHD and Shore A values tend to be more variable when measured across small curved surfaces, as is the case with O-rings.

Vulcanization: A thermosetting reaction involving the use of heat and pressure, resulting in greatly increased strength and elasticity of rubber-like materials.

Engineer: Field Engineer in charge, consulting with CSD nonmetallic engineer.

5 Requirements

5.1 General

- 5.1.1 Design of Tanks and Vessels to be lined.
- 5.1.2 Tanks and vessels design to be lined shall be sufficiently rigid to avoid any possibility of deformation which may result in damage to the lining during transportation, installation and operation.
- 5.1.3 All welded joints shall be continuous and ground smooth to a minimum of $\frac{1}{8}$ " radius for convex corners and to a minimum of $\frac{1}{4}$ " radius for concave corners.
- 5.1.4 All welds shall have been ground smooth and flush on the side to be covered with the selected rubber. The welds shall be free from defects such as undercutting, cracks, porosity, or surface cavities.
- 5.1.5 All surfaces shall be free of weld splatter and foreign material.
- 5.1.6 Bolted joints shall be allowed only if they can be dismantled for lining.
- 5.1.7 The Contractor shall be responsible for ensuring that he is fully conversant with the requirements of this specification.
- 5.1.8 The Contractor shall notify the engineer, in writing of the shelf-life and pot-life of all adhesive and primer materials. All adhesives and other materials that have exceeded their shelf-lives shall be removed from the site at the Contractor's expense.
- 5.1.9 The Engineer shall designate ground area for the storage and mixing of materials.

5.2 Documentation

Before the commencement of lining, the Contractor shall have the latest issues of the following documentation:

- **A quality plan:** shall comply with the requirements of this specification.
 - **Test reports and documentation:** shall be as required by Section 5 of this specification.
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- **Material certificates:** required to verify analysis and properties of materials used.
- **Repair methodology:** details of repair methods shall be submitted for review and approval.
- **An initial inspection report:** shall be completed before work is commenced and shall contain details of the extent of the proposed repair. The report shall be submitted with the tender.

5.3 Methods of Surface Preparation

Blast cleaning shall be Sa 2½ in accordance with the requirements of the Swedish Standard SIS 05 5900. The finish is defined as one from which oil, grease, dirt, rust scale and foreign matter have been completely removed from the surface, except for light shadows streaks or discoloration and pitting. For old tanks, the surface might have been pitted, allowing slight residues settling at the bottom of the pits. These should be removed by brushing. Following cleaning, all dust shall be removed. The surfaces to be lined shall be dried.

The Contractor shall inspect the surfaces to be lined and confirm that after cleaning and blasting, they are acceptable for application of the elastomeric liner.

Immediately prior to the application of the selected elastomeric liner, the surface to be lined shall be free of all rust and foreign matter. Spot cleaning may be done by wire brushing followed by solvent cleaning.

All surfaces to be lined shall be maintained at a temperature of at least 3°C above the dew point throughout the preparation and lining processes. If there is a risk that this condition will not be maintained due to ambient temperature, dehumidifying and/or heating equipment shall be used.

6 Materials and Equipment

6.1 Adhesives

Elastomeric lining are sheet-applied and bonded to the steel substrate.

Selection of adhesive shall depend on the type of elastomer to be used as a liner and a laboratory adhesion test.

Adhesives shall be tested for their viscosity and homogeneity before applications onto the surface of the tank or vessel to be lined. It is mandatory to give a first and primer coat of the adhesive over the blasted surface immediately after sandblasting. Solvent in the adhesive shall be allowed to evaporate

between the application of successive coats and subsequent application of the lining.

The degree of Adhesion shall be determined by a 90% peel-pull test conducted in accordance with [BS 903 Part A21](#).

Mixing and application of adhesive shall be in accordance with the manufacturers' recommended procedures and the supplementary requirements of this Section.

6.2 Type of Elastomer

The type of elastomer shall be identified, as per Table 1, and agreed upon with the contractor and shall be such that the lining Contractor is prepared to state that it will satisfy the chemical and physical conditions specified as regards any agreed service life and deterioration by prolonged contact with the contents of the tank or vessel.

Selection of the correct elastomer for a specific application requires that all details concerning the tank or vessel to be lined, and the process to be contained, shall be itemized as shown below:

- *Chemicals.* Fluid composition and per cent of each component.
- *Abrasion.* Abrasive particle type, weight, and size; velocity of particles movement; proportion of solids; nature of abrasion action (sliding or impinging).
- *Temperature.* Maximum, minimum, operating temperatures and temperature cycle time.
- *Pressure.* Maximum, minimum, operating pressure and vacuum and pressure cycle time.

