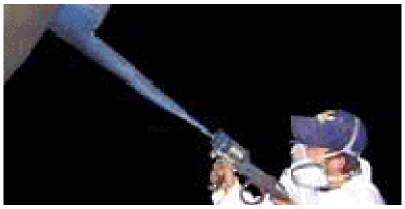
Technical Information On Rubber Lining



Kevin Gerber
Applications Engineer
Kevin@Proco-FWI.com

Dave Dieringer
Applications Engineer
Dave@Proco-FWI.com

Protective Coatings, Inc.
1602 Birchwood Ave.
Fort Wayne, IN 46803
PH (260) 424-2900
FX (260) 422-7147
www.proco-fwi.com

RUBBER LINED PIPE

Rubber lined pipe is used to transport corrosive chemicals, abrasive slurry solutions and many other liquids from one place to another. There are many material options that are capable of meeting overall pipe design criteria. Making an economic analysis of acceptable candidates based only upon material costs poses a very real danger. Well over half of the true required investment for a piping system (i.e. the in-place cost of the system) includes material, fabrication and installation costs as well as life-cycle considerations. Rubber lined carbon steel pipe is very cost effective when compared to other material selections:

INSTALLED COST COMPARISONS			
Carbon Steel (Sch. 40)	1.00	Glass-lined Carbon Steel (Sch. 40)	2.69
Rubber-lined Carbon Steel (Sch. 40)	**1.16**	PTFE-lined Carbon Steel (Sch. 40)	2.94
304L Stainless Steel (Sch. 40)	1.31	FEP-lined Carbon Steel (Sch. 40)	2.99
316L Stainless Steel (Sch. 40)	1.45	Monel (Sch. 40)	3.24
FRP/vinyl ester	1.78	Alloy 20 (Sch. 40)	3.32
FRP/epoxy	1.86	Hasteloy C-276 (Sch. 40)	4.46
FRP/polyester	1.86	Nickel (Sch. 40)	4.27
Polypropylene-lined Carbon Steel (Sch. 40)	1.90	Hasteloy B (Sch. 40)	5.71
PVDF-lined Carbon Steel (Sch. 40)	2.47	Zirconium (Sch. 40)	7.04

Reference: N.L. Lindley & J.C. Floyd, "Piping Systems: How Installation Costs Stack Up" published in *Chemical Engineering Magazine*

We can install rubber lining in pipe as small as 1½" dia. and as large as 144" dia. We vulcanize (cure) the lining installed in pipe up to 88" diameter in our autoclaves. Curing in an autoclave produces superior adhesion properties over other processes (i.e. atmospheric and internal steam). Autoclave curing also maximizes the lining life in the pipe versus other methods.

We can apply rubber lining over many different pipe substrates including: carbon steel, aluminum, copper, brass, cast iron, stainless steel & fiberglass. We can fabricate and rubber line your pipe with a minimum lead-time. All rubber lined pipe orders receive the same attention, whether it's a large order, or a single piece.

Some of the Larger Customers We Have Served:

Customer	Type of Installation
Bailly Generating Station Portage, IN	Piping for Flue Gas Desulfurization (FGD) Limestone Scrubber
Hoosier Energy REC Merom, IN	Strip and Reline Piping for Flue Gas Desulfurization Scrubber
NIPSCO Wheatfield, IN	System and Waste Water Treatment Piping
B.F. Shaw Laurens, SC	Flue Gas Desulfurization (FGD) Piping
Babcox & Wilcox Barberton, OH	Flue Gas Desulfurization (FGD) Piping
Illuka Resources Green Cove, FL	Mining Process Piping
Lynn Water & Sewer Lynn, MA	Rubber Lined Pipe for Fluidized Combustion System – Lynn, MA
SNC Lavalin Constructors Montreal, QC Canada	Salt Water Intake Piping for Power Plant Cooling – Skikda, Algeria
Ducon Technologies Farmington, NY	Rubber lined Pipe for (4) FGD Absorber Units - China
Corrosion Fluid Products Carmel, IN	Rubber Lined Pipe for FGD – Gibson Generating Station – Owensville, IN
Corrosion Fluid Products Carmel, IN	Rubber Lined Pipe for Duke Energy – Cayuga Station – Terre Haute, IN
Pioneer Pipe Marietta, OH	Rubber Lined Pipe for Alstom Power Spurlock Station – Maysville, KY
Pipe Products Evansville, IN	Rubber Lined Pipe for FGD – Santee Cooper Winyah Station – Georgetown, SC
Pioneer Pipe Marietta, OH	Rubber Lined Pipe for FGD – Miami Fort Generation Station – Cincinnati, OH
Doosan Hydro Technology Tampa, FL	Rubber Lined Pipe for Sea Water Desalinization – Jeddah, Saudi Arabia
SNC Lavalin Constructors Montreal, QC Canada	Rubber Lined Pipe for Water Purification Plant – Hadjret, Algeria
Pipe Products Evansville, IN	Rubber Lined Pipe for Fluor Global Services – Alcoa – Newburgh, IN
Hitachi Power Systems Basking Ridge, NJ	Rubber Lined Pipe for Ameren – Sioux Plant – Saint Louis, MO
Kennecott Utah Copper Corp Magna, UT	Rubber Lined Pipe for Abrasion Resistance from Copper Ore – Magna, UT
Babcock Power & Environmental Worchester, MA	Rubber Lined Pipe & Rubber Covered Beams for FGD Absorber – Santee Cooper Cross Station – Pineville, SC
Hitachi Power Systems Basking Ridge, NJ	Rubber Lined Pipe for Ameren – Coffeen Plant – Montgomery County, IL
Hitachi Power Systems Basking Ridge, NJ	Rubber Lined Pipe for Ameren – Duck Creek Plant – Canton, IL
Pipe Products Evansville, IN	Rubber Lined Pipe for Gibson Unit 5 – Owensville, IN
Springfield Water Power & Light Springfield, IL	Re-Line Piping for Flue Gas Desulfurization
Corrosion Fluid Products Farmington Hills, MI	Rubber Lined Pipe for Clarifier Unit – Monroe, MI
Pipe Products Evansville, IN	Rubber Lined Pipe for Midwest Generating Station – Joliet, IL

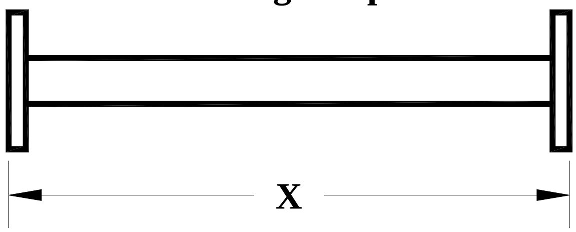
Kevin Gerber
Applications Engineer
Kevin@Proco-FWI.com

Dave Dieringer
Applications Engineer
Dave@Proco-FWI.com

Protective Coatings, Inc.
1602 Birchwood Ave.
Fort Wayne, IN 46803
Phone (260) 424-2900
Fax (260) 422-7147
Web Site: http://www.proco-fwi.com

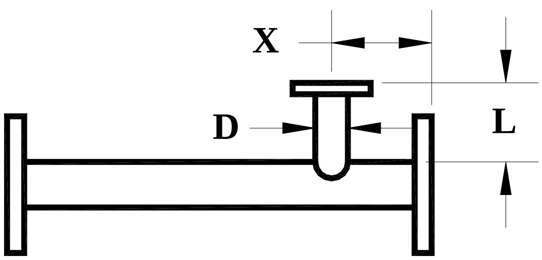
Pipe Design Criteria

Straight Pipe



Pipe Size	X (Max.)
1½” to 2” Diameter Pipe	10’-0”
2½” to 3½” Diameter pipe	20’-0”
4” to 24” Diameter Pipe	30’-0”
Above 24” Diameter Pipe	No Limit

Nozzles (Branched Spools)

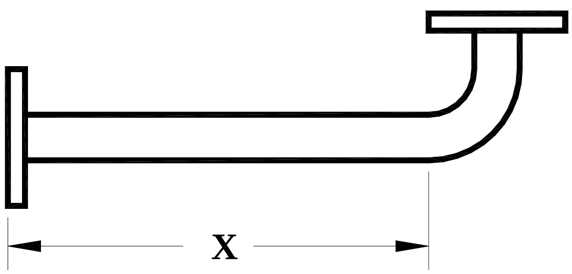


L = 2 × D (Max.) up to 20” Diameter

L = 3 × D (Max.) over 20” Diameter

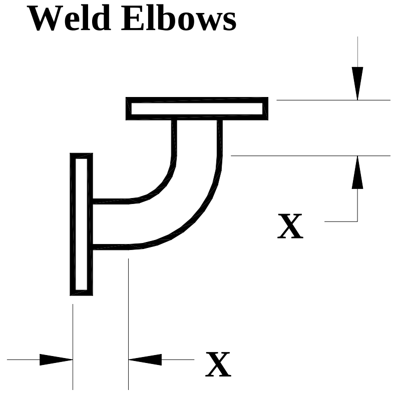
Nozzle Size	X (Max.)
4” to 6” Diameter Pipe	6”
6” & Larger Diameter Pipe	No Limit

Weld Elbows on Pipe



Pipe Size	X (Max.)
4” to 6” Diameter Pipe	24”
8” to 16” Diameter Pipe	48”
18” to 24” Diameter Pipe	10’-0”
Over 24” Diameter Pipe	No Limit

Weld Elbows



Pipe Size	X (Max.)
1½” to 2” Diameter Pipe	2½”
2½” to 4” Diameter Pipe	3”
6” to 12” Diameter Pipe	4½”
14” to 18” Diameter Pipe	5½”
20” & Larger Diameter Pipe	60”

NOTE: The above details are to be used for design and fabrication of pipe assemblies to be rubber lined. Although some variance in dimensions can be accepted, the above details will provide the best design for a quality, serviceable and most economical lining construction.

