MTI MANUAL NO. 7

PRACTICAL GUIDE TO THE USE OF ELASTOMERIC LININGS

Materials Technology Institute of the Chemical Process Industries, Inc.

FOREWORD

The chemical process industries have utilized elastomeric linings to protect equipment from corrosion and abrasion for scores of years. Advantage has been taken of the unique properties of these materials of construction; they can be applied to most equipment shapes and sizes and have a known spectrum of corrosion resistance. A variety of industrial apparatus including process vessels, pumps, fans, filters, transportation equipment, pipe, scrubbers, electrolytic cells and storage tanks regularly receive linings.

The selection and application of elastomeric linings is a well developed art form. The Materials Technology Institute wished to have a compilation of technical information to assist lining users and designers.

Dr. A. F. Hall, drawing on his vast experience with elastomeric lining materials in the United Kingdom, has produced this manual to include guidelines for selection, design, application and inspection of lining materials. The report is laced with sketches of designs generally considered good practice as well as designs that are not recommended. A description of the types of lining materials available helps selection. Practical information on maintenance, handling, inspection and rectification of faults is included.

Valuable comments were received from B. I. Zolin—E. I. duPont de Nemours & Company, H. G. Clem—Union Carbide Corporation and A. O. Fisher—Monsanto Company, and are included in the manual.

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I INTRODUCTION

The use of elastomers for the protection of process plant has been well proven over many years. With proper selection of the grade of rubber to be used, the correct design and fabrication of the equipment, and control of the lining process, the possible uses of elastomeric linings are many and varied. Correctly specified and applied, such linings will protect equipment fabricated in other materials—the most common being carbon steel, cast iron and concrete.

This report describes the types of rubber available and an indication is given as to the properties of these rubbers. Selection of the type of rubber to be used is most important and the information required to make that selection is detailed. When the use of a lining is considered appropriate, a decision should be made before the design of the equipment is finalized because there are design requirements for lining and these are described. Fabrication of equipment is also considered. The application of linings is generally the business of specialist contractors but it is important that designers of equipment and operators of plant know the processes involved and these are described. Indeed, selection of a thoroughly competent applicator is as important as the selection of the rubber or the design of the equipment.

As with many types of work, specifying materials and work content is not sufficient to ensure the quality of the work and guidance is given on testing and inspection.

Finally, the question of maintenance and repair of linings is considered.

II RUBBERS USED FOR LINING OF EQUIPMENT

There are many elastomers available commercially but not all are suitable for application as linings.

The elastomers that are used will be compounded by the manufacturer of the rubber sheet used for lining; the properties of these compounds vary according to the type of rubber, fillers and vulcanising agents, and the proportions employed.

It is important to recognise that from the same generic type of rubber different compounds can be made which will have different properties, especially with regard to chemical and temperature resistance. For example, when linings are to be used for acid duty (service), it is essential that the filler is inert. Normally, rubbers are not conductive but compounds can be formulated in an anti-static or conductive form.

When linings are especially required to withstand erosion or abrasion, suitable compounds can be formulated, normally from natural rubber.

Compounds will also vary according to the method of vulcanisation which is to be employed in the lining process. Vulcanisation is carried out at elevated temperature; in some cases, the sheet will be prepared pre-vulcanised. For repairing rubber, special compounds can be vulcanised using a chemical such as one based on carbon disulfide. Other repair compounds vulcanise at room temperature and must be stored at temperatures below 0° C (32° F).

Because there are so many factors which control the detailed properties of rubber, it is not possible when describing individual types of rubber to be precise about the chemical resistance and the temperature range over which they may be used. Therefore, the following information about the different rubbers is intended for guidance. Similarly, chemical resistance tables issued from various sources are indicative rather than precise. Final selection will be made in the light of experience, manufacturers' detailed knowledge of their compounds, or actual testing.

Rubbers are obviously identified by generic type but they can also be divided into two classes, namely hard and soft. Soft rubbers have a hardness in the range 40-80 International Rubber Hardness Degrees or a Durometer A hardness of 30-75. Hard rubber linings, some of which are referred to as ebonite, have a Durometer D hardness of 35-85. The Durometer hardness test method is described in ANSI/ASTM D2240. The test method for International hardness is described in ANSI/ASTM D1415.

2.1 Soft Rubbers

- Natural (NR) or Synthetic Polyisoprene (IR)
  Linings based on these rubbers are resistant to most inorganic chemicals with the exception of strong oxidising agents. The resistance of these rubbers to organic chemicals is limited. They are satisfactory with alcohols and other polar organic chemicals. They should not be used in the presence of aliphatic, aromatic hydrocarbons, halogenated hydrocarbons and mineral oils. Soft compounds (40-50 IRHD or Durometer A 30-50) based on these rubbers have excellent resistance to abrasion and erosion. The service temperature range is about -30° to about 100° C (-22° to 212° F).