6.3 Special Properties

When required, a lining shall have one or more of the following properties.

- Resistance to heat
 - Resistance to ozone
 - Resistance to chemicals
 - Abrasion resistance
 - Resistance to release of contaminants
 - Resistance to water
 - Resistance to oil.
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The information shown in the chemical resistance, Table 1, shall be used by the Contractor to select the type of elastomer for each application. Plant engineer shall evaluate the selected type of elastomer to ensure that the selected elastomer satisfy the application requirements.

6.4 Test Samples

The contractor shall be required to supply a reference number for the approved mix and samples of the vulcanized rubber sheet for test and future reference in case of dispute, and shall not change the mix in any way except by agreement with the engineer.

Table 1 – The Physical and Chemical Properties of Elastomers Typically Used as Liners for Tanks and vessels

Properties	NR ¹	SBR ²	NBR ³	EPDM ⁴	CR ⁵	SILICONE ⁶	VITON ⁷
Hardness, A	30-95	40-95	40-95	30-85	30-90	40-80	50-95
Heat Resistance: Max Cont. °C	75	85	100	130	95	205	205
Max. Intermittent °C	105	115	130	150	125	300	300
Low Temp Resistance	-60	-55	-20	-50	-35	-60	-20
Oxidation Resistance	Fair	Fair	Good	Excellent	Very Good	Excellent	Out-standing
Ozone and Weathering	Poor	Fair	Fair	Out-standing	Very Good	Out-standing	Out-standing
Oil Resistance	Poor	Poor	Excellent	Fair	Good	Excellent	Excellent
Solvent: - Alcohol	Good	Good	Good	Good	Good	Good	Good
- Acetone	Fair	Fair	Poor	Good	Fair	Fair	Poor
- Benzene	Poor	Poor	Poor	Poor	Poor	Poor	Good
Chemical: -Acids	Good	Good	Good	Good	Good	Fair	Excellent
- Bases	Good	Good	Fair	Good	Fair	Fair	Good
Physical Strength	Excellent	Good	Good	Good	Good	Poor	Good
Compression Set	Good	Good	Good	Good	Good	Good	Good
Tear and Abrasion	Excellent	Good	Good	Good	Good	Poor	Good

Properties	NR ¹	SBR ²	NBR ³	EPDM ⁴	CR ⁵	SILICONE ⁶	VITON ⁷
Resilience	Excellent	Good	Good	Very Good	Very Good	Fair	Poor
Gases Permeability	Poor	Fairly Low	Good	Fairly Low	Very Good	Good	Very Low
Electrical Strength	Excellent	Excellent	Poor	Excellent	Good	Excellent	Good
Flame Resistance	Poor	Poor	Poor	Poor	Self Extinguishing	Good	Self Extinguishing
Water Resistance	Very Good	Fair	Good	Excellent	Good	Good	Good

1; Natural Rubber, 2; Styrene Butadiene Rubber, 3; Acrylonitrile Butadiene Rubber,
 4; Ethylene Propylene Diene M-class rubber, 5; Polydimethylsiloxane

6.5 Application of Elastomeric Liners and Workmanship

6.5.1 Temperature and Humidity

Linings shall not be applied when the humidity of the surrounding air exceeds 80% R.H, the ambient temperature is below 10°C, or dusty conditions.

6.5.2 Adhesive Application

Before application, the adhesive shall be thoroughly mixed and applied to a primed substrate by brush, roller or spry to form a smooth, continuous unbroken coating. Solvent in the adhesive shall be allowed to evaporate between the applications of successive coats.

6.5.3 Application of Sheets of Elastomeric Liners

The thickness of the elastomeric liner shall be selected to fulfill the chemical and physical requirements of the type of the fluid and its operating conditions. Linings of nominal thickness of 6 mm should be applied in at least two or more layers. The thickness tolerance of the elastomeric liner shall be $\pm 10\%$.

6.5.4 Pre-shrinking

In unvulcanized sheet any preshrinking shall be carried out as a first step. Faulty joints in a lining can be caused by certain elastomeric compounds shrinking on vulcanization. Pre-shrinking (in the factory or on site) prior to vulcanization will be necessary.