Kevin Gerber
Applications Engineer
Kevin@Proco-FWI.com

Dave Dieringer
Applications Engineer
Dave@Proco-FWI.com

Protective Coatings, Inc.
1602 Birchwood Ave.
Fort Wayne, IN 46803
Phone (260) 424-2900
Fax (260) 422-7147
Web Site: http://www.proco-fwi.com

Shop Inspection and Test Plan

Protective Coatings, Inc.
1602 Birchwood Ave.
Fort Wayne, IN 46803

Customer P.O.	PCI–SAMPLE–ITP	Rev. –
Customer Name & Project:		

Procedure No.	Procedure Description	Code/Std/ Dwg	Inspection Activities FAB	PCI	CUST	TPI	Other	Verification / Record Document	Remarks
	Drawings & Calculations – Submit for Approval		H		V-D			Customer Approval Stamp on Drawings	
	Order Materials		D	D				Purchase Order(s)	
	Receive Materials		V-X-D	V-X-D				Manufacturer's MTR's	
	Cut Pipe, Fit-Up, Dimensional Check		X-D					Weld Traveler	
	Weld Pipe		V-X-D					Weld Traveler	
	Radiographic Inspection – N/A		H-D			D		X-Ray Report	
	Hydrostatic Test – N/A		H-D					Hydro Test Report	
TL09–R	**Receive**			V-X-D				Packing Slip / C of C Routing Traveler	
TL09–I	**Material Identification**			V-D				Routing Traveler	
TL11	**Blast** – Per Rubber Manufacturer's Specification			V-D				Profile Meter / Routing Traveler	
TL13	**Cement** – Per Rubber Manufacturer's Specification			V-D				Visual / Routing Traveler	
TL14	**Line** – Per Rubber Manufacturer's Specification			V-S-H-D				Routing Traveler	
TL15	**Cure** – Per Rubber Manufacturer's Specification			D				Cure Log / Adhesion Plate / Routing Traveler	
TL16	**Finish** – Per Rubber Manufacturer's Specification			V-X-D				Visual, Spark Test / Routing Traveler	
TL11	**Blast for Paint** – As Required by Paint Specification			V-H-D				Profile Meter / Routing Traveler	
TL16–P	**Paint** – Per Customer's Specification (Primer min.)			V-D				Thickness Meter / Routing Traveler	
TL09–S	**Packaging** – Per Customer's Specification			V-H-D				Visual / Routing Traveler	
TL99	**Final Inspection** – Per Rubber Manufacturer's Specification			V-D				Visual / Routing Traveler	

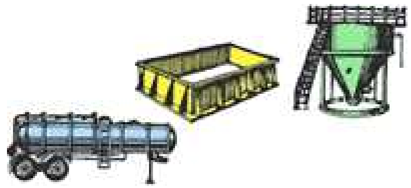
NOTES:

Abbreviations:

FAB – Pipe Fabricator
PCI – Protective Coatings, Inc.
CUST – Customer
TPI – Third Party Inspection Agency
Other –

V – Visual Inspection
X – Dimensional Inspection
S – Spark Test
D – Documentation
H – Hold Point

RUBBER LINED TANKS



Protective Coatings, Inc. (Proco) has rubber lined all types of tanks from the very small to the extremely large. Our experience in the industry (since our founding in 1958) allows us to select and install the lining best suited to your service conditions. We can install a new lining, or replace your existing lining at your facility or ours. Our technicians will install the lining in a manner to maximize the service life of your lining. Your inquiry will receive swift attention from our experienced estimating staff to provide you with a quick response. We can fabricate smaller tanks at our facility, and maintain a liaison with the best fabricators in the area for larger tanks.

Some of the Larger Projects We have Completed	
Mobay Chemical Friendly, WV	1,000,000 Gallon Hydrochloric Acid Storage Tank
E.I. DuPont Belle, WV	600,000 Gallon Hydrochloric Acid Storage Tank
Mobay Chemicals Friendly, WV	2,000,000 Gallon Hydrochloric Acid Storage Tank (World's Largest)
IMC Chicago, IL	(85) 14,000 Gallon Rail Cars for Fertilizer Service
Texas Gulf Raleigh, NC	(24) 14,000 Gallon Rail Cars for Fertilizer Service
E.I. DuPont Edgemoor, DE	57' Diameter x 44' Tall Ferric Chloride Storage Tank
Georgia pacific Taylorsville, IL	14' Diameter x 32' High Slurry Accumulator Tank
Commonwealth Edison Mount Zion, IL	(15) Demineralization Tanks
Hilton-Davis Cincinnati, OH	(5) 20' Diameter x 20' High Process Tanks
A.E. Staley Decatur, IL	(6) 14' Diameter Process Tanks
AK Steel Middletown, OH	(2) 25' Diameter x 20' High Hydrochloric Acid Storage Tanks
I/N Kote New Carlisle, IN	(13) Galvanizing Process Tanks
Sun Chemicals Cincinnati, OH	(3) 25' Diameter x 30' High Chemical Mixing Tanks
A.E. Staley Louden, TN	(6) 14' Diameter Process Tanks
PPG Industries, Inc. Natrium, WV	Strip and Reline 24,000 Salt Saturator Tank
G.E. Plastics Mount Vernon, IN	Strip and Reline (2) 20,000 Gallon Brine Recovery Tanks
Cabot Corporation Tuscola, IL	Strip and Reline 250,000 Gallon Hydrochloric Acid Storage Tank
Fruehauf Industries Des Moines, IA	(6) 5,000 Gallon Hydrochloric Acid Trailers

Kevin Gerber
Applications Engineer
Kevin@Proco-FWI.com

Dave Dieringer
Applications Engineer
Dave@Proco-FWI.com

Protective Coatings, Inc.
1602 Birchwood Ave.
Fort Wayne, IN 46803
Phone (260) 424-2900
Fax (260) 422-7147
E-mail: linings@proco-fwi.com
Web Site: http://www.proco-fwi.com

Selecting Elastomeric Linings For Storage Tanks

GARY E KUJAWSKI, Chief Chemist
Tank Linings
Uniroyal Engineered Products
Mishiwaka, IN, and
FREDERICK HAINES, Vice President
Protective Coatings, Inc.
Fort Wayne, IN

REPRINTED WITH PERMISSION FROM THE OCTOBER 13, 1983
ISSUE OF *PLANT ENGINEERING*

Selecting Elastomeric Linings For Storage Tanks

GARY E. KUJAWSKI, Chief Chemist
Tank Linings
Uniroyal Engineered Products
Mishiwaka, IN, and
FREDERICK HAINES, Vice President
Protective Coatings, Inc.
Ft. Wayne, IN

Conventional carbon steel and other alloy materials used for pressure vessels and processing and storage tanks, frequently require linings that protect the metal against attack from corrosive solutions. When barriers to protect these vessels are being considered, natural and synthetic rubber linings are frequently chosen. Elastomeric material formulations can be tailored for practically every process and storage situation and survive in service for 20 yr or longer. This article **describes the material properties of** elastomeric lining materials and the criteria that should be used in specifying them.

Lining Materials - The vast array of lining materials can be organized in two basic categories: permanent and temporary. The characteristic that sets one category apart from the other is the curing level of the material before application.

Temporary linings are made from prevulcanized (completely cured) loose materials that are considered only temporary solutions to corrosive problems. They cannot be considered a permanent solution because the slightest pinhole leak in the lining permits fluids to migrate between the lining and the tank wall.

Permanent linings are properly applied uncured with adhesives and then vulcanized by heat so that they are tightly bonded and are in intimate, total contact with the tank's metal surface. Before vulcanization

INFORMATION NECESSARY FOR TANK LINING SELECTION

Selection of the correct lining for a specific application requires that all available details concerning the tank and other equipment to be lined, and the process to be contained, be itemized. Some of the essential data follow:

- Chemicals: the type of chemicals contained in the tank and their concentration; the amount of impurities and contaminants, if any, potential chemical reactions
- Abrasion: abrasive particle type, weight, and size; velocity of particle movement; proportion of solids; nature of abrasive action (sliding or impinging)
- Temperature: maximum, minimum, and operating temperatures; severity and spread of temperature change; temperature cycle time
- Pressure: maximum, minimum, and operating pressure or vacuum; pressure cycle time
- Equipment: complete description of tank to be lined including physical design, dimensions, and information on whether it is stationary or portable
- Operating conditions: any other pertinent external and internal operating conditions
- Product condition: levels of discoloration, contamination, odor, or taste allowed for lading; Food and Drug Administration requirements, if any
- Experience: Past experience under similar conditions such as lining compound used and length of previous service life.

Armed with this information, plant engineers should be prepared to evaluate the various types of linings that satisfy application requirements. Each of the parameters listed should be analyzed separately so that the final lining selection takes into account all of the specific needs of the application.

Plant engineers should not make the mistake of selecting a lining material because it has performed well in applications similar to tank lining. For example, butyl rubber that is used to provide abrasion resistance for coal-handling conveyor belts may not provide the same abrasion resistance in a coal slurry tank.

And a lining material should not be selected on the basis of just one outstanding physical property. For example, ethylene propylene rubber may be known to withstand 300 F temperatures, but it does not necessarily follow that a tank lining of this material can withstand such a high temperature over a prolonged period. The specific tank lining material must be compounded to be compatible with application and curing procedures that could alter the properties of the cured material.

the lining is soft, pliable, and easily applied to the areas requiring protection. During vulcanization the rubber is cured to its final state, either soft or hard depending on the compound, to achieve its full physical and chemical resistance properties.

The physical makeup of lining materials is also a factor in achieving barrier protection. Each lining is made from numerous plies so that an imperfection or void in one ply does not affect the continuity of the final sheet. In the manufacture of a 3/16 in. thick sheet, for example, uncured rubber lining material is calendered in thin 1/64in. thick plies. Twelve of these plies are layered to form the3/16in. thick sheet. Thermosetting adhesives, which cure in the same cycle as the linings, are used to attach these linings to tank walls. After curing, they resist physical change, such as softening, in the same fashion as the linings. These adhesives have an upper temperature limit; they may fail if the temperature reaches 300 F or more.

Selection Criteria-The factors that influence the plant engineer's choice of lining material include the material properties of the lining as well as its end use (see accompanying table). A logical starting point in selecting a lining, therefore, is to obtain manufacturers' literature containing chemical resistance tables for various types of lining materials. These tables also list the maximum temperature ranges for linings used with specific chemicals. Some general guidelines on the compatibility of linings and their particular application follow:

• Temperature and Chemical Environment - The necessary properties of natural rubber can be evaluated according to the following rule: the harder the lining material, the higher the operating temperature it can withstand and, to a lesser degree, the higher the chemical concentrations it can tolerate.

Natural and synthetic rubber materials as a group are not resistant to hydrocarbons such as oil products or solvents. Exceptions do exist, however. Chlorinated polyethylene (CPE), neoprene, and cholorosulfonated polyethylene (CSPE) synthetic rubber linings, for instance, resist moderate amounts of oil. Hard rubber linings are resistant to small amounts of oil. Although nitrile synthetic rubber (Buna N) provides good resistance to aliphatic hydrocarbons such as kerosene, it is expensive and difficult to work with as a lining material. Ethylene-propylene-diene-terpolymer (EPDM) and butyl rubber have good resistance to polar and oxygenated solvents such as methyl and ethyl ketone and acetone.

All selections of tank linings should be supported by laboratory testing results or evidence of successful experience under identical conditions, information that is generally available from manufacturers. Plant engineers should ask the manufacturer for additional information when the proper choice is not obvious. For example, a lining that is recommended for several individual chemicals may not be suitable for a blend of those chemicals.

• Abrasive Action - When impingement on the lining is expected, a resilient type of rubber provides the most satisfactory service because it absorbs impact and permits the particles to bounce off without damaging the lining. A soft natural rubber with a Shore A durometer reading of 30 to 40 is generally specified in such applications. When sliding or cutting also is expected in service, a tougher, harder, tear-resistant lining material with a Shore A durometer reading of 50 to 60 should be specified. Hard rubbers, those with a Shore A reading of 90 and above, have poor abrasion resistance and should be avoided.

"... a *lining recommended for several individual chemicals may not be suitable for a blend of these chemicals."*

• Temperature Variations - Not all linings exhibit the same degree of resistance to thermal shock, as shown in the table. Soft natural rubber and most synthetic linings have outstanding resistance to themal shock, and hard rubber has less resistance. Hard rubber linings can be made to withstand fairly rapid temperature changes, but a thorough study of the conditions, proper material selection, and special lining constructions must be employed if hard rubber is to perform successfully.

