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(formerly RP0298-98)
Item No. 21085

Standard Practice

Sheet Rubber Linings for Abrasion and Corrosion Service

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Foreword

Sheet rubber linings are frequently used for the protection of surfaces such as metal, concrete, or fiberglass against chemical attack, abrasion, or both. Selection of proper lining materials and good lining workmanship are important components of lining performance.

The purpose of this standard practice is to outline procedures for providing sheet rubber lining protection to new and used equipment, such as piping and vessels. Included are recommendations for surface preparation and the dimensions of piping that can be rubber lined. An explanation of types of rubber lining materials available and their methods of cure are also given.

This standard is useful to the specification writer as well as the end user. This standard can be used alone or in conjunction with detailed specifications addressing special needs of the end user.

This standard was originally prepared in 1998 by NACE International Task Group T-6A-62, a component of Unit Committee T-6A on Coating and Lining Materials for Immersion Service. It was reaffirmed in 2007 by Specific Technology Group (STG) 03 on Coatings and Linings, Protective—Immersion and Buried and is published by NACE under the auspices of STG 03.

In NACE standards, the terms *shall*, *must*, *should*, and *may* are used in accordance with the definitions of these terms in the *NACE Publications Style Manual*, 4th ed., Paragraph 7.4.1.9. *Shall* and *must* are used to state mandatory requirements. The term *should* is used to state something considered good and is recommended but is not mandatory. The term *may* is used to state something considered optional.

NACE International Standard Practice

Sheet Rubber Linings for Abrasion and Corrosion Service

Contents

Section 1: General

1.1 This standard provides requirements for sheet rubber lining of various equipment for protection against corrosion and abrasion. This standard can be used in design, installation, inspection, testing, and storage of rubber-lined equipment.

1.2 This standard addresses sheet rubber (both natural and synthetic) applied over surfaces such as metal and concrete substrates.

1.3 Brushed, trowel-applied, or sprayed rubber linings are outside the scope of this standard.

Section 2: Definitions

Adhesion: The bond between a rubber surface and a nonrubber surface (e.g., metal, wood); the strength of the bond between two uncured rubber surfaces or plies.

Adhesive: Part of a cement system applied over prepared surfaces for bonding them to rubber.

Autoclave: A heavy steel vessel in which rubber articles are vulcanized by means of steam under pressure.

Blister: A cavity within the lining material, between the lining material layers, or between the lining and substrate.

Butt joint: A joint made in a rubber part before or after vulcanization by placing the two pieces to be joined edge-to-edge.

Calender: A machine equipped with two or more heavy, internally heated or cooled rolls used for the continuous sheeting or “plying up” of rubber compounds.

Closed skive: A reverse-angle cut along the edge of a rubber panel. This enables the installer to stitch down the cut edge so that the bottom layer of rubber is protected from exposure to the commodity.

Curing: Chemical process of developing the intended properties of a coating or other material (e.g., resin) over a period of time. For the purposes of this standard, the act of vulcanization; a description of a definite time and temperature of vulcanization.

Defect: An abnormal flaw in the lining that prevents it from performing its function.

Durometer gauge: Apparatus for determining the hardness of rubber by measuring its resistance to the penetration of a blunt indenter point impressed on the surface by spring action.

Durometer hardness: An arbitrary numerical value that measures the resistance to indentation of the blunt indenter point of the durometer.

Extruder: A machine for continuous forming of rubber by forcing through a die.

Fisheye: A thin, elongated void in a calendered sheet that is not detrimental to the lining.

Laitance: A layer of weak and nondurable material containing cement and fines from aggregates, brought by bleeding water to the top of overwet concrete, the amount of which is generally increased by overworking or overmanipulating concrete at the surface by improper finishing or by job traffic.

Lap joint: A joint made by overlapping the edge of one piece of material flat over the edge of another.

Overlay: The addition of another layer of lining over an in-place lining construction before vulcanization.

Patch or **repair:** Remedy of a defect in the lining after vulcanization; involves applying sheet stock to fully cured or vulcanized lining.

Pinhole: A small, pore-like defect or leak extending entirely through the lining thickness and appearing as a discontinuity; synonymous with holiday.

Ply: One layer in a laminated structure.

Primer: The first coat of an adhesive system applied over a prepared surface for adhesion of rubber.

Rubber: Natural rubber or any synthetic, elastomeric material with physical properties similar to those of natural rubber.

Skive: A cut made on an angle to the surface, producing a tapered or feathered edge.

Spark tester: A high-voltage test unit used to detect breaks or holes in a lining.

Substrate: The surface on which a lining is applied.

Surface imperfection: Condition on the surface of rubber that results in a nonuniform appearance but is not detrimental to the serviceability of the lining.

Tie gum: A backing layer of rubber employed to promote bonding of two surfaces; usually a soft rubber compound.

Vulcanization: An irreversible process during which a rubber compound achieves its designed properties through a change in its chemical structure.

Wrinkle: A crease in the rubber; thickness is reduced in the valleys of the crease.

Section 3: Design of Equipment to Be Lined

3.1 The basic design of equipment to be lined shall be based on applicable standards for such equipment. The rubber lining shall not be relied upon to provide any structural strength in these designs.

3.2 Tank Design

3.2.1 Tanks and vessels fabricated from steel that are to be rubber lined shall be designed in accordance with NACE SP0178.[1] This standard provides guidelines for the following.

(a) Weld preparation: Designation C is required as a minimum.

(b) Weld profile

(c) Grinding corners to a radius

(d) Weld spatter removal

3.2.2 When designing tanks and vessels that will be rubber lined, additional care shall be taken to prevent built-in voids or air pockets such as those inside pipe and tube sections, in angles welded back-to-back, and in similar fabrications. Because heat cure is a common method of rubber curing, any air trapped in such voids or pockets expands on heating and may cause blistering in the rubber. Air pockets shall be vented on the outside of the vessel, and these vents shall be plugged after cure is complete.

3.2.3 This method of test voltage adjustment shall be performed while the exploring electrode and grounding are in the expected operating positions. If the above conditions change, it may be necessary to readjust the test voltage setting.

3.3 Steel Pipe Design

3.3.1 The design requirements in NACE SP0178 shall be followed in the fabrication of pipe that is to be rubber lined. Additional requirements are given in Paragraphs 3.3.2 through 3.3.6.

3.3.2 Pipe connections shall be made with flanges or grooved mechanical couplings. If flanged connections are used, flat-faced flanges should be used.

3.3.3 The ends of grooved pipe shall be specially machined for rubber lining. Regular grooved pipe may be lined if service is only abrasive and not corrosive.