6.5.5 Joints

There are primarily two types of joints, although there are variations of each, the 2 inch lap joint and the butt joint with cap strip. The joint selected is usually determined by the elastomeric liner to be used.

6.5.6 Sheet Lining

After the application of adhesive, the metal shall be inspected to determine the best method of lining. Because equipment to be lined varies as to size, shape, location of projections, irregularities and flanges, there is no set method of lining.

The selected protective lining shall provide the maximum chemical and mechanical resistance for the identified service.

6.5.7 Workmanship

Workmen shall be suitably qualified to carry out lining in either the rubber lining contractor own workshops, at the fabricators workshop or at the construction site.

Workmanship shall be high quality in all areas and the finished appearance shall conform to the highest standards.

6.5.8 Verification of Continuity of Linings

After the completion of the rubber lining and before vulcanization, a high frequency sparks test shall be carried out as described in Clause 6.7 and any defects detected shall be rectified.

6.6 Vulcanization

6.6.1 Vulcanization Methods

The method of vulcanization shall be as agreed upon between the Engineer and the lining Contactor and shall be one of the following:

- Autoclave vulcanization – carried out under pressure in an autoclave or, if the vessel is suitable, using the vessel as an autoclave. This method is preferable to the other methods when the size of the vessel to be lined permits its use.
 - Open vulcanization – carried out by covering the tank or vessel with canvas to form an enclosure, and injecting exhaust steam or hot gas into the enclosure. The heat should be evenly distributed to achieve a uniform vulcanization.
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- Hot water vulcanization – achieved by filling the tank or vessel with water which is then heated to the required temperature.
- Chemical vulcanization (self-vulcanization) – obtained at room temperature by either incorporating chemicals in the compound, or applying chemicals to the surface of the lining, or both.

6.6.2 Vulcanization of Lining

Vulcanizing or curing methods, including temperature, time required, etc., shall comply with the stock manufacturer's written procedures for the rubber stock to be used. Uniform temperatures shall be maintained during the curing process, and the lining or covering shall be protected against excessive heat losses to insure uniform vulcanizing conditions. Tanks or Vessels should be covered or otherwise insulated from the detrimental effects of inclement weather and temperatures below 10°C.

The following instrumentation shall be installed to monitor temperatures:

- Internal temperature and pressure measuring devices
- Internal temperature recorder
- Outside steel temperature measuring devices.

Contractor shall use a multi point recorder to measure temperatures. These readings are to be recorded hourly, every shift during temperature warm-up and throughout the entire cure cycle. Cure times may have to be adjusted in accordance with data or curves on outside metal surface temperature vs. time provided by the lining manufacturer. After completion of the cure cycle, the cured linings shall attain hardness values per those recommended by the manufacturer.

6.7 Inspection and Repairs after Cure

Following complete vulcanization, the lining shall be subjected to the following inspections:

6.7.1 Hardness

A durometer (Shore "A") hardness survey shall be made of the cured lining. A sufficient number of readings shall be taken at all elevations to assure all areas of the lining are properly cured. At the discretion of the Engineer or his representative, tests for durometer hardness shall be undertaken in accordance with the requirements of [ASTM D2240](#). In cases where the lining fails to meet specification, the lining shall be

rejected and the costs of inspection and repair shall be borne by the Contractor.

6.7.2 High-voltage Spark Tests

In accordance with the requirements of [BS 6374-5](#), high voltage spark tests shall be made before and after vulcanizing. If any defects are revealed, proper repairs shall be made, and the repaired area shall be re-tested to ensure that the defect has been eliminated. Such repairs shall meet the required specification and be to the satisfaction of the Engineer. Spark testing shall be conducted over the entire surface lining with a high potential spark tester adjusted to 10,000 - 15,000 volts.

6.7.3 Thickness and Adhesion

The thickness tolerance on nominal dimensions shall be $\pm 10\%$.

The degree of adhesion shall be determined by a 90% peel-pull test conducted in accordance with [BS 903 Part A21/ISO 813](#). When specified, or when poor application is suspected, hydraulic or vacuum testing (or both) at an agreed pressure or vacuum, and for an agreed time, shall be applied to the lined equipment. The application shall be in a manner agreed to by the Engineer or his representative. During the pressure test, no leakage shall occur. During the vacuum test, the lining shall show no defects upon re-inspection. The elastomer shall be adhered to the steel so that tests will show strength of adhesion that is specified for each lining.

6.7.4 Visual Examination

All joint and seam areas shall be visually inspected. Defective areas shall be repaired and the lining shall be retested and inspected after curing.