• Pressure or Vacuum conditions - Normal pressure ranges are seldom a problem. When full vacuum or pulsating pressure conditions exist, hard rubber liners are used because they reduce diaphragm action. This may occur, for example, if a pinhole in the steel container allows atmospheric pressure to act on the underside of the lining,

• Weather Conditions Large outdoor storage tanks are subject to expansion and contraction caused by extreme weather fluctuations. Soft natural and synthetic rubber linings should be considered for such applications. Expansion and contraction of the tank does not usually present a problem indoors; fairly steady temperature conditions can be assumed to exist even if the building is not heated.

Special Linings for Extreme Conditions - Complex or severe service conditions, for example, those that require both chemical and abrasion resistance, may be successfully treated with a three-ply lining. This type of lining incorporates an inner layer of semihard rubber for chemical and heat resistance with two softer outer layers that contribute flexibility and abrasion resistance. Three-ply linings are designed to withstand temperatures between 180 and 230 F. When a combination of severe temperature and abrasive action is encountered, the three-ply lining is formulated with an inner layer of hard rubber and two outer layers of high-temperature resistant soft rubber.

Inspection of Lining Installa-tio - Reputable lining applicators inspect and test the rubber lining extensively before permitting it to be placed in service. The newly lined tank or container is closely examined for leaks and defects such as poor adhesion. Pinhole leaks may be detected using a spark tester, although this method introduces a potential hazard. If the spark testing equipment is not carefully used,

PROPERTIES OF ELASTOMERIC LININGS

Lining type	Shore A durometer reading	Upper Temperature limit, F	Thermal shock resistance	Resistance to hydrocarbons	Typical uses
Soft natural rubber	30 to 60	160	Excellent	Poor	Acid storage; transportation equipment; abrasive services; white rubber for food grade; sulfur dioxide scrubbers
Semihard natural rubber	80 to 85	180	Good	Fair	Chemical processing and plating
Hard natural rubber	90 to 100	200	Poor	Fair	Chemical processing; high temperature nickel-copper plating; steel pickling; vacuum service
Flexible hard natural rubber	90 to 100	212	Fair	Fair	Same uses as hard natural rubber; better crack and heat resistance
Graphite loaded hard rubber	95 to 100	212	Fair	Fair	Special lining for wet chlorine gas in chlorine cells and associated equipment
Three-ply (soft, hard, soft)	40 to 50	230	Excellent	Fair	Combined abrasion and corrosion services; becoming popular for steel pickling lines; phosphoric acid
Neoprene	40 to 70	230	Excellent	Very good	Chemical or abrasive services with oil present; best for strong bases; good weather resistance; fire retardant
Nitrile	60 to 90	200	Excellent	Excellent	Aliphatic hydrocarbons, kerosene, animal, vegetable, and mineral oils
Butyl	50 to 75	225	Excellent	Fair	Oxidizing acids; 70 percent hydrofluoric acid; super phosphoric acid; best water resistance; good for alternative service
Chlorobutyl	40 to 60	200	Excellent	Fair	Much the same as butyl but easier to apply and faster curing; sulfur dioxide scrubbers
EPDM	40 to 60	180	Excellent	Poor	Hypochlorite bleach; ozone and weather resistant
CSPE	50 to 70	210	Excellent	Good	Strong acids such as chromic acid; high concentrations of nitric and sulfuric acids
CPE	50 to 75	230	Excellent	Good	Strong acids; alternative service

it may burn through the lining when held in one place for too long. It is usually wise for the plant engineer to witness this test.

During the inspection procedure, nozzle flange edges are closely examined for loose adhesion. For permanent protection, full lining adhesion is essential for tanks that operate under vacuum or flowing conditions. Loose liners would collapse or obstruct flow under those circumstances.

Seam construction is also inspected before the lined tank is put in use. All seam edges must be beveled. A simple way to detect air pockets behind seams is to press down at the edge of the lap seam where the under-lining sheet ends. Poor seam construction can be easily observed then: if air is trapped under the rubber, the bubble can be felt as a soft spot. Attempting, and succeeding, to lift the seam edges also reveals looseness in the lining.

The inspection procedure includes a check for over and under cure of the lining material. Shore A durometer readings are taken at several points; a low reading indicates that the lining has not cured completely, and a high reading may indicate that the rubber is over cured.

Repair of Leaks in Tank Linings-If any leaks are detected after cure, they are repaired with uncured rubber that is vulcanized to the cured lining. Repair procedures are designed so that the repaired area is protected at least as well as the remaining lining.

The specific method of repair depends on the type of the original lining, the extent of repair needed, and the facilities available. If plant engineers repair the lining themselves, they must follow the recommendations of the lining contractors. The following procedure is typical:

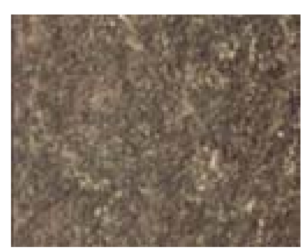
- The defective and adjacent lining are thoroughly neutralized, cleaned, and dried. In some cases, it may be necessary to treat the whole lining. All loose and defective rubber is cut away, the exposed edges of the lining are beveled, and the shell of the equipment is buffed clean.
- The exposed area is cleaned with a suitable solvent and any excess solvent is allowed to evaporate. The adhesive solutions are then applied according to the lining contractor's instructions and allowed to dry.
- A patch of new sheet, which has been cut to shape and made tacky by the application of the adhesive or other solution, is then applied to the prepared area and rolled down firmly with an edge-wheel to exclude any air. In areas where tension is likely to develop, for example at struts, the patch is tightly wrapped and then vulcanized.
- The repaired area should be checked for hardness and continuity.

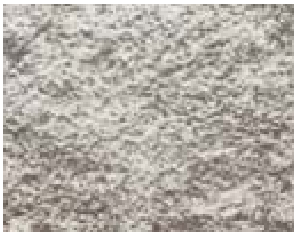
Proco Protective Coatings, Inc.

SURFACE PREPARATION

1958 - 2008 50 YEARS OF EXCELLENCE Protective Coatings, Inc.

SSPC - Formerly the Steel Structures Painting Council, now the Society for Protective Coatings for more information about SSPC visit their WEB site at http://www.sspc.org/.

SSPC-SP 1 **Solvent Cleaning -** Removal of all detrimental foreign matter such as oil, grease, dirt, soil, salts, drawing and cutting compounds, and other contaminants from steel surfaces by the use of solvents, emulsions, cleaning compounds, steam or other similar materials and methods which involve a solvent or cleaning action.	
SSPC-SP 2 **Hand Tool Cleaning -** Removal of all rust scale, mill scale, loose rust and loose paint to the degree specified by hand wire brushing, hand sanding, hand scraping, hand chipping or other hand impact tools or by a combination of these methods. The substrate should have a faint metallic sheen and also be free of oil, grease, dust, soil, salts and other contaminants.	
SSPC-SP 3 **Power Tool Cleaning -** Removal of all rust scale, mill scale, loose paint, and loose rust to the degree specified by power wire brushes, power impact tools, power grinders, power sanders or by a combination of these methods. The substrate should have a pronounced metallic sheen and also be free of oil, grease, dirt, soil, salts and other contaminants. Surface should not be buffed or polished smooth.	
SSPC-SP 5 (NACE 1) **White Metal Blast Cleaning -** Removal of all mill scale, rust, rust scale, paint or foreign matter by the use of abrasives propelled through nozzles or by centrifugal wheels. A White Metal Blast Cleaned Surface Finish is defined as a surface with a gray-white, uniform metallic color, slightly roughened to form a suitable anchor pattern for coatings. The surface, when viewed without magnification, shall be free of all oil, grease, dirt, visible mill scale, rust, corrosion products, oxides, paint, or any other foreign matter.	
SSPC-SP 6 (NACE 3) **Commercial Blast Cleaning -** Removal of mill scale, rust, rust scale, paint or foreign matter by the use of abrasives propelled through nozzles or by centrifugal wheels, to the degree specified. A Commercial Blast Cleaned Surface Finish is defined as one from which all oil, grease, dirt, rust scale and foreign matter have been completely removed from the surface and all rust, mill scale and old paint have been completely removed except for slight shadows, streaks, or discolorations caused by rust stain, mill scale oxides or slight, tight residues of paint or coating that may remain; if the surface is pitted, slight residues of rust or paint may by found in the bottom of pits; at least two-thirds of each square inch of surface area shall be free of all visible residues and the remainder shall be limited to the light discoloration, slight staining or tight residues mentioned above.	
SSPC-SP 7 **Brush-Off Blast Cleaning -** Removal of loose mill scale, loose rust, and loose paint, to the degree hereafter specified, by the impact of abrasives propelled through nozzles or by centrifugal wheels. It is not intended that the surface shall be free of all mill scale, rust, and paint. The remaining mill scale, rust, and paint should be tight and the surface should be sufficiently abraded to provide good adhesion and bonding of paint. A Brush-Off Blast Cleaned Surface Finish is defined as one from which all oil, grease, dirt, rust scale, loose mill scale, loose rust and loose paint or coatings are removed completely but tight mill scale and tightly adhered rust, paint and coatings are permitted to remain provided that all mill scale and rust have been exposed to the abrasive blast pattern sufficiently to expose numerous flecks of the underlying metal fairly uniformly distributed over the entire surface.	

SSPC-SP 8 **Pickling -** Removal of all mill scale, rust and rust scale by chemical reaction, or by electrolysis, or by both. It is intended that the pickled surface shall be completely free of all scale, rust, and foreign matter. Furthermore, the surface shall be free of unreacted or harmful acid or alkali, or smut.	
SSPC-SP 10 (NACE 2) **Near-White Blast Cleaning -** Removal of nearly all mill scale, rust, rust scale, paint, or foreign matter by the use of abrasives propelled through nozzles or by centrifugal wheels, to the degree hereafter specified. A Near-White Blast Cleaned Surface Finish is defined as one from which all oil, grease, dirt, mill scale, rust, corrosion products, oxides, paint or other foreign matter have been completely removed from the surface except for very light shadows, very slight streaks or slight discolorations caused by rust stain, mill scale oxides, or light, tight residues of paint or coating that may remain. At least 95 percent of each square inch of surface area shall be free of all visible residues, and the remainder shall be limited to the light discoloration mentioned above.	
SSPC-SP 11 **Hand Tool Cleaning -** Covers the requirements for power tool cleaning to produce a bare metal surface and to retain or produce a surface profile. (1 mil minimum)Suitable where a roughened, clean, bare metal surface is required, but where abrasive blasting is not feasible or permissible. Differs from SSPC-SP 3 in that SP 3 requires only the removal of loosely adherent materials and does not require producing or retaining a surface profile. Surfaces prepared per this spec, when viewed without magnification, shall be free of all visible oil, grease, dirt, dust, mill scale, rust, paint, oxide, corrosion products, and other foreign matter slight residues of rust and paint may be left in the lower portions of pits if the original surface is pitted.	
SSPC-SP 13 (NACE 6) **Concrete Preparation -** This standard gives requirements for surface preparation of concrete by mechanical, chemical, or thermal methods prior to the application of bonded protective coating or lining systems. The requirements of this standard are applicable to all types of cementitious surfaces including cast-in-place concrete floors and walls, precast slabs, masonry walls and shotcrete surfaces. An acceptable prepared concrete surface should be free of contaminants, laitance, loosely adhering concrete, and dust, and should provide a dry, sound, uniform substrate suitable for the application of protective coating or lining systems. Depending upon the desired finish and system, a block filler may be required. **Block (Cinder and Concrete) -** Remove all loose mortar and foreign material. Surface must be free of laitance, concrete dust, dirt, form release agents, moisture curing membranes, loose cement, and hardeners. Concrete and mortar must be cured at least 30 days at 75°F. The pH of the surface should be between six and nine. On tilt-up and poured-in-place concrete, commercial detergents and abrasive blasting may be necessary to prepare the surface. Fill bug holes, air pockets, and other voids with a cement-patching compound.	