3.3.4 Use of bolt holes that must be rubber lined shall be avoided. If it becomes necessary to rubber line bolt holes, the bolt holes shall be oversized to allow for the thickness of the rubber lining.

3.3.5 Plain-end pipe shall have rubber extended over the plain end and carried onto the exterior surface, at least 50 mm (2 in.) over the plain end.

3.3.6 ANSI[(1)] standard fittings may be rubber lined. If nonstandard fittings are involved, their suitability for rubber lining shall be checked before use.

3.4 Cast iron and ductile iron pipe work and fittings are suitable for rubber lining. However, these are susceptible to brittleness and porosity, which may present problems during handling and rubber lining installation.

3.5 Straight Pipe: The typical maximum lengths (measured between ends) of straight pipe that can be satisfactorily lined are given in Table 1.

[(1)] American National Standards Institute (ANSI), 1819 L St. NW, Washington, DC 20036.

TABLE 1
Typical Maximum Lengths for Straight Pipe

Pipe Size[(A)]	Pipe Length
51 mm (2.0 in.)	1.8 m (6.0 ft)
76 mm (3.0 in.)	3 m (10 ft)
100 mm (4.0 in.)	6 m (20 ft)
150 mm (6.0 in.)	9 m (30 ft)
200 mm (8.0 in.)	12 m (40 ft)
> 200 mm (> 8.0 in.)	> 12 m (> 40 ft)

[(A)] All pipe diameters nominal pipe size (NPS)

3.6 Fabricated Pipe Spools with Elbows

The typical maximum dimensions of bends and elbows that can be satisfactorily lined are given in Table 2. An example of an elbow is shown in Figure 1.

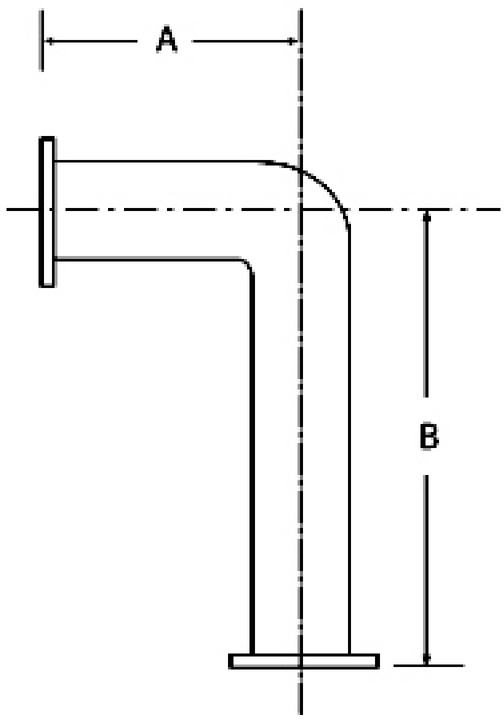


FIGURE 1
Elbow

TABLE 2
Typical Maximum Dimensions for Bends and Elbows

Pipe Size[(A)]	A maximum	**B maximum**
76 mm (3 in.)	150 mm (6 in.)	0.3 m (1 ft)
100 mm (4 in.)	250 mm (10 in.)	0.6 m (2 ft)
150 mm (6 in.)	380 mm (15 in.)	1.2 m (4 ft)
200 mm (8 in.)	460 mm (18 in.)	1.8 m (6 ft)
250 mm (10 in.)	530 mm (21 in.)	1.8 m (6 ft)
300 mm (12 in.)	610 mm (24 in.)	1.8 m (6 ft)
360 mm (14 in.)	760 mm (30 in.)	1.8 m (6 ft)
410 mm (16 in.)	1 m (40 in.)	1.8 m (6 ft)
460 mm (18 in.)	1 m (40 in.)	6 m (20 ft)
> 510 mm (> 20 in.)	1.5 m (60 in.)	> 12 m (> 40 ft)

[(A)] All pipe diameters NPS

3.7 Fabricated Pipe Spools with Reducers, Tees, etc.

The typical maximum dimensions of reducers and tees that can be satisfactorily lined are given in Table 3. A 50-mm (2-in.) diameter nozzle is the minimum recommended diameter that may be lined. Larger diameters should be used. Examples of a reducer and tee are shown in Figures 2 and 3.

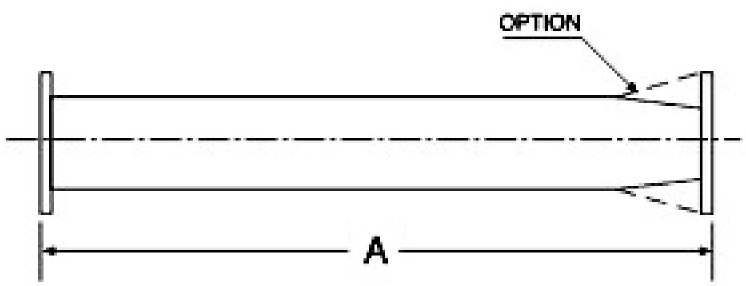


FIGURE 2
Reducer

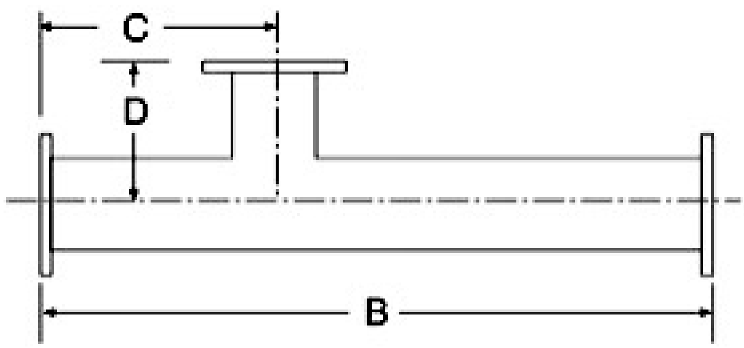


FIGURE 3
Tee/Nozzle

TABLE 3
Typical Maximum Dimensions for Reducers and Tees

Pipe Size[(A)]	A maximum	B maximum	C maximum	D maximum
64 mm (2.5 in.)	300 mm (12 in.)	1.8 m (6 ft)	150 mm (6 in.)	150 mm (6 in.)
76 mm (3 in.)	300 mm (12 in.)	3 m (10 ft)	150 mm (6.0 in.)	150 mm (6 in.)
100 mm (4 in.)	410 mm (16 in.)	6 m (20 ft)	200 mm (8 in.)	230 mm (9 in.)
150 mm (6 in.)	6 m (20 ft)	6 m (20 ft)	300 mm (12 in.)	460 mm (18 in.)
200 mm (8 in.)	6 m (20 ft)	12 m (40 ft)	300 mm (12 in.)	460 mm (18 in.)
250 mm (10 in.)	6 m (20 ft)	12 m (40 ft)	300 mm (12 in.)	530 mm (21 in.)
300 mm (12 in.)	6 m (20 ft)	12 m (40 ft)	300 mm (12 in.)	610 mm (24 in.)
360 mm (14 in.)	6 m (20 ft)	12 m (40 ft)	300 mm (12 in.)	610 mm (24 in.)
410 mm (16 in.)	6 m (20 ft)	12 m (40 ft)	360 mm (14 in.)	610 mm (24 in.)
>460 mm (18 in.)	12 m (40 ft)	12 m (40 ft)	410 mm (16 in.)	1.2 m (48 in.)