6.7.5 Patch Repair

The repair materials, application methods and curing procedures shall be based upon the type, size and frequency of the defects. All lining material containing bubbles and blisters shall be removed to an area of good adhesion. Bevel edges of remaining elastomer to approximately 30° angle to the metal and buff existing elastomer back at least 4" from the edge of area to be repaired. All exposed steel surfaces shall be prepared by grinding to a clean bright metal finish. Upon completion of surface preparation, adhesives shall be prepared and applied in accordance with the procedures for Adhesives, Mixing and Application; prime coat only on the steel and the remaining adhesive system on the entire patch area.

Upon completion of adhesives system application, elastomer shall be applied to repair cracks and small areas, fill in the area flush with existing lining using full thickness original lining stock. Cover this with larger patch extending out 4" over the existing lining. For larger areas (above 12" diameter or equivalent) it will be satisfactory to use a single layer of the full thickness original lining stock over the metal area bringing stock up over the bevel and back 4" over the existing lining.

7 Documentation

This Section outlines all inspections and documentation required by the Contractor for the satisfaction of the contract. It shall be the Contractors' responsibility to maintain all documentation and turn over a complete package to the Company Site Representative at the completion of the contract. Routine type "log" entries such as temperature, pressure, relative humidity, time, date, etc. will be entered by the Contractor. Other entries for documentation concerning the quality of work such as surface profile, seams, overlaps, spark testing, etc., will be made by the Contractor after proper testing and inspection by the Company Site Representative. The Company Site Representative will review all entries on a daily basis.

The following inspections are required for surface preparation:

- Inspection after elastomer removal and buffing to assure no metal damage has taken place.
- Inspection after solvent cleaning
- Inspection after abrasive blast cleaning. Use a KTA-Tator Comparator or something similar for this inspection and document. Make one check at minimum of 90° increments for each staging level.
- Inspection after blow down, brush and/or vacuum cleaning prior to application of primers and adhesives.
- Documentation: All inspections listed above shall be documented.

8 Certification

A test certificate, signed and dated by the Contractor shall be provided with each unit and shall contain, but shall not necessarily be limited to, the following information:

- The contractor's name
 - The contractor's job number/reference number
 - The customer's company name
 - The customer's order reference number
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- The unit description
- The unit's identification number

9 Packing and Marking

9.1 PACKING

Except in the case of items lined in situ, the tanks and vessels shall be suitably protected in order to prevent damage during normal storage and transportation.

9.2 MARKING

The following information shall appear in legible and durable marking on a label securely attached to each lined item:

- The standard to which the lining was applied
- The lining Contractor's name, trade mark or both
- The date of the application of the lining
- Any other information requested by the Engineer

10 Quality Assurance and Control Provisions

10.1 Quality Management System (Contractors)

The requirements of [ISO 9002](#) shall apply.

The Contractor shall supply an assessment report on the Contractor's Quality Management and Quality Control System issued by an independent Quality Assurance Authority approved by the Engineer. This assessment report shall be dated not more than twelve months prior to tender closing date and shall be submitted with the tender.

Responsibility for and all associated costs of compliance with this clause shall rest with the Contractor.

10.2 Quality Management System (Sub-contractors)

All contracts issued by the Contractor shall require that sub-contractors comply with the requirements of this specification and [ISO 9002](#).

10.3 Quality Assurance Enhancement

Should the Contractor, or any of the proposed sub-contractors, not comply with Clause 5.1 or 5.2 at the time of tender, a contract may be awarded subject to a

written undertaking, to enhance the Contractor's and/or sub-contractor's quality assurance system to the satisfaction of the Engineer before commencement of the contract.

10.4 Quality Plan

The Contractor shall submit a quality plan at time of tender for review by the Engineer.

10.5 Quality Control

10.5.1 General

The Contractor shall provide all the facilities necessary to ensure satisfactory surface preparation and application of linings. All workmen shall at all times be under the supervision of an experienced supervisor.

10.5.2 Access

The Engineer's representative shall have access at all reasonable times to inspect the surface preparation and the application of any or all of the lining to ensure compliance with this specification. No steelwork or items of plant shall be delivered to site until inspection has been carried out and a release certificate issued.

Revision Summary

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New Saudi Aramco Materials System Specification.

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Editorial revision to remove the committee members list.

27 February 2013

Editorial revision to change the Document Responsibility from Materials and Corrosion Control to Non-metallic Standards Committee.