Kevin Gerber
Applications Engineer
Kevin@Proco-FWI.com

Dave Dieringer
Applications Engineer
Dave@Proco-FWI.com

Protective Coatings, Inc.
1602 Birchwood Ave.
Fort Wayne, IN 46803
Phone (260) 424-2900
Fax (260) 422-7147
Web Site: http://www.proco-fwi.com

Facility & Equipment

Proco
Protective Coatings, Inc.

1958 - 2008
50
YEARS OF EXCELLENCE
Protective Coatings, Inc.

Compression Molding Presses

Platen Press Name	Width	Maximum Length	Opening	Rams		Clamping Force in Tons
				Qty	Dia.	
30 Foot Press	52 in.	30 ft.	12 in.	20	12 in.	1630
20 Foot Press	63 in.	20 ft.	18 in.	20	8 in.	724
15 Foot Press	54 in.	15 ft.	25 in.	14	9 in.	642
6 by 8 Foot Press	77 in.	98 in.	20 in.	6	9 in.	412
7 Foot Walk-In	33 in.	84 in.	18 in.	2	24 in.	981
Baldwin	56 in.	78 in.	40 in.	1	42½ in.	1531
31 Inch Press	31 in.	32 in.	23 in.	1	26 in.	382
42 Inch Press	44 in.	42 in.	25 in.	1	20 in.	226


30 Foot Press


20 Foot Press


15 Foot Press


6 x 8 Foot Press


7 Foot Walk-In


Baldwin


31 Inch Press


42 Inch Press

Additional Support Equipment

• 90,000 Square Foot Factory – Warehouse	• Blast Building w/ Dust Collection System
• Worthington VTE High Pressure Pump	• Refrigerated Raw materials Storage
• Lancaster Steam Autoclave 10'6" Dia. x 60' Long	• Stationary and Portable Heat Tables
• Lancaster Steam Autoclave 9' Dia. x 40' Long	• 4,000 to 20,000 lb. Capacity Fork Lifts
• Adamson Steam Autoclave 5' Dia. x 4' Tall	• 22' Flat Bed Truck for Pick-Up & Delivery
• Harris Products Autoclave 3' Dia. x 7' Long	• 54" Slitter
• 300hp Cleaver Brooks Boiler	• Misc. Metal Fabrication Equipment
• 150hp Sullair Compressor	• Portable Blast Equipment

Kevin Gerber
Applications Engineer
Kevin@Proco-FWI.com

Dave Dieringer
Applications Engineer
Dave@Proco-FWI.com

Protective Coatings, Inc.
1602 Birchwood Ave.
Fort Wayne, IN 46803
Phone (260) 424-2900
Fax (260) 422-7147
Web Site: http://www.proco-fwi.com

ALL ABOUT RUBBER LINININGS
PROTECT-O-LINE NEWS
PROTECTIVE COATINGS: THE RUBBER LINING PEOPLE
Volume One – Number One Published By Protective Coatings, Inc. - Fort Wayne, IN

Elastomeric Sheet Linings in Today's Market

By Frederick H. Haines, Protective Coatings, Inc.

An Introduction to Rubber Linings

This paper describes the elastomeric sheet linings available for protection of carbon steel or other metals from severe corrosive and/or abrasive service conditions. Elastomeric sheet linings are those materials manufactured in the unvulcanized sheet form, applied as unvulcanized sheet to the prepared metal surface, and finally vulcanized to the metal surface through the application of heat. The attributes of a satisfactory, permanent elastomeric lining installation are outlined; and the application methods and standards for attaining satisfactory lining installations are described. The available types of materials, their uses, limitations, and advantages are explained; with emphasis on new materials available for selection by the corrosion engineer and purchaser. The highly important process of selecting the best elastomeric lining material for each application is pursued in depth. A look at the future for elastomeric sheet linings is provided. In short, an attempt is made to furnish a comprehensive guide to: (1) the application, (2) selection, (3) limitations, (4) and uses of elastomeric sheet linings.

The purpose of a rubber lining is to provide a permanent corrosion and/or abrasion resistant protective lining for carbon steel equipment. The steel provides the strength to contain the solution and the process and the lining provides the necessary resistance to the service conditions. A perfect example of the need for a rubber lining would be to fabricate a hydrochloric acid storage tank from plain 1/4" carbon steel plate. Within 24 hours after the hydrochloric acid is placed in the tank; leakage of acid from the tank would start, the expensive chemical would pour out, causing damage or personal injury as well as severe damage to the tank itself. It takes just about that long for hydrochloric acid to dissolve and penetrate through 1/4" thick carbon steel. On the other hand, if you were to have correctly applied a 3/16" rubber lining to the interior of this same tank, in hydrochloric acid service the chances are that twenty years later this tank would still be doing its job with no leak-age or problems. This is only one of thousands of chemical processes and abrasive flow situations that can be contained successfully by natural or synthetic rubber linings.

What kind of equipment is protected by elastomeric sheet linings today?

1. **Storage tanks -** 500 gallon to 500,000 gallons and larger.
2. **Process equipment -** filters, crystallizers, evaporators, chlorine cells.
3. **Fume scrubbing equipment -** flue gas desulfurization in power plants, wet fume scrubbing in chemical plants.
4. **Steel pickling tanks -** continuous lines up to 500 feet long.
5. **Plating tanks** - copper, nickel, etc.
6. **Tank cars -** 8,000 gallon through 20,000 gallon
7. **Trailer tanks** - 3,000 through 6,000-gallon capacity.
8. **Pipe and fittings** - ½" and larger with no upper size limit.
9. **Pumps, valves, fans.**

About The Author:

After employment with Uniroyal. in 1958 Frederick H. Haines was instrumental in the founding of Protective Coatings, Inc. Mr. Haines holds a Mechanical Engineering Degree from Princeton University. This paper was originally presented to The Connecticut Rubber Group Seminar: "Engineering With Rubber-March 1979". Similar papers have been presented at the Liberty Bell Corrosion Course, sponsored by the Engineer's Club of Philadelphia and The National Association of Corrosion Engineering.

Table Of Contents

Basic Attributes Of A Permanent Rubber Lining

As mentioned earlier, we are concerned here with permanent installations of elastomeric linings. In order to function on a permanent basis a rubber lining must have certain basic attributes, as follows:

1. The lining material must be able to **withstand the conditions** for which it is used. Through experience or testing the correct choice from the many available rubber and synthetic rubber lining materials must be made.
2. **Seams between lining sheets** must not be weaker than the rest of the lining. As you will see later, these materials are all applied in the uncured sheet form, so that as sheets are applied side by side, the joint or seam between sheets must be at least as good as the remaining areas.
3. The lining must be fully and **completely adhered** to the carbon steel or metal surface to which it is applied. The best way to explain why full adhesion is necessary is to think of what would happen if a loose liner were installed in an acid tank. The first time that the loose liner developed even one tiny pinhole leak, you would have acid on the outside of the liner as well as inside. It would take only a short time for the acid to cause tank failure. This is not an indictment of those companies who offer loose liners for tanks. The loose liner is usually inexpensive and provides a temporary solution to a problem. However, elastomeric linings with full adhesion provide a permanent installation, which can be repaired. Full adhesion of the lining to the steel is absolutely essential under vacuum conditions *(loose liner would simply collapse)* or under flowing conditions (loose *liner would tend to bunch up and obstruct flow).*
4. The lining and adhesive system must **be fully vulcanized,** that is, in its final cured state. If the vulcanization is not completed, then the lining material does not have the physical properties or the chemical resistance for which it was designed or intended, and a number of difficulties could occur. In this case, you might ask, "Why not vulcanize the lining sheets fully at the place of manufacture, and eliminate the problem of vulcanizing after application to the steel?" The answer to this is that application of the sheets in the uncured unvulcanized state makes lining possible, while application would be in most cases impossible if the sheets were prior cured. In the uncured state, an elastomer is soft, pliable, flexible, and has little or no elasticity or memory; so that it can be placed around a corner, over a bump, through a small opening, etc., and remain in the shape or configuration in which you place it. However, the same rubber material, after cure, reaches its final state, in most cases with high elasticity and good memory; so that

(Continued On Next Page.)

Basic Attributes Of A Permanent Rubber Lining

(Continued From Page 1.)

it would return to its original configuration, rather than the configuration of the surface to which it was applied. Furthermore, in the uncured state, any lining material can be easily adhered to itself by simply cleaning and slightly dissolving the surface to be joined; so that seaming with the uncured material is simple and permanent, providing after vulcanization, a continuous lining with no weakness whatsoever at the seams between sheets.

5. The lining must be completely **free from pinholes** or connections of any kind through the lining to the steel. The necessity for absolute freedom from leaks is demonstrated by the earlier example of hydrochloric acid penetrating through 1 /4" carbon steel in 24 hours You can visualize the devastation resulting from a pin hole leak in a tank car rubber lining; undetected until the car was out on the railroad and in 24 hours leaking acid out on the rails as it moved along

If a rubber lining lacks even one of the above five attributes, it would not be a permanent installation, and its performance would probably be measured in days rather than years.

Application Procedures For Elastomer Linings

Assuming that the correct lining material has been chosen (discussed later), how do we apply rubber lining so that the above last four essential attributes or qualities can be obtained? The correct process for applying a permanent rubber lining is as follows:

1. Metal preparation starts with the fabrication shop that builds the metal tank or piece of equipment to be lined. Specifications given to the fabricator should call for all continuous welding at any location over which rubber is to be applied. The welds should be smooth with no porosity, holes, under-cutting, or high spots. The welds should be ground to remove all sharp edges, high spots and weld spatter Partitions, braces or supports should be full welded from both sides. All sharp edges on plates or corners should be rounded All work de-scribed so far is normally carried out by the steel fabricator.

2. The next operation is sand or grit blasting, and this must be performed by the rubber lining facility. All dirt, rust, grit, and scale must be removed by this operation. The metal must have a uniform white metallic color, with a deep profile *(at least 2 mils)* to provide a firm anchoring surface for the adhesives. The first coat of adhesives must be applied within *a* few hours after the blasting is completed; at least before the blasted surface has changed color or rusted in any way. Successive coats of adhesives, three or more additional as required, must be applied after the previous coat has been allowed to dry so that solvents will not be trapped under the lining. Poor metal preparation in any of the above operations can cause poor adhesion or blisters in the lining.