[(A)] All pipe diameters NPS

3.8 Concrete Equipment

3.8.1 Concrete shall be properly cured by being allowed to dry slowly. The curing time shall be at least 28 days.

3.8.2 The moisture level on the surface of the concrete shall be minimized before rubber lining installation.

3.8.2.1 One method for determining the presence of humidity on the concrete surface involves putting a 460 mm x 460 mm (18 in. x 18 in.) piece of clear plastic down on the concrete surface to be lined. The plastic shall be taped on all four sides so as not to allow any moisture to escape from underneath. The sheet shall be examined after 16 hours of application to detect any visible signs of condensation. If dew or condensation is noted under the sheet, the concrete surface is considered not completely dry.[2]

3.8.3 All underground vessels should be protected from water penetration. Application of a waterproofing membrane to external surfaces can provide adequate protection.

Section 4: Types of Rubber

4.1 Polyisoprene:[3] Polyisoprene has the chemical form $(C_5H_8)_x$. Natural rubber consists principally of polyisoprene, although some other molecular species may be present in some samples. Lining compounds based on polyisoprene rubber are resistant to the majority of inorganic chemicals with the exception of strong oxidizing agents. Resistance to organic chemicals is limited; polyisoprene rubber is unsuitable for use with hydrocarbons, halogenated hydrocarbons, mineral oils, esters, and many vegetable oils.

4.2 Styrene-Butadiene Rubber (SBR): These rubbers are copolymers of styrene ($C_6H_5CH{:}CH_2$) and butadiene (C_4H_6) monomers. They have properties broadly similar to those of the polyisoprene (or natural) rubbers compounded for similar applications.

4.3 Polychloroprene Rubber (CR) or Neoprene: Polychloroprene $(C_4H_5C1)_x$ linings have greater resistance to heat, ozone, sunlight, and many oils than the polyisoprene (or natural) rubbers. Polychloroprenes should not be used with halogenated hydrocarbons or aromatic hydrocarbons.

4.4 Butyl Rubber (IIR) or Chlorobutyl: Butyl rubbers are copolymers of isobutylene ($[CH_3]_2CCH_2$) with small proportions of isoprene (C_5H_8). Chlorinated butyl rubbers are generally easier to process than those that have not been chlorinated.

4.4.1 Lining compounds based on butyl rubbers have very good resistance to heat and chemicals, including some oxidizing agents, and have lower permeability to gases. They should not be used in the presence of free halogens, petroleum oils, hydrocarbons, or halogenated hydrocarbons.

4.4.2 If suitably compounded, linings based on butyl rubbers have lower water absorption than most other rubbers.

4.5 Ethylene Propylene Rubbers (EPR): Ethylene propylene rubbers are available as the copolymer (EPR) or the terpolymer (EPDM [ethylene propylene diene monomer]) of ethylene (C_2H_4) and propylene ($CH_3CH=CH_2$). Lining compounds based on these polymers have very good resistance to acids, alkalis, salts, ozone, and many organic chemicals, but they are not resistant to oils, hydrocarbons, or chlorinated solvents.

4.6 Nitrile Rubbers (NBR): Acrylonitrile (CH_2CHCN) butadiene copolymer (nitrile rubber) has excellent resistance to swelling caused by mineral oils and fuels. Its structure is $-CH_2CH=CHCH_2CH_2CH(CN)-$. The polymers should not be used with phenols, ketones, strong carboxylated acids, aromatic hydrocarbons, or nitrogen derivatives.

4.7 Hard Rubber and Ebonite Linings: Hard rubber linings are usually produced by incorporating higher levels of sulfur in the formulations than are used in soft rubber linings. Ebonites are highly unsaturated rubbers that have been compounded with sulfur levels between 25 and 50 parts per 100 by weight of rubber. They can be produced from natural or synthetic polyisoprenes, styrene-butadiene, acrylonitrile-butadiene, or polybutadiene rubbers, or from blends of these rubbers.

4.7.1 Some hard rubbers are produced with relatively low sulfur levels by the incorporation of various resins.

4.7.2 Hard rubbers and ebonites generally have higher chemical resistance than soft rubbers based on the same polymer types. Resistance to chlorine gas and to most aliphatic carboxylic acids is particularly improved. Chemical resistance generally increases with increased saturation of the vulcanized polymer.

4.7.3 Ebonites usually have an elongation of 2% to 10% at break. Ebonites are brittle compared to soft rubber lining materials at ambient temperatures. Brittleness can be reduced by using additives.

Section 5: Properties of Linings

5.1 Selection of Lining Materials: Detailed service conditions, including concentrations of different chemicals and the operating/design temperatures, shall be given to the rubber manufacturer or applicator during the selection of a suitable lining material.

5.2 Rubber Designation.

5.2.1 Rubber shall be identified with at least the following information.

(a) Manufacturer's name and product designation or generic product designation

(b) Hardness of rubber after vulcanization

(c) Method of vulcanization

(d) Lining thickness

5.3 Lining thickness refers to the nominal thickness of rubber before application. The thickness tolerance on nominal thickness shall be ±10% before cure.

5.3.1 The lining may be calendered in plies or extruded as a single thickness.

5.3.2 A commonly used thickness is 4.8 mm (0.19 in.). Thinner linings (3.2 mm [0.13 in.]) may be used. Thicker linings (6.4 mm [0.25 in.]) are necessary in cases of severe chemical exposure, abrasion or mechanical damage potential, or high operating temperatures. Lining thicknesses greater than 6.4 mm (0.25 in.) are typically applied in more than one layer. In special cases for abrasion service, in which adhesion is not critical, linings of 9.6-cm (0.38-in.) thickness can be applied in a single layer. Changes in thickness may occur during application or curing.

5.4 Bulkheads, outer radii of elbows, leading edges of agitator blades, and other high-wear areas may be lined with two layers of rubber if required by the purchaser.

Section 6: Application of Linings

6.1 Prejob Conference: The applicator and purchaser should resolve specific details of the rubber lining job before the start of work. These details include, but are not limited to, the following:

(a) Inspection hold and witness points

(b) Definition of responsibility for correcting defects

(c) Acceptable method of vulcanization of the rubber

(d) Brand name and nominal thickness of the specified lining material

(e) Acceptable repair methods, materials, and curing procedures

(f) An acceptable number and size of repairs after vulcanization

6.2 Atmospheric Conditions: To eliminate the possibility of any condensation occurring on the surfaces to be lined, the following temperature/humidity limitations shall be used:

(a) During surface preparation and application of adhesives, the surface temperature shall be at least 3°C (5°F) above the dew point.

(b) During application of rubber, the surface temperature shall be above 10°C (50°F) and at least 3°C (5°F) above the dew point.

6.3 Surface Preparation

6.3.1 Metals

6.3.1.1 All surfaces to be lined shall be abrasive blast cleaned to white metal (NACE No. 1/SSPC[(2)] SP 5).[4] In small areas where blasting is not practical, preparation by grinding equal to that specified in SSPC-SP 11[5] is acceptable.

6.3.1.2 Blasting profile shall be uniform with a minimum of 38 µm (1.5 mil). It shall be less than 102 µm (4.0 mil). Blast profile between 38 to 64 µm (1.5 to 2.5 mil) is optimum, although profile higher than 64 µm (2.5 mil) is acceptable.

6.3.1.3 Prior to blast cleaning, any visible oil or grease shall be removed by solvent cleaning in accordance with SSPC-SP 1.[6] Used equipment that is suspected of salt or chemical impregnation should be evaluated (and if necessary, neutralized) and high-pressure water jetted to remove contamination.

6.3.1.4 After blast cleaning, surfaces shall be free of dust or debris before application of adhesive.

6.3.2 Concrete

6.3.2.1 Concrete surfaces shall be prepared by blast cleaning to remove all laitance and form release agents. The profile shall be kept to a minimum, similar to that of 80 to 100 grit sandpaper.

6.3.2.2 After blast cleaning, surfaces shall be free of dust or debris.

6.3.2.3 Any voids shall be filled with appropriate filler.

6.3.2.4 Concrete surfaces to be lined shall be sealed by application of one coat of epoxy. The epoxy shall be allowed sufficient time to cure before application of an adhesive system.

6.3.3 Fiberglass

6.3.3.1 Fiberglass surfaces shall be lightly abrasive blasted or etched.

CAUTION: Consult the fiberglass manufacturer regarding temperature resistance of fiberglass because heating may be necessary to vulcanize rubber.

6.4 Application of Adhesives

6.4.1 The adhesive system shall be recommended by or meet the approval of the rubber manufacturer.

6.4.2 The primer coat of the adhesive system shall be applied to the substrate as soon as possible after completion of surface preparation and shall be completed before any visible rusting or surface contamination takes place.

6.4.3 The adhesive type, thickness of adhesive coats, compatibility with substrate, and the minimum and maximum drying times for the adhesives shall be as recommended by the rubber manufacturer.

6.4.4 Minimum drying times for adhesives are dependent on temperature and humidity. The adhesives also have a maximum drying time, after which the adhesive coat needs to be reapplied. The rubber manufacturer's recommendation shall be followed in this regard.

6.4.5 The adhesives may be applied by brush, roller, or spray methods.

6.4.6 Certain adhesives are degraded by exposure to direct sunlight. All surfaces shall be kept away from direct sunlight, and if an adhesive is exposed to sunlight, the adhesive manufacturer shall be consulted before proceeding.

6.4.7 Surfaces shall be kept dry and examined for any presence of oxidation if the surfaces are inadvertently exposed to moisture.

(2) SSPC: The Society for Protective Coatings, 40 24th St., 6th Floor, Pittsburgh PA 15222-4656.

6.5 Laying of Sheet Rubber

6.5.1 Some rubber materials require preshrinking. Rubber should be preshrunk as necessary, based on the rubber manufacturer's directions.

6.5.2 Types of Joints:

(a) Butt Joint: The adjoining sheets of rubber are laid next to each other, or "butting" each other (see Figure 4).

(b) Lap Joint: In this joint, the adjoining sheets are overlapped. (see Figure 5). The width of overlap is generally 50 mm (2 in.). It may be less in hard-to-reach areas.

(c) Slight Overlap: The adjoining sheets are skived at an angle of 45° or less and joined together to obtain an overlap of roughly 13 mm (0.5 in.), keeping the joint to a minimum of roughly half the thickness of the rubber (see Figure 6).

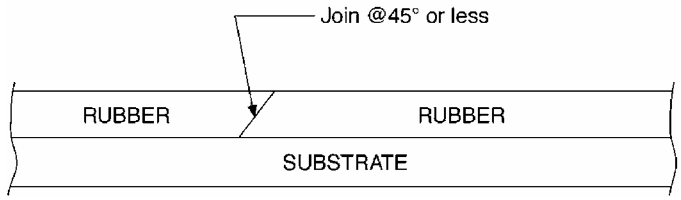


FIGURE 4
Butt Joint

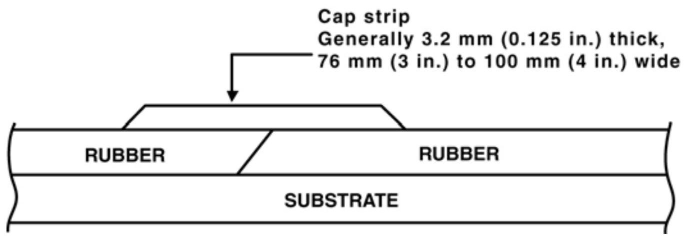


FIGURE 5
Lap Joint

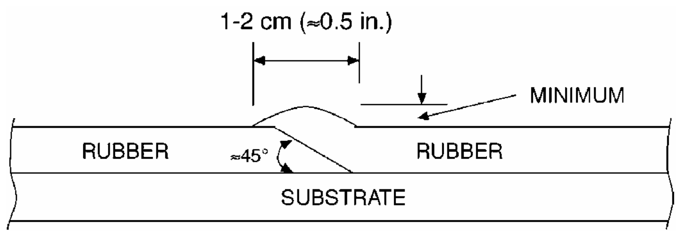


FIGURE 6
Slight Overlap

6.5.3 Joints in multilayered linings shall employ butt joints on the bottom layer. The joints in different layers shall be staggered.