Inside a tank being lined, the area is being rolled with a rubber roller to eliminate all air trapped between the sheet and the metal surface.

3. The application of the uncured sheet lining material requires the greatest skill of all the operations The uncured lining materials come in rolls 36" to 48" wide by approximately 20 yards long. The material is wrapped in polyethylene or cloth to prevent sticking to itself. Thickness ranges from 1/8" to 1/4" It is possible to line with two or even three layers, so that up to 3/4" total thickness can be obtained Since all uncured rubber and synthetic rubber material is soft, it is very vulnerable to damage or surface abuse at this stage. The rubber sheets are measured accurately to fit a specific lining pattern in the tank or other item to be lined All edges are beveled *(skived)* at an angle 45" or less with the surface to be lined The uncured. skived rubber shoots are freshened with solvent on the down side and when tacky, applied to the cemented surfaces in the tank. Seams between sheets are made by over lapping the skived *(beveled)* edges 1½" to 2", An alternate seam construction consisting of a skived butt join! with cap strip of the same material over the joint is sometimes employed for specific materials After application of a shoot, its entire area is rolled with a rubber roller to eliminate all air trapped between the sheet and the metal surface Seams are completely stitched (r*olled down by a small tool with a narrow serrated wheel)* The cutting and placing of sheets in this manner is continued until all surfaces are correctly covered

4 After careful checking, the rubber-lined item is then ready for vulcanization. In vulcanization the object is to bring about a chemical change in the rubber and adhesives, so that they will reach their final physical properties. At the place of manufacture, the different types of rubber and synthetic rubber are mixed with different curing agents and accelerators to enhance the basic chemical change to the cured state The vulcanization is accomplished usually by the application of heat in the form of steam the greater the heat, the quicker the cure can be accomplished Most applicators have large autoclaves, in which they can vulcanize the quickest, in say eight hours by curing with as high as 5O lbs. pressure and 298" F. However, it is possible, using specific rubber com-pounds, to vulcanize with open steam at 200° F. An example is a huge tank which could not be pressurized Another type of vulcanization is the chemical cure, in which the application of chemicals only brings about the necessary chemical change. The use of this type of cure is usually confined to rubber lining repair materials, where the shortest possible down time is the most important consideration.

5 Electrostatic testing is the method by which the rubber liner makes sure that there are no leaks through the lining to the stool The instrument used most often is a spark tester which is essentially a low current high voltage transformer. Spark test voltage should be at 10,000 to 15,000 volts for a satisfactory test on most natural rubber materials A lower voltage is necessary on most of the synthetic rubbers, in order to obtain a definitive test without damaging the lining The steel is grounded and the spark tester is passed over the lining surface A blue spark constantly passes through the rubber lining. A leak is detected when the spark turns bright white and there is a snapping sound This indicates a direct connection through the lining to the stool This test is conducted not only after vulcanization, but also before, since any leaks detected be-fore vulcanization are easily repaired with uncured rubber II any leaks are detected after cure, they are repaired with uncured rubber and vulcanized to the already cured lining This repair procedure is designed so that the repaired area is at least as fully protected as the remaining lining

If each of these operations is performed with proper planning, skill, and care, the resulting lined piece of equipment will perform as expected.

Having established that we are looking for permanent rubber lining installations and having looked at the application methods which contribute to this quality, lot us turn now to the available rubber and synthetic rubber lining materials and the very important process of then selection for a specific job.

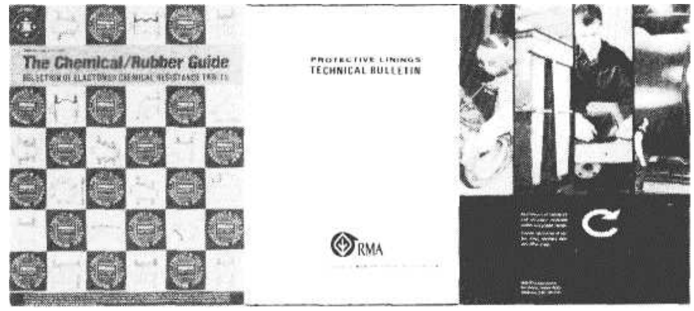
Descriptions Of Various Types Of Natural And Synthetic Rubber Lining Materials

There are many different rubber formulations or compounds as the rubber industry calls them. Each compound is mixed to an exact recipe, not only from the standpoint of quantities of ingredients, but also from the standpoint of the time of mixing in each stage and the temperature at each stage. Each lining compound manufacturer has his own set of recipes, and it is safe to assume that each compound he furnishes will be prepared by exactly the same recipe each time, with only slight adjustments to compensate for weather conditions or changes in raw material suppliers.

Table #1 lists the common types of natural and synthetic rubber lining compounds along with their properties and typical uses. In showing these various properties, we are leading up to the fact, brought out later, that there is a lot more to the selection of the type of lining material than the simple determination of the fact that it will withstand a certain solution.

An explanation of the meaning of these various properties, as shown in **Table** #1, is in order.

1. First of all, we show **the Shore Durometer Hardness** range for each lining type. This means, taking the first elastomer for example, that all soft natural rubber compounds fall into the 30 to 65 hardness range. Any specific soft natural rubber compound (*made to a specific recipe* as *indicated above)* would have a designated hardness with an allowable range of usually + or -5 points. Therefore, you might have a soft natural rubber compound designated as 40 Durometer.
2. Under the **Upper Degree Fahrenheit Limit** we have shown the top temperature to which each lining could be subjected on a continuous operating basis with expectations of full service life. In most cases these temperatures could be exceeded by up to 50° F on a momentary or short run basis. The limitation here is the ability of the adhesive system to withstand the higher temperature.
3. **Under Thermal Shock Resistance** we have shown ratings which are only relative to each other, since it is difficult to define what time and temperature cycle would be detrimental to a specific type of lining, considering the broad range of equipment that is rubber lined.
4. What we mean by **Physical Integrity** of the lining material is its physical qualities such as ease of application, strength of seams, strength of the bond to the steel, resistance to me chemical abuse, and resistance to vibration.
5. **Resistance to Hydrocarbon Contamination** is the performance under exposure to these organic materials as a low concentration impurity. Nitrile rubber and Vitons are the only materials that will continuously withstand full concentrations of any petroleum products. The aromatic type of hydrocarbons are the most detrimental to elastomeric materials, and more than 1000 parts per million cannot usually be tolerated.



Additional materials to assist you in the specification of rubber linings are available from Protective Coatings. Call us today: (260) 424-2900 for your copies!

As shown in **Table 1,** the natural rubbers are listed first: Soft Natural, Hard Natural, Graphite Loaded Hard Natural and Triply. The Hard Natural rubber is always backed by a layer of soft rubber between the hard rubber and the steel. This is used for greater flexibility of the lining and better adhesion to the metal. The Triply is a sandwich type of lining, which employs a layer of chemical, and heat resistant hard rubber sandwiched between two soft rubber layers, combining abrasion resistance with corrosion resistance in a single sheet lining material. Under the synthetic rubber materials, Neoprene and Chlorobutyl are the most commonly used. Chlorobutyl is gaining quite a bit of usage because of its somewhat easier application than the regular Butyl. EPDM, ***(Ethylene Propylene),*** is a new synthetic rubber made from petroleum products. It has excellent resistance to weathering *(ozone)* and shows great promise in the tough to handle sodium hypochlorite bleach service. It has not been completely evaluated in other services Hypalon has unsurpassed resistance to strong sulfuric and chromic acids, but it is so difficult to apply that is use is some what limited. Nitrile **(Buna *N)*** rubber has been in use many years as a maximum oil resistant rubber. It has recently been compounded as a tank lining material to take advantage of these properties Chlorinated Polyethylene Elastomer ***(CPE) i***s a newly developed material with a couple of years of actual experience as a tank lining If CPE lives up to its expectations - broad resistance to inorganic acids, organic acids, hydrocarbon impurities - ability to handle alternate services - high temperature resistance - it should be a valuable addition to the stable of elastomeric sheet lining materials.

We should bear in mind that the list of rubber and synthetic rubber linings types shown here represents approximately 30 to 40 specific lining compounds regularly furnished by each of the lining material manufacturers, so there certainly is a wide range of materials in the rubber lining field to choose from. We will be referring to **Table** #1 as we proceed to the heart of the subject of this paper, the selection of the lining material.

Table 1: For Specific Elastomer Recommendations. See: PROCO "The Chemical Rubber Guide"

Lining Type	Shore A Durometer Hardness	Upper Operating °F Limit	Thermal Shock Resistance	Physical Integrity	Resistance To Hydrocarbon Contamination	Price Range	Typical Uses
Soft Natural Rubber	30 to 65	120° F	Excellent	Excellent	Not Recommended	Lowest	Acid storage, transportation equipment abrasive services soft white rubber for food grade service
Hard Natural Rubber	85 to 100	200° F	Good	Excellent	Fair	Low	Chemical processing high temp nickel, copper plating steel pickling semi-hard to 180° F, good for vacuum service
Graphite Loaded Hard Natural Rubber	95 to 100	210° F	Fair	Very Good	Fair	Medium	Special lining for wet chlorine gas in chlorine cells and associated equip. this lining is standard for chlorine industry
Triply (*Soft, Hard. Sol! Combination)*	40 to 50	160° F	Excellent	Excellent	Not Recommended	Low	Combined abrasion and corrosion services, becoming popular for steel pickling lines
Neoprene	40 to 70	230° F	Excellent	Excellent	Very Good	Medium	Chemical and/or abrasive services with oil present Caustic Good weather resistance Fire retardant
Butyl	60 to 75	200° F	Excellent	Very Good	Fair	Medium	Oxidizing acids, Hydroflouric acid, super phos. acid Now handles 70% HF
Chlorobutyl	40 to 60	200° F	Excellent	Very Good	Fair	Medium	Oxidizing acids, HF super phos. same services as regular Butyl *(somewhat easier application than regular Butyl).*
EPDM	40 to 60	200° F	Excellent	Good	Fair	Medium	Sodium Hypochlorite bleach, Ozone resistance
Hypalon®	50 to 70	210° F	Excellent	Fair	Fair	Highest	Strong sulfuric, oxidizing acids, Chromic acid (*Application is difficult)*
Nitrile *(Buna N)*	50 to 70	200" F	Excellent	Good	Excellent	High	Chemical and oil services (*difficult to apply)*
Chlorinated Polyethylene Elastomer *(CPE)*	50 to 75	250° F	Excellent	Good	Excellent	High	Acids with hydrocarbon contaminants, alternate services high temperature *(new material with limited experience).*

®Hypalon is a registered trademark of E I duPont

Selection of the Best Lining Materials for the Job

An intelligent selection of the best lining material for a specific application goes far beyond its simple resistance to chemical concentrations, temperatures, abrasive particles, etc. A very searching evaluation of all factors at hand should be made to determine the selection of a rubber or synthetic rubber lining material for a specific piece of equipment. First of all, do not select a lining based only on the fact that it performed well in some function other than as a protective lining. Just because a butyl covered conveyor belt handles coal does not mean that it is a good abrasion resistant rubber lining. Furthermore, do not select a lining material purely on the basis of laboratory tests. Laboratory tests, for instance, could not prove one way or the other how a lining would withstand the expansion and contraction of a 500,000 gallon outside storage tank. Again, please do not select a lining material based only on an article or talk describing the basic material. For example, the fact the Ethylene Propylene rubber is listed as resistant to temperatures in the range of 300° F does not mean the tank lining Ethylene Propylene material will withstand that high a temperature. The tank lining material must be compounded to permit acceptable application and curing procedures that may or may not result in different properties than the basic material. What we are saying here is that, although outside information such as the above could be a valuable part of the lining selection, please treat it as one piece of information contributing to the whole picture, not as the only deciding factor.