6.5.4 No area of lining on a lap joint shall have more than two layers of sheet stock. Where three sheet corners come together, the overlay shall be cut down before laying the third layer.

6.5.5 The rubber lining sheet shall be cut to fit the dimensions of the substrate. For complex shapes, the rubber shall be cut to fit the contours of the substrate in such a way that the rubber is exposed to the least amount of stretch. For some complex applications, it may be necessary to discuss application methods in the prejob conference.

6.5.6 If there are unlined weldments on rubber-lined areas, the rubber lining shall cover the weld area and a minimum of 13 mm (0.5 in.) on the unlined weldment.

6.5.7 The contact face of rubber lining shall be made tacky by wiping with a suitable solvent or application of tack cement. Rubber materials that have a pretacked layer may not require this treatment.

6.5.8 Air trapped behind the rubber shall be removed by use of rollers and stitchers. Sufficient pressure should be used to completely evacuate the air. When using rollers, a minimum of 25% overlap shall be employed between passes. The seams, corners, and edges shall be flattened using stitchers.

6.5.9 A closed/reverse skive shall be used in the joints of rubber materials that have either a tie gum made of a different material or contain multilayered rubber sheet construction (See Figure 7).

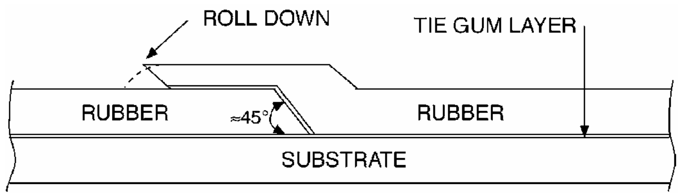
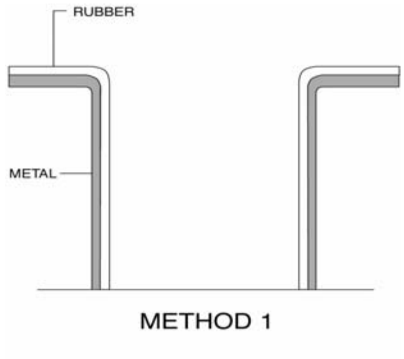


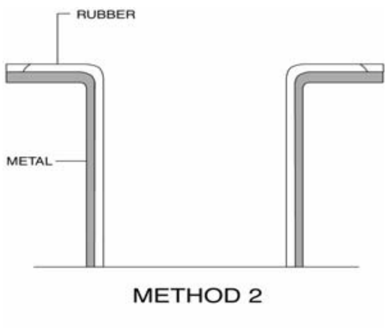
FIGURE 7
Reverse Skive

6.5.10 If lap joints are used, the top layer overlay edge shall be in the direction of flow wherever practical.

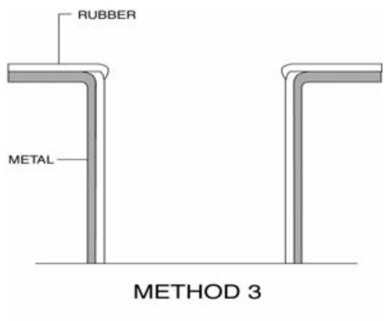
6.5.11 Flanges may be rubber lined by any of the three methods shown in Figure 8. Method 1 is the recommended method for all flanges less than 200 mm (8 in.) in diameter. Method 3 restricts the flow of liquids slightly and shall not be used for lining pipe flanges.



Note: Rubber from the inside of the pipe is stretched up to the outer edge of the flange.



Note: Rubber from the inside of the pipe is stretched to the middle of the flange face. An additional piece of rubber covers the rest of the flange face with a butt joint.



Note: Rubber from the inside of the pipe is trimmed at the flange face. A rubber piece covering the entire flange face slightly overlaps the inside edge of the pipe.

FIGURE 8
Methods of Rubber Lining Flanges

6.5.12 When lining the ends of grooved-end pipe, the rubber lining shall be carried from the inside of the pipe to the outside of the pipe into a special groove cut in the pipe for that purpose (see Figure 9). If no special groove has been cut in the pipe for lining, the rubber shall be carried from the inside to the outside of the pipe and buffed flat, flush with the exterior of the pipe (see Figure 10).

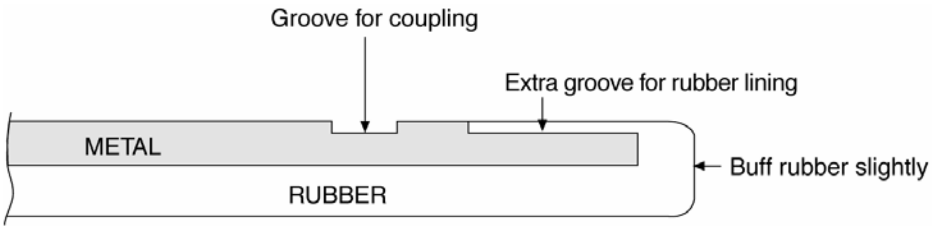


FIGURE 9
Grooved End Pipe with Extra Groove

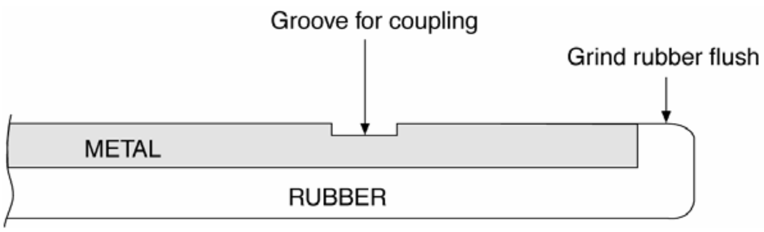


FIGURE 10
Grooved End Pipe without Extra Groove for Lining

6.6 Lining of Pipe

6.6.1 Large-diameter pipe into which a person can crawl may be lined just as other equipment is lined.

6.6.2 Rubber lining of small-diameter pipe may be done by the following method. The rubber sheet is rolled into a tube, and the tube is pulled through the pipe using a protective cloth to prevent premature adhesion. After the entire rubber tube has been pulled through the pipe, the protective cloth shall be removed by pulling it from one end. The rubber tube is adhered to the walls of the pipe either by using compressed air, which presses the rubber against the wall, or by using inflatable bags that are pulled through the tube. The bag is inflated to press the rubber against the pipe wall, and deflated to move it. The bag is moved section by section through the entire length of the pipe.

Section 7: Vulcanization

7.1 The five methods used to vulcanize sheet rubber lining onto substrates are described below. All are not appropriate for every rubber lining application. The specific method of vulcanization chosen depends on the type of rubber, the design and overall dimensions of the equipment, and the facilities available on site. Shielding or insulating the equipment during cure to contain heat reduces the duration of cure. Rubber thickness also affects curing time. Thicker rubber takes longer to cure. Time and temperature of cure shall be as directed by the rubber manufacturer. Certain rubber formulations can only be cured by steam under pressure.

7.2 Description of Methods

7.2.1 Method A—Autoclave Cure: The rubber-lined equipment is placed in an autoclave and subjected to steam under controlled temperature and pressure. This method of curing is preferred because it allows better heat transfer and a shorter cure cycle.

7.2.2 Method B—Internal Steam Cure: The pressure vessel is used as its own autoclave by closing off all openings and filling the vessel with steam under controlled temperature and pressure. The temperature of the steam and steel skin shall be monitored and a log shall be kept. Precautions shall be taken against failure of the steam supply or sudden cooling. The steam pressure shall not exceed the design pressure of the equipment.

7.2.3 Method C—Atmospheric Steam Cure: Vulcanization is achieved without pressure using atmospheric steam. The temperature of the steam and steel skin shall be monitored and a log shall be kept. To prevent collapse of a closed vessel, precautions shall be taken against failure of the steam supply or sudden cooling.

7.2.4 Method D—Water Cure: The rubber-lined equipment is filled with water and steam is injected to boil the water. The temperature and water level are maintained for the required period of time. Temperature of water and steel skin shall be monitored and a log shall be kept.

7.2.5 Method E─Chemical Cure: Vulcanization is achieved at ambient temperatures by topically applying a liquid vulcanizing agent to the surface of the rubber. Supplementary heat can help to speed up the cure.

Note: Some rubber products are prevulcanized or self-vulcanizing and do not require vulcanization after application.

7.3 Procedures Used For Vulcanization Methods

7.3.1 Autoclave Cure

7.3.1.1 Equipment shall be placed in an autoclave in such a manner to prevent the collection of condensate on the rubber.

7.3.1.2 The lining system shall be vulcanized using a time/temperature cycle approved by the rubber manufacturer.

7.3.1.3 The autoclave shall be equipped with calibrated temperature and pressure recording devices.

7.3.1.4 The vessel shall be removed from the autoclave after completion of cure and cooldown.

7.3.1.5 The curing process should be completed without interruption.

7.3.2 Internal Steam Cure

7.3.2.1 Equipment shall have a safety valve to prevent overpressure and a check valve to prevent vacuum during cooldown.

7.3.2.2 All equipment shall be positioned during cure so that complete condensate drainage is obtained. Tanks shall be cured with a steam trap connected to a bottom outlet.

7.3.2.3 Equipment shall be equipped with calibrated temperature and pressure recording devices.

7.3.2.4 The lining system shall be vulcanized using a time/temperature cycle approved by the rubber manufacturer.

7.3.2.5 During cooldown following the cure, air pressure should be maintained at 34 kPa (5 psi) above the curing pressure in order to prevent a vacuum.

7.3.3 Atmospheric Steam Cure

7.3.3.1 Outlets on equipment should be closed.

7.3.3.2 Open-top tanks shall be covered with fabric or plastic.

7.3.3.3 Proper provisions shall be made so that the bottom outlet drains away condensate.

7.3.3.4 All equipment shall have calibrated external metal temperature measuring devices. At least one such device shall be at the location farthest from the introduction of steam.

7.3.3.5 The steam inlet pipe should be brought in through an outlet near the bottom. Direct impingement of steam onto the lining should be avoided.

7.3.3.6 Internal steam shall be introduced to bring the temperature up to a target temperature of 93 to 99°C (200 to 210°F).

7.3.3.7 Air should be displaced from the tank with steam before the start of cure.

7.3.3.8 The temperature shall be raised gradually in accordance with the rubber manufacturer's recommendation so that the first stage of vulcanization is attained before blisters are formed.

7.3.3.9 Precure is optional and is acceptable if in accordance with applicator or rubber manufacturer recommendations. Precuring is a method of interrupting the cure for the purpose of detecting defects, blisters, etc., before final vulcanization.

7.3.3.10 During precure, steam should be introduced for approximately two hours. This time varies according to the size of the tank and the size of the steam line. The time should be long enough to expand any trapped air so that it can be found and repaired, and short enough so that the surface of the lining will not be cured to a state at which a repair cannot be made.

7.3.3.11 After precure repair, steam shall be introduced into the tank for completion of cure.

7.3.3.12 Uniform temperature shall be maintained during the curing process.

7.3.3.13 The exterior steel temperature should be a minimum of 68 to 71°C (155 to 160°F). The steam supply should be adequate to meet the needed heating capacity.

7.3.3.14 The duration and temperature of the curing cycle shall be as recommended by the rubber manufacturer. The duration of cure shall be based on the lowest recorded temperature reading.

7.3.4 Water Cure

7.3.4.1 The tank shall be filled with water.

7.3.4.2 The water shall be heated with open steam to a boil and monitored with a calibrated temperature-measuring device.

7.3.4.3 The duration of the curing cycle shall be as recommended by the rubber manufacturer.

7.3.4.4 At completion of cure, the tank should be allowed to cool before removal of the water. This is essential for maximum adhesion of the lining to the tank. The head of water keeps the rubber and steel in direct contact during the cooldown period.

7.3.5 Chemical Cure

7.3.5.1 Liquid curing agents shall be brushed on the surfaces of the rubber lining.

7.3.5.2 Rubber linings may be allowed to vulcanize under normal atmospheric conditions.

7.3.5.3 The curing time shall comply with the rubber manufacturer's specifications.

7.3.5.4 External heat may be used to reduce the cure time. The number and location of temperature recording devices shall be determined at a prejob conference. Climatic conditions and heat sinks associated with the vessel should be taken into account.

7.3.5.5 Certain chemicals can be extremely hazardous, and care should be taken in handling these, according to applicable material safety data sheets (MSDS).

7.3.5.6 Chemical cure takes place from the rubber surface inward. The adhesion achieved by this method is less than that achieved by other curing methods.