The first step in lining selection is to obtain all available facts concerning the equipment to be lined and the process to be contained by the lining, including:

1. **Chemical action:**
   A. Concentrations
   B. Impurities or contaminants
   C. Chemical reactions
2. **Abrasive action:**
   A. Particle type, weight and size
   B. Velocity
   C. Percent of solids
   D. Sliding or impinging action
3. **Temperature:**
   A. Maximum, minimum, and operating
   B. Speed of change
   C. Cycle
4. **Pressure or vacuum:**
   A. Maximum, minimum and operating
   B. Cycle
5. **Physical design of equipment:**
   A. Approximate dimensions
   B. Stationary or moving service
6. **Environmental conditions:**
   A. Inside or outside
   B. Local climate
7. **Previous experience with linings under similar conditions:**
   A. Exact lining compound used
   B. Approximate size of items lined
   C. Service life

Of course it is almost never possible to come *up* with 100% of the above information, but a reasonable effort to obtain most of it will be worth while in making the best lining selection The larger the installation, the more important the correct lining selection can be.

Having obtained the above information, how do we use it to arrive at the best selection? Our plan of attack should be: first, evaluate and select a top choice to satisfy each individual category of facts separately and: **second,** make one selection considering all categories at the same time.

How do we go about this with respect to

1. **Chemical action and the maximum and operating temperatures** - First obtain a set of chemical resistance tables for tank lining material from one of the tank lining material suppliers. The most helpful one would be the type in which the resistance of various types of lining materials to each chemical listed is depicted, instead of only one material selection for each chemical One with selection for each temperature range would be additionally helpful
2. **Abrasive action** - This is usually not covered in chemical resistance tables. See guidelines discussed later.
3. **Temperature changes** - Thermal shock is an entirely different problem than maximum or operating temperatures. Consult **Table** #1 for the relative resistance to thermal shock in various lining materials. It could be said that dumping 180" F acid into an outside tank during winter at 10° F would be a severe thermal shock. The soft linings, natural and synthetic, can be considered as completely resistant to thermal shock. Hard rubber linings can sometimes be used where abrupt thermal changes occur, provided the lining applicator knows of these changes and can provide for them in his lining material selection and application.
4. **Pressure or vacuum** - Pressure is no problem, as long as the design of the seals does not affect the rubber lining construction. Under full vacuum conditions, especially pulsating, the use of a hard rubber lining material is recommended because the hard material would have much less diaphragm action in the situation where a pinhole in the steel permitted atmospheric pressure to reach the underside of the lining.
5. **Physical design** - Large outside storage tanks would be subject to expansion and contraction due to weather changes Moving equipment, railroad tank cars and trailer tanks, are subjected to so much twisting, turning, and vibration that experience has proved that only the soft natural and synthetic lining materials can be used in this type of equipment.
6. **Environmental conditions** - If the item is inside a building, even if the building is not heated, a fairly steady temperature can be expected. If the lined equipment is outside, then a quite wide range of temperatures could be expected, and this temperature fluctuation should be considered when analyzing the flexibility of the lining material being considered.

I believe that some guidelines in certain areas would be helpful in selecting a lining material:

1. When considering natural rubber a general rule is that the harder the lining material *(more combined sulfur)* the higher operating temperature it will withstand, and to a lesser extent, the higher chemical concentration it will withstand.
2. Abrasive action occurs in two ways - the impingement type and the sliding or cutting type. For pure impingement the resilience or elasticity of the rubber permits the particles to sink in and bounce off without damage to the rubber, and in this case the softest natural rubber should be used. In the case of sliding or cutting action, then a tougher, somewhat harder, tear resistant rubber should be used.
3. In consulting chemical resistance tables the fact that a certain lining is recommended for several different chemicals does not mean that the lining is suitable for all those chemicals mixed together in one vessel In such cases, a reasonable answer can only be obtained through laboratory tests or evidence of actual experience under similar conditions.
4. In general, natural and synthetic rubbers do not withstand hydrocarbons, oil products, or solvents. Neoprene synthetic rubber is one lining material that does a reasonable job of withstanding chemical or abrasive services with *a* small amount of oil products present. Hard rubber probably has the next best resistance to small amounts of oil. Nitrile synthetic rubber ***(Buna N)*** has very good resistance to petroleum products but its application as a tank lining material is difficult and very expensive. The new chlorinated polyethylene elastomer CPE may very well satisfy the need for a lining to withstand solvent contaminated acid.

As the set of service conditions becomes more complex or more severe, there are additional ways to find a suitable lining material in the situation where there is chemical action and abrasion at the same time, a three-ply lining might be the proper selection. The three ply material employs a hard rubber inner layer for chemical and heat resistance, with two soft outer layers for flexibility and abrasion resistance If the conditions are more severe, say in the 180° to 200° F range, where a full thickness of hard rubber is needed, it is also possible to vulcanize a full extra layer of high temperature resistant soft rubber on top of the hard rubber at locations where there is abrasive wear. If the conditions are even more severe yet, then a brick lining inside of the rubber lining might be the answer. Each course *(4")* of brick reduces the temperature of the lining by approximately 20° F The brick also provides complete protection of the rubber lining from mechanical abuse.

In treating the subject of lining selection, all available information is valuable. There is one great advantage in working with the rubber lining industry Given all this valuable information, the reputable rubber lining applicator will make the selection of a lining material for a specific job, and he will guarantee that the lining material will perform properly in service provided the given conditions are not exceeded The best that can be done in selecting a lining for a large project is for the customer and the lining supplier to pool their information and experience, coming up with the best possible recommendation.

What Is Important To Specify When Purchasing A Rubber Lining?

In order to provide for reasonable quality materials and workmanship, a purchasing specification for elastomeric lining should include the following:

1. **The rubber lining material should be calendered in approximately 1/32" thick plies.** This means that the uncured rubber material would be mixed and then squeeze rolled out to a thin 1/32" sheet. In the calendar, which is a series of large rolls, six of these 1/32" sheets would be rolled together to form a 3/16" thick sheet. This calendering in thin plies prevents an imperfection or void in the mixing cycle from affecting more than one 1/32" ply of the finished lining. The possibility of any sort of a pinhole leak in the lining is greatly reduced. **There are some good materials that are manufactured by the extrusion method.** These materials can be used, provided good experience under similar conditions is the basis of selection.
2. **The adhesives should be specified as the thermosetting type.** This is the type in which a chemical change occurs with the application of heat, so that the adhesives will cure and reach their final state at the time the lining is cured. After the adhesives are cured then there is no physical change *(such as softening)* when the lining is in service under hot conditions. The only way in which a thermosetting type adhesive system can fail is for the temperature to reach the destructive point, which is around 300° F for this type of adhesive system. Thermoplastic adhesive systems are not recommended be-cause the adhesive becomes softer as the temperature goes higher, resulting in the possibility of failures in the 150° F range.
3. **The lining application should be performed by a qualified applicator with at least five year's experience in the rubber-lining field.** In the lining application there are many little known factors which can seriously affect quality and performance. Unless the applicator has had a reasonable amount of experience, with successful installations to his credit over a period of time, it would not be wise to entrust a large rubber lining installation to him.
4. **The method of application should be essentially as outlined in Paragraph 3; Application Procedures For Elastomer Linings.** Some latitude should be extended on the construction of the seams between sheets, depending on the particular lining material used and the item to be lined.
5. **The completed lining should be tested for pinhole leaks with a spark tester at the correct voltage for the lining material used.** All leaks are to be repaired in such a manner that the repaired area is as good or better than the rest of the lining.

Advantages Of Using Rubber Linings

There is a large quantity of rubber lined metal items in service today, because this type of equipment has certain inherent advantages, as follows:

1. **Versatility**
   a. Combined abrasion and corrosion resistance.
   b. Brackets, bolt holes, weirs, and nozzles, practically anything can be lined or covered.
   c. No maximum size limit on tanks to be lined.
   d. Lining can be applied to cast iron, stainless steel, aluminum, Monel and copper as well as carbon steel
2. **Economy**
   a. With the strength provided by economical steel, the inexpensive lining needs to contribute only resistance to the service.
   b. Long service life makes cost per year low.
   c. Possible to renew investment in tank by stripping old lining and applying new.
   d. Ease of application.
3. **Safety**
   a. Steel and rubber construction resists mechanical abuse, b. No catastrophic failures.
4. **Physical Toughness**
   a. Ability to withstand full vacuum.
   b. Ability to withstand twisting, turning, vibration of a moving vehicle.
   c. Thermal shock resistance.

Disadvantages Of Using Rubber Linings

There are also disadvantages in the use of rubber lining and these must be considered when working with rubber lined equipment.

1. A rubber-lined tank, strictly speaking, does not have outside corrosion resistance. In order to achieve this, it is necessary to have the tank exterior sandblasted and spray or brush coated with an industrial corrosion resistant coating or paint, and to overcoat this paint every few years during the life of the tank.
2. Repairs to rubber lined equipment must be performed by skilled people in order to insure reasonable success. If a company has a large quantity of rubber lined equipment, it may be economical for them to have one or two of their men trained in this work. Otherwise, it is best to have skilled rubber lining technicians come to the job site. It is very difficult to remove a good quality rubber lining, even though it has reached the end of its service life. Usually it is necessary to heat the metal to which the rubber is bonded to approximately 450° F in order to destroy the bond quickly. In the case where a tank has an expensive insulation on the exterior, it is then not possible to apply heat to the exterior metal, and lining removal must be done with air hammers and chisels. Some success in the use of solvents for removal of old linings has been achieved.

What to Look For when Inspecting a Lining

This will cover the inspection of a new rubber lined tank or piece of equipment as well as an old rubber lined item that has been in service. The defects to look for and the method of detection is shown below:

1. **Pinhole leaks,** detected with a spark tester. This should be performed by a skilled man familiar with rubber lining; because it is possible to burn through the lining and create leaks with a spark tester.
2. **Loose adhesion,** detected by examining the edges of nozzle flanges, checking for hollowness inside the tank. If vacuum service is involved, ask for a sample pull test on a loose plate that followed the complete lining process.
3. **Voids or blisters,** detected by examining the lining surface, tap surface and listen for hollowness, and shine a flashlight parallel to and close to the lining surface.
4. **Poor seam construction,** detected by observation, all edges must be skived *(beveled),* and there must be no air trapped behind a seam. Press fingers at the start of the lap seam, where the underneath sheet ends, to detect air pockets under the rubber. Also try to lift the extreme edge of the seam to detect looseness.
5. **Surface defects,** detected by observing the general lining surface. Round or oblong, deep impressions, caused by calender blisters, and long wrinkles caused by sagging during rubber shipment are the most common surface problems. Either type should be repaired if their depth results in under gauge rubber at that point.
6. **Under or over cure,** detected by taking a Shore A Durometer hardness reading at several points. A low reading will indicate the lining is not completely cured. A high reading would in-dicate, in the case of hard rubber, that there is a possibility of over cure. In the case of tanks that have been in service, the tendency is for the hardness reading to increase with the years of service.

New Problems and New Answers

The applications and uses for elastomeric sheet linings have become more complex. Longer service life is expected. Service conditions are more complicated. Examples: By-product acids containing solvents and other impurities, severe abrasive conditions along with chemical action, the threat of lining destruction through fire, larger and larger equipment to be lined in the field.

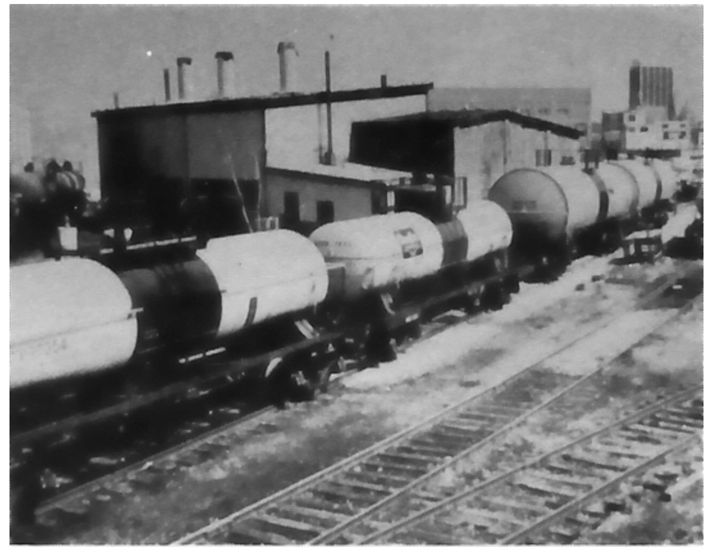
It appears that the elastomeric lining industry is responding to these new demands with some thought and ingenuity. Rubber lining is no longer a black art practiced by a few companies unwilling to share their knowledge and experience. Technical industry groups, including the Rubber Manufacturers Association Protective Linings Subdivision, ASTM, and NACE are working on industry standards. The next few years should bring greater technical expertise in the industry and more knowledge of elastomeric lining capabilities, strengths, and weaknesses on the part of the chemical engineers and corrosion engineers. ***(Continued On Next Page.)***

New Problems and New Answers
(*Continued from Page 5.)*

Some of the new answers to the new and old problems are as follows:

1. The use of Chlorinated Polyethylene *(CPE)* for hydrocarbon contaminated acids, for multiple services, and for greater heat resistance is going to increase the capabilities of elastomeric materials.
2. A Chlorobutyl lining material with flame-retardant equal to neoprene is in the development stage. Such a material would be extremely valuable in FGD scrubber lining applications to reduce the threat of fire before startup and during scrubber shutdowns
3. Advances in rubber manufacturing technology have been responsible for the manufacture of uncured tank lining sheets by the extrusion method, instead of calendering. Also continuous extruded uncured rubber tubes are being produced for pipe linings. These developments will result in material and labor cost reductions
4. Chlorobutyl and Ethylene Propylene ***(EPDM)*** are two elastomers for which possible new uses have not yet been fully developed or tested Both of these materials should be adding to the range of capability for elastomeric sheet linings

In the selection, application, and use of elastomeric lined equipment; success can be achieved through full cooperation between the users of this equipment and the applicators or suppliers.



Rail tank car awaiting rubber lining at The Protective Coatings, "Round House" in Ft. Wayne, Indiana.

Procedure for Application of Rubber Lining

1. **Metal Construction**

Metal fabrication shall be in accordance with standard commercial practice to obtain a practical product and uniform quality. Design should provide adequate structural strength for intended service. Body seams must be butt welded with continuous solid welding. All welds over which rubber is to be applied shall be continuous and shall be ground smooth and be free from pinholes, pits, high spots, etc. For detailed instructions, please refer to Protective Coatings' specification, **Welding And Metal Fabrication Requirements Of Parts To Be Rubber Lined.**

2. **Metal Preparation**

All surfaces to be lined and/or covered shall be steel grit or sand blasted to a near-white, uniform metallic color, with a deep anchor pattern. These surfaces are to be free from oil, grease, dirt, mill scale, rust, and other foreign matter. The first coat of adhesive must be applied without delay after the blast cleaning is completed, before any rust can form. On large items that take more than a day to blast, the area blasted on one day must be primed that same day.

3. **Adhesive System**

Adhesives are the thermosetting type, which means that the adhesives are vulcanized along with the rubber and do not thereafter lose adhesive strength unless their temperature limitation is exceeded. The adhesives consist of a base cement of which at least two coats are applied to the metal and an intermediate cement of which at least two coats arc applied to the metal. In some cases, depending on the rubber compound used, an additional tack coat of adhesive is applied. It is important that sufficient drying time for each coat of adhesive is maintained. Too quick application of the next coat of adhesive might cause the under coat to lift up or cause blisters in the rubber lining during cure; due to trapped solvents between the adhesive coats.

4. **Method of Applying Uncured Rubber**

The rubber lining sheets are calendered (rolled) as follows: Each ply of stock is calendered to a gauge of .020" to .030". These separate plies are calendered together to build up a sheet of not less than specified thickness, usually 1/8", 3/16", or 1/4". The process of calendering the stock to the thin gauge is included to eliminate blisters and to make certain that the stock is homogeneous throughout. A few synthetic rubber-lining materials have been successfully made by the extrusion process.

Preparation for application to the tank is as follows: After cutting and skiving all edges of each uncured rubber sheet, both the sheet and the cemented metal surfaces are freshened by wiping with Xylene (solvent) or white gasoline. The sheet is then allowed to dry until tacky, but not wet or slippery.

The calendered sheets, prepared as specified above, shall be applied to the cemented surfaces in sections of proper size, each section being individually applied and carefully rolled and stitched down to assure against the trapping of air behind the rubber lining.

All edges shall be laid straight and all seams shall be made overlapping adjacent calendered sheets by not less than 2" (including skives); unless restricted by close tolerances in corners or inside nozzles, etc. All overlapping edges shall be skived. In cases where the lining material has a tie gum inner layer which is a different compound than the face material, the outer skived edge at a lap seam shall be turned down to avoid exposure of the tie gum to the service condition. A different seam construction, consisting of a skived butt seam with cap strip (minimum 3" width), is also acceptable. The number of seams shall be kept to a minimum. The bond between adjacent sheets shall be such that separation cannot occur without tearing the rubber

The rubber lining shall extend out over the full face of all flanges of nozzles and manholes unless otherwise noted. All manhole covers and blind flanges shall be lined. Nozzles shall be lined so as to provide a smooth opening of maximum possible diameter. Circumferential joints shall be located so as not to restrict the opening.

Application of the adhesives and uncured rubber lining sheets should be performed under cover from weather conditions and at a minimum temperature of 60° F so that the adhesives will dry properly and the rubber sheets will not be stiff and difficult to apply.

5. **Vulcanization**

After the rubber has been applied in accordance with the above, vulcanization shall be carried out under conditions such that no blisters will develop between the rubber and metal during this operation. The vulcanization conditions and stock shall be such that during curing no sagging takes place so that a uniform layer of rubber lining, not less than the specified thickness, is obtained throughout the equipment.

Vulcanization can be carried out in an autoclave under air and steam pressure. If the tank or item to be lined is too big for the autoclave, then exhaust steam at atmospheric pressure is confined in the tank to bring about vulcanization of the rubber. The autoclave cure is conducted at approximately 280° F for a period of approximately 14 hours including warm up and cool down. The exhaust steam atmospheric cure is con-ducted at 190 - 210° F and for a period of approximately 36 hours or more.

The cure is accomplished by means of the sulfur curing agents, and accelerators mixed with the rubber in combination with the heat of vulcanization. Certain repair materials can be cured with the application of a liquid activator and a small amount of heat. This provides for vulcanization in a short time, but this procedure is restricted to small repairs.

6. **Testing**

After vulcanization, the lining shall be visually inspected for blisters, open seams, and other defects. Also, the entire surface shall be spark tested with an electrostatic tester for detection of pinhole leaks that cannot be seen. For complete instructions, refer to Protective Coatings' Specification, **Electrostatic (Spark) Testing of Rubber and Synthetic Rubber Linings.** Any defects or spark leaks shall be repaired using the proper repair materials and procedures, to insure that the repaired area is at least as resistant as the rest of the lining.

Atmospheric Cured Versus Pressure Cured: Rubber Lining

1. Some rubber lining compounds must be cured or vulcanized under pressure, as in an autoclave. Other compounds can be cured either with atmospheric steam or steam under pressure. The type of cure depends on the curing agents and accelerators that combine with the sulfur in the rubber and bring about the vulcanization, which is a chemical change. Some accelerators kick over the cure at higher temperature (270° F), others at lower temperatures (180° F)

2. with in certain limits the higher the temperature, the faster the cure is com-pleted (pressure cure) the lower the temperature. the slower the cure is accomplished (atmospheric cure) It is, therefore, advantageous to vulcanize parts under pressure because of the time saving element. With the proper curing time and the right compound, just as complete a cure or vulcanization can he obtained with an atmospheric cure as with a pressure cure.

3. Some lubber materials usually are not atmospheric cured, even though they have the right accelerator. Hypalon and Butyl, for example, are difficult due to the possibility of calender blisters between rubber plies forming during cure This is not the case with the natural rubber compounds In fact, there is a whole group of compounds which can be atmospherically cured with absolutely no difficulty

4. It is true that certain types of com pounds would have more porosity when atmospherically cured rather than pressure cured This is not true of Triply® It may be true of some materials not developed and compounded specifically for atmospheric cure

5. To our knowledge, there is not the slightest difference in the chemical and/or heat resistance of Triply lining compound when atmospheric cured as opposed to pressure cured.

6. It is necessary to have available atmospherically cured compounds because a material is needed for lining large storage vessels that are not possible to pressurize. Atmospherically cured compounds are also needed for making repairs to rubber lining materials having been in service and making field splices on vessels too large to ship to the job site all in one piece.