Section 8: Inspection and Testing

8.1 Stages of Inspection: A complete inspection program shall consist of the following:

(a) Substrate Inspection

(b) Blast Cleaning

(c) Adhesive Application

(d) Laying of Rubber

(e) Precure Inspection

(f) During-Cure Inspection

(g) Post-Cure Inspection

(h) Testing of Repairs

(i) Final Inspection

8.1.1 Documentation of each inspection shall be maintained for review by the customer (see Appendix A─Nonmandatory).

8.2 Blasting shall conform to NACE No. 1/SSPC-SP 5 with profile as described in Section 6. For fiberglass and concrete, the surface preparation shall be as previously defined in Paragraphs 6.3.2 and 6.3.3.

8.2.1 If certain defects are revealed in welds after blasting, the applicator shall inform the fabricator and purchaser for remedial action. These defects include porosity in the welds, pinholes, and similar defects that are not visible before blast cleaning. These defects shall be corrected before proceeding.

8.3 The applicator shall verify that the adhesives are in accordance with the manufacturer's recommendations and are within shelf life.

8.3.1 Adhesives shall be applied in their proper sequence and shall completely cover the surfaces to be lined. The surfaces shall be protected from exposure to direct sunlight after the adhesive is applied.

8.4 The thickness of the rubber lining material shall be inspected prior to application to ensure that it is within ±10% of the specified thickness.

8.4.1 Certification that the rubber material meets the specified physical characteristics for the lining shall be obtained from the rubber manufacturer.

8.4.2 After application of the lining, surfaces shall be visually inspected for defects, such as mechanical damage, cuts, blisters (trapped air), poor seam joints, roller skips, and wrinkles.

8.4.3 Any defects found before vulcanization shall be removed and lining overlayed with the original lining material. Any overlays made before vulcanization are not considered repairs.

8.5 Charts/logs of the time and temperature of cure shall be kept. The rubber manufacturer's recommendations shall be used as references for temperature and duration necessary to achieve full cure.

8.5.1 During an atmospheric cure or internal steam cure, condensate must be removed, and steam shall be distributed evenly throughout the equipment to avoid cold spots.

8.6 The lining shall be inspected visually for any defects by shining a light along the lined surface. Defects shall be marked and repaired.

8.6.1 Lined areas shall be spark tested with a high-voltage spark tester. This testing shall be done both before and after cure. Testing shall be done by trained personnel to avoid burning holes in the lining.

8.6.2 The spark test voltage shall vary depending on thickness and type of rubber. As a general guide, a 15,000-V testing voltage is sufficient for 6.4-mm (0.25-in.) thick natural rubber. See NACE SP0188[7] for details of the testing procedure.

8.6.3 For a cap strip construction (see Figure 11), the joints shall be spark tested before laying the cap strip. Lap areas in overlap construction have potential leak paths that exceed the spark gap and may not be detectable. All laps shall be visually inspected carefully to confirm continuity. For multilayer construction, each layer shall be spark tested before the next layer is laid.

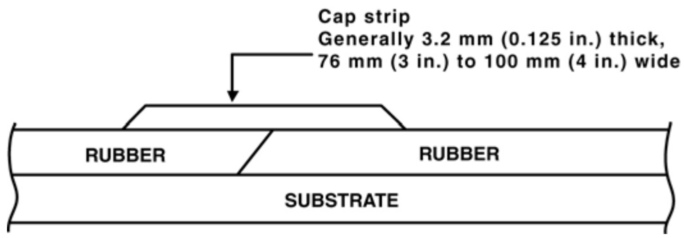


FIGURE 11
Cap Strip Joint

8.7 The cured rubber sheet shall be checked for hardness in accordance with ASTM D 2240.[8] The hardness shall be within the tolerance limits of the rubber manufacturer. At least one reading per 9 m^2 (100 ft^2) of lined area shall be recorded. Where inadequate steam or heat sinks may have caused rubber not to cure completely, additional measurements shall be taken to ensure proper hardness and cure. If areas with incomplete cure are detected, more steam shall be necessary to attain complete cure.

8.8 Steel test specimens (See Figure 12) shall be lined and cured with the equipment. At least one test specimen shall be lined and cured per 46 m^2 (500 ft^2) of lining area. For large pieces of equipment, the number of test specimens shall be as directed by the customer. The test specimens shall be tested for bond strength in accordance with ASTM D429,[9] Method E.

8.8.1 Adhesion testing may be done using a calibrated spring scale, and the adhesion values shall be recorded. An average adhesion of less than 0.45 kg/mm (25 lb/in.) shall be cause for rejection of the lining. If the rubber breaks during the test, the adhesion shall be considered adequate. Some hard rubbers break when bent to 90°.

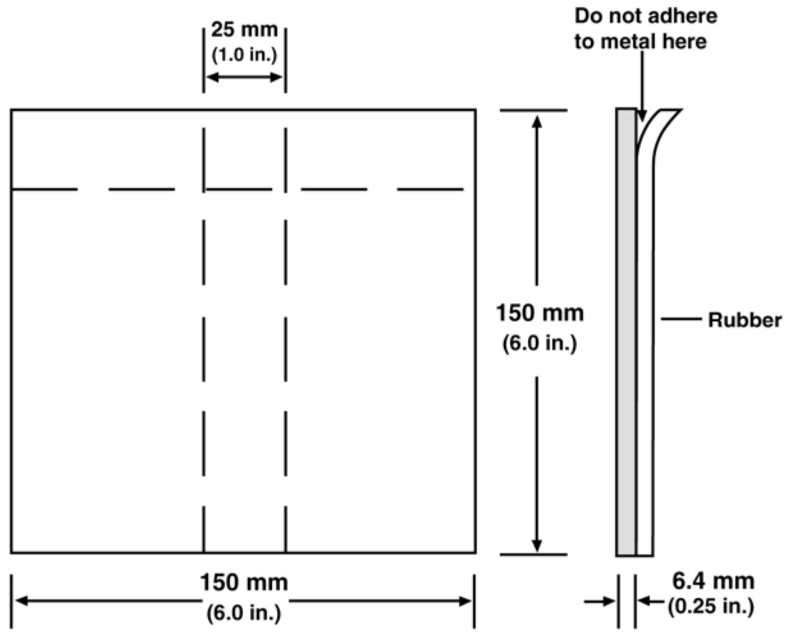


FIGURE 12
Sample for Adhesion Testing

Section 9: Repairing Rubber Lining

9.1 All damaged, defective, or nonadherent rubber lining must be repaired.

9.2 The repair of lining shall be preceded by removal of all defective lining. All loose lining, bubbles, etc., shall be cut out and only sound, properly adhered lining shall remain.