7. It is said that a pressure cure puts the rubber lining down on the metal tighter. This may be true to a certain extent. However, when removing old rubber lining, both the atmospheric and pressure cured compounds must be removed by air chippers, demonstrating a tightness of bond. Where the difficulty is encountered is from air trapped between the rubber lining and the metal. If the rubber lining applicator leaves some air behind the lining on a compound which is going to be pressure cured, the air might diffuse into the lining or spread out under the lining. With an atmospheric cure the same air trapped behind the rubber lining will have more of a tendency to expand and blow-up into a very noticeable blister which can be easily found and repaired The better the workmanship, the fewer the blisters It is conceivable that a pressure cure could hide sortie poor workmanship winch could cause trouble later through non-adhesion over an area

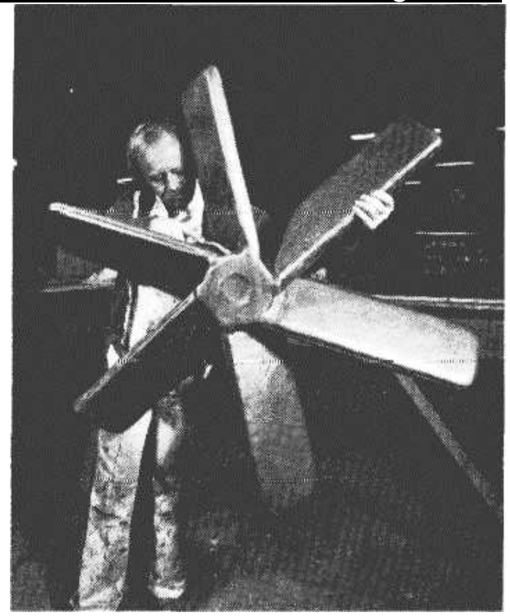
8. A good rubber lining applicator can line successfully for vacuum service where the vacuum is actually exerting a force to pull the lining off the metal Protective Coatings has applied rubber linings on vacuum service vessels, using an atmospheric cured rubber, with very satisfactory results

9. Atmospherically cured rubber compounds are probably at least as thoroughly cured as the pressure cured compounds because a longer time is involved. This means that the metal has more time to reach the desired temperature for curing

10. Some rubber lining applicators have attempted to raise doubt that an atmospheric cured rubber is of sufficient quality This is done in an effort to rule out other competitive applicators who do not have the very largest vulcanizers or autoclaves 11. The primary reason for the rubber lining applicator to have vulcanizers for their operation is to offer speed in curing the compound, convenience in the shop for expediting orders and for curing special compounds.

Conclusion: With Triply® and other specifically compounded rubber lining materials, there is no disadvantage in using the atmospheric steam curing process.

References: Protective Coatings, Inc. has had many years of past experience in supp-lying atmospherically cured and pressure cured rubber lining compounds to custo-mers having a wide range of service condi-tions References are available upon request.



Welding And Metal Fabrication Requirements Of Parts To Be Rubber Lined

1 All vessels intended for rubber or synthetic rubber lining shall be continuously welded on all surfaces to he lined with full, smooth, continuous weld beads free from sharp edges, porosity, pinholes undercut-ting, slag pockets and other imperfections Rough welds must be ground smooth but not necessarily flush All protrusions, sharp edges and weld splatter shall be removed by grinding.

? All seams are to be butt-welded with full penetration, corners are to be fillet welded. Misalignment of plates and seams shall not exceed 25% of the plate thickness and in no case shall exceed 1/8" Lap welded construction is not acceptable **(See Drawings A & G).**

3. Partitions, braces, supports, or other att-achments to be rubber lined shall be full welded on all sides. For vacuum services, see Item 5 below for welding and fitting requirements

4. Nozzles and manholes shall be fully seal-welded on the inside of the vessel with proper bracing, if necessary, to prevent war-page during the welding process Nozzles and manholes shall not protrude on tank interior **(See Drawing D).**

5. If the vessel is to be used under vacuum service, fabricator must eliminate all under-cutting, voids, or pits in the welds and steel plates.

6. All closed vessels must have one access manhole of not less than 18" inside diameter.

7. Voids in porous cast metal must be welded and ground smooth Sharp projections, casting fins, or burrs on casting must be completely removed Surfacing cements for porous metal or rough castings are not permitted Cast iron should not be used for vacuum service

8. All internal corners to be rubber lined external corners to be covered shall be ground to a radius of at least 1/8". **(See Drawing B & C).**

9. The condition of the interior must meet the above requirements and be acceptable to Protective Coatings, Inc. Drawings of unacceptable and acceptable workmanship are shown in Table 2.

Table 2: Welding Examples

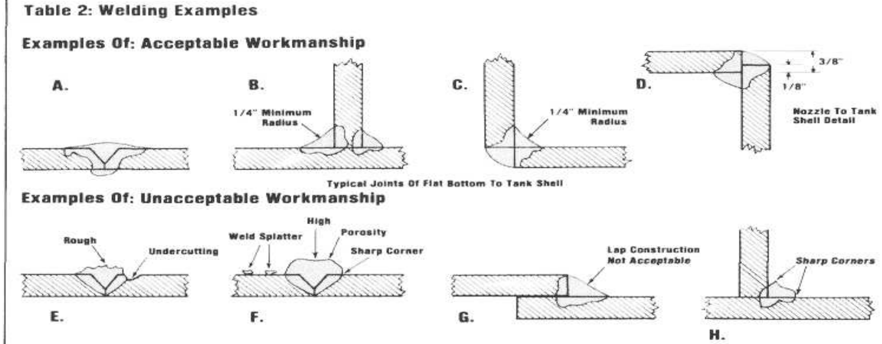
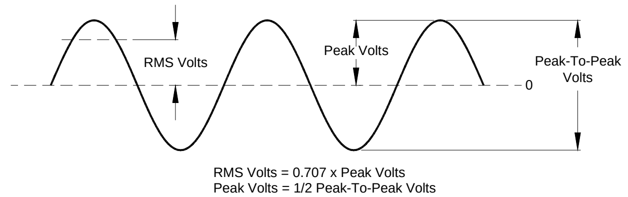


Figure 1. Sinusoidal Voltage Waveform



Electrostatic (Spark) Testing of Natural and Synthetic Rubber Linings

I. **General**

Spark testing is an excellent method for detecting rubber-lining leaks not visible to the human eye. Complete spark testing should be performed on all rubber lined equipment, unless it is impossible to do so, as is the case with conductive lining materials The spark testing is performed with an electrostatic tester which produces sufficient voltage to detect a pin hole leak; but not too much voltage, which would burn through and create a leak in the rubber lining.

II. **Calibration**

Before testing, the electrostatic (Spark) tester must be calibrated to suit the item to be tested and provide the maximum contrast between good lining and a leak or connection to the metal To do this the spark tester is plugged into a 110 volt AC source and the voltage turned up to the point where blue sparks are emitted to the rubber lining surface to be tested; as the spark tester is passed over it. Then the spark tester probe is moved near to a lining edge where there is exposed metal. The spark gap, where a white spark jumps to the metal, is measured. The voltage knob is then adjusted to: (1) provide a 1/2" to 1" white spark length from probe to metal and, (2) to provide the maxi-mum color contrast between white spark to the metal and blue spark to the rubber. After calibration of the spark tester in the above manner, the spark test of the rubber lining for pinhole leaks should then be performed.

III. **Procedure**

This test consists of passing the spark test probe (electrode) over every square inch of the rubber lining to be tested. The spark tester is kept moving at all times to avoid damaging the rubber lining. Identification of leaks is made by a change in the color of the spark. Where there are no leaks or direct contact with the metal, the spark will be blue in color At a leak, the spark will turn bright (white) and the direction of the spark will remain at the leak if the end of the tester is swept around it. Sparks to a leak will be identical to the sparks that go to the metal when the electrode is moved close to the edge of the lining. Once a positive leak is found, it will always show when the spot is re-tested. Damp spots will show fairly bright sparks. Specks of dirt, depressions and foreign matter will change the color of the spark. These should be considered as a possibility before definitely establishing that a leak is present. These areas should be wiped off with a clean dry cloth and then re-tested to establish the presence of a leak

IV. **Precautions in Testing**

Care must be exercised in testing rubber linings, especially the synthetics such as neoprene or butyl, to make sure leaks are not burned through the lining by the tester itself Because of this danger, it is necessary to sweep the spark tester point over the area and not hold it in one place on the lining. 10,000 volts will burn holes through 3/32" thick neoprene or butyl rubber very quickly and it is possible to burn holes through linings thicker than 3/32" by holding the tester point against the lining until it becomes hot

V. **Information on Spark Testers**

The general practice is to use a high frequency Tesla type, electrostatic tester, with a rated peak voltage of 0 to 50,000 volts. After constant use for 15 to 30 minutes, the tester may become hot and/or the spark intensity may decrease, in which the tester should be turned off and allowed to cool off for 10 to 15 minutes. Before proceeding with the test, the spark tester should be re-cali-brated as indicated above under Paragraph II. This method will prolong the life of the tester as well as insure a complete test

Facts about Spark Testing

1. Before specifying spark test voltages, the definition of AC voltage should he established. Spark tester manufacturers refer to peak voltages producing a certain spark gap length. However, AC voltmeters read in RMS, mean effective volts. Due to the sinusoidal waveform of alternating current, these two voltages are not the same See Figure I for the relationship between peak voltage and RMS voltage.
2. For the same power (voltage) input, different lengths of spark gap result from different geometrical shapes of test probes. Tables I, II, III, and IV bring out this point. It is possible that different metals used in test probes result in different gaps. Note Tables II and III from reliable sources, show different spark gaps, although both are assumed to be measured between needle points
3. An experiment was conducted using 1/4" thick soft natural rubber vulcanized to a piece of steel. A straight pin was used to puncture the rubber. The pinpoint was pushed against the steel and twisted to make sure a leak occurred. A spark tester equipped with a voltmeter, reading 20,000 volts RMS maximum, was then connected. This spark tester, turned up to the maximum 20,000 volts, did not detect the leak. Both a brush probe and a pointed probe were tried. Then a hand held spark tester was set up at a high voltage, probably 30,000 to 35,000 volts. This tester easily detected the leak. Subsequent to finding the leak with the hand held unit, the 20,000 volt metered unit was tried again. This time it easily detected a leak, indicating that the hand held unit must have enlarged the leak by burning. **This experiment prompts us to reach the following conclusions:**
   - A. Recommended spark test voltages of 10,000 or 15,000 volts are probably not high enough to detect all leaks.
   - B. Going to a higher voltage will detect most leaks, but the danger of burning through the lining then becomes much greater.
   - C. Possibly the voltage designation should be eliminated from spark test specifications and the length of spark gap should replace it as a measure of ability to detect leaks.

Proco
Protective Coatings, Inc.

Table Number	Source of Spark-Gap Data	Settings Are "Peak Voltage" Except Table III That Is "Mean Effective Voltage"					
		5,000	10,000	15,000	20,000	25,000	50,000
		Spark Gap CM – Inches	Spark Gap CM – Inches	Spark Gap CM – Inches	Spark Gap CM – Inches	Spark Gap CM – Inches	Spark Gap CM – Inches
I	Buckley's Uvral Spark-Gap Setter	0.29 - 0.11	0.58 – 0.23	0.88 – 0.35	1.18 – 0.46	N/A – N/A	N/A – N/A
II	Handbook Of Chemistry And Physics (Assuming Needle Point Probes)	0.42 – 0.17	0.85 – 0.33	1.30 – 0.51	1.75 – 0.69	N/A – N/A	N/A – N/A
III	The American Electricians Handbook (Assuming Needle Point Probes)	0.57 – 0.22	1.19 – 0.47	1.84 – 0.72	2.54 – 1.00	N/A – N/A	N/A – N/A
IV	Electro-Technic Products (Assuming Needle Point Probes)	0.25* - 0.10*	0.51* - 0.20*	0.76* - 0.30*	1.02* - 0.40*	N/A – 0.50*	N/A – 1.00*

***Approximate**