9.2.1 The sound lining shall be buffed to about 25 mm (1.0 in.) on all sides, preparing it to bond to the repair patch.

9.3 The exposed metal shall be either ground to white metal in accordance with SSPC-SP 11, or blast cleaned to white metal in accordance with NACE No. 1/SSPC-SP 5. The complete adhesive system shall be applied as recommended by the manufacturer. The periphery around the exposed metal and the backs of the repaired and overlay layers shall be cemented with tack cement.

9.4 For areas up to 0.09 m^2 (1 ft^2), an inlay of rubber shall be cut to fit the area to be repaired and adhered to the metal using the complete adhesive system recommended by the rubber manufacturer. Another piece of rubber shall be cut to cover this inlay rubber plus 25 mm (1.0 in.) in all directions. The periphery around the repair area, the top of the inlay rubber, and the back of the overlay rubber shall be cemented using tack cement.

9.5 If the repair area is more than 0.09 m^2 (1 ft^2), a rubber sheet shall overlay it by at least 25 mm (1.0 in.) in all directions.

9.5.1 The repaired and overlay layers shall be rolled in place using rollers or stitchers.

9.6 The curing of the rubber shall be achieved by either topical application of curing compound (for chemically cured rubber) or by steam (for steam cured rubber). The rubber lining shall be sufficiently cured before the equipment is put in service.

9.6.1 Because of the lower adhesion value of chemically cured repairs, equipment being used for vacuum service shall be cured by autoclave cure (Paragraph 7.3.1), internal steam cure (Paragraph 7.3.2), or atmospheric steam cure (Paragraph 7.3.3).

9.7 After the repair is cured, the repair shall be inspected for defects and hardness.

9.8 The material used for repair shall be recommended by the manufacturer of the original rubber and compatible with the service conditions of the equipment. The thickness shall be at least equal to the thickness of the original rubber lining.

Section 10: Storage and Handling of Rubber-Lined Equipment

10.1 Rubber-lined equipment shall be used for the service intended. Some service conditions include the chemicals to be handled, their concentrations, and operating temperatures. In case of any desired change in service conditions, the rubber manufacturer should be contacted to determine suitability for the desired service.

10.2 Rubber-lined equipment is susceptible to damage by extreme heat or cold temperatures during storage. To reduce such damage, painting exterior metal with light-color paint to reflect heat is recommended for equipment stored outside.

10.3 Rubber-lined equipment shall be stored away from sources of ozone, which include welding machines and electric generators.

10.4 Equipment lined with hard or semi-hard rubber shall not be exposed to freezing or below-freezing temperatures. These materials turn brittle at such temperatures, and thermal and mechanical stresses can cause them to crack.

10.5 To prevent shipping damage, full-face plastic and/or plywood caps shall be fastened to all pipe ends and vessel openings. These protective caps shall not be removed until the equipment is ready to be installed.

10.6 Rubber lining materials are subject to deterioration by weathering if subjected to long-term storage. To minimize the damage because of weathering, any or all of the following may be used:

(a) All openings may be sealed to prevent free circulation of air through the rubber-lined equipment.

(b) The rubber-lined equipment may be filled with the process fluid, dilute acid, sodium carbonate solution, or water to inhibit deterioration of the rubber.

(c) Special anti-aging coatings may be applied directly to the rubber.

10.7 If rubber-lined flanges are being sealed, gaskets made of soft rubber compatible with the service shall be used to prevent cracking of rubber on flange faces. The rubber lining shall not be compressed more than 10% (except hard rubbers which shall not be compressed) to obtain a seal. Overcompressing the rubber can cause it to crack, or to squeeze out into the flow path. This can cause obstruction of the flow of liquids and can eventually erode and wear out the lining prematurely.

References

1. NACE SP0178 (formerly RP0178) (latest revision), "Fabrication Details, Surface Finish Requirements, and Proper Design Considerations for Tanks and Vessels to Be Lined for Immersion Service" (Houston, TX: NACE).

2. ASTM D 4263 (latest revision), "Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method" (West Conshohocken, PA: ASTM).

3. ASTM D 1418 (latest revision), "Standard Practice for Rubber and Rubber Latices - Nomenclature" (West Conshohocken, PA: ASTM).

4. NACE No. 1/SSPC-SP 5 (latest revision), "White Metal Blast Cleaning" (Houston, TX: NACE and Pittsburgh, PA: SSPC).

5. SSPC-SP 11 (latest revision), "Power Tool Cleaning to Bare Metal" (Pittsburgh, PA: SSPC).

6. SSPC-SP 1 (latest revision), "Solvent Cleaning" (Pittsburgh, PA: SSPC).

7. NACE SP0188 (formerly RP0188) (latest revision), "Discontinuity (Holiday) Testing of Protective Coatings" (Houston, TX: NACE).

8. ASTM D 2240 (latest revision), "Standard Test Method for Rubber Property - Durometer Hardness" (West Conshohocken, PA: ASTM).

9. ASTM D 429 (latest revision), "Standard Test Methods for Rubber Property - Adhesion to Rigid Substrate" (West Conshohocken, PA: ASTM).

10. NACE No. 2/SSPC-SP 10 (latest revision), "Near-White Metal Blast Cleaning" (Houston, TX: NACE and Pittsburgh, PA: SSPC).

11. NACE No. 3/SSPC-SP 6 (latest revision), "Commercial Blast Cleaning" (Houston, TX: NACE and Pittsburgh, PA: SSPC).

Appendix A: Rubber Lining Inspection Worksheet (Nonmandatory)

CUSTOMER NAME: ____WORK ORDER NO. ______________

ITEM DESCRIPTION:____

____

____

BLAST/CEMENT:

BLAST DATE:____________________ BLAST TYPE: [ ] NACE No. 2/SSPC-SP 10

[ ] NACE No. 3/SSPC-SP 6

[ ] NACE No. 1/SSPC-SP 5

BLAST PROFILE:____

CEMENT SYSTEM:____

LINING:

TYPE & THICKNESS:____

SPARK TEST BEFORE CURE: [ ] YES [ ] NO VOLTAGE: _____________________________

CURE TIME & TEMPERATURE: ____

HARDNESS AFTER CURE: ____

SPARK TEST AFTER CURE: [ ] YES [ ] NO VOLTAGE:____________

BOND STRENGTH RESULTS (if specified):____

REPAIR (after cure)**:**

1. NUMBER OF REPAIRS: ______________________________

2. REPAIR - LINING MATERIAL: ____

3. BRIEF DESCRIPTION (SIZE, LOCATION):____

CUSTOMER'S SIGNATURE: **INSPECTOR'S SIGNATURE:**

_____________________________________ _______________________________

DATE: __________________________ DATE: __________________________