- Polybutadiene (BR) and Styrene-butadiene (SBR) Copolymer
  These materials can be used either singly or in blended form with natural rubber and will have similar properties to natural rubber.

- Polychloroprene (CR)
  Compounds made from CR possess greater resistance than natural rubber to ozone and sunlight and also have resistance to some oils. They should not, however, be used in conjunction with halogenated or aromatic hydrocarbons. Suitably compounded grades of polychloroprene can be used in the temperature range -20° to 70° C (-4° to 158° F).

- Butyl Rubber (IIR)
  Butyl rubber is a copolymer of isobutylene and isoprene. Butyl rubber has better resistance to oxidising acids than natural or polychloroprene rubbers. Butyl rubber has a low permeability to gases and lower water absorption than other soft rubber compounds. Butyl rubber is not suitable for use with chlorine and other halogens, mineral oils, halogenated or aromatic hydrocarbons. The service temperature range is about -30° to about 95° C (-22° to 203° F).

  In the case of halogenated butyl (chlorobutyl) rubbers, the upper temperature limit is 125° C (257° F). These rubbers have properties somewhat similar to those of butyl rubber and are somewhat easier to apply.

- Nitrile Rubbers (NBR)
These rubbers are copolymers of acrylonitrile and butadiene. Use in large-scale lining operations has been limited up to the present to occasions where oil resistance is required. Polymers which contain the higher ratios of acrylonitrile to butadiene are particularly resistant to swelling by mineral oils and fuels; similarly, gas impermeability is increased. Nitrile rubber should not be used with phenols, ketones, strong acetic acid, and most aromatic hydrocarbons. The useful temperature range is about -20° to about 105° C (-4° to 221° F).

- Chlorosulphonated Polyethylene Rubber (CSM)
This is a synthetic rubber with excellent resistance to ozone and oxidising chemicals and has good abrasion resistance. It can be compounded for very good resistance to oxidising chemicals such as sodium hypochlorite solutions, to sulphuric acid and to sulphuric acid saturated with chlorine. It has good resistance to most oils, lubricants and aliphatic hydrocarbons, but is unsuitable for use with esters and ketones. The useful temperature range is about -10° to about 110° C (14° to 230° F). This material is used on a limited scale for lining.

- Ethylenepropylene Rubbers (EPR and EPDM)
These are available as co- and ter-polymers but are only used on a limited scale for linings. Their properties are very similar to those of butyl rubber. Selected compounds have very good resistance to water and steam at temperatures up to 100° C (212° F) but they may crack if highly stressed.

- Fluoro Rubbers (FPM)
Fluoro rubbers have excellent resistance to a very wide range of chemicals but their use as linings is limited to small ancillary equipment. The notable exceptions in their chemical resistance are low weight, polar organic chemicals, e.g., methyl alcohol, ketones, amines and anhydrous ammonia. Many grades are unsatisfactory for use with high pressure steam. The service temperature range is about -30° to about 100° C (-22° to 212° F).

2.2 Semi-hard and Hard Rubbers

The hardness of the rubber is dependent on the amount of sulphur added for curing or cross-linking the polymer. Soft rubber (Durometer A 30-75) has 0.1 to 4% sulfur; semi-hard rubber (Durometer D 35-60), 13 to 20% sulphur; and hard rubber (Durometer D 60-85), 25 to 31% sulphur. Hard rubbers are classified in ANSI/ASTM D2135.

An indication of the chemical resistance of natural, polychloroprene and butyl rubbers is given in Appendix A.

The ratings quoted are for exposure to the fluid at 20° C (68° F). Again it is emphasised that the full service conditions be considered when referring to tables of chemical resistance. For example, reference to Appendix A and experience will indicate that soft natural rubber is satisfactory for use with concentrated hydrochloric acid. This is correct. However, if the lined equipment which is exposed to concentrated hydrochloric acid is washed out frequently with water then soft natural rubber is not a satisfactory choice.

Impact resistance of hard rubbers may be improved by the addition of plasticisers. Hard rubbers have better chemical and heat resistance than soft rubbers of the same type. They are susceptible to impact damage especially at low temperatures.

- Natural (NR) and Polyisoprene (IR) Hard Rubbers
  These materials are more resistant than soft rubbers to all organic and inorganic acids, caustic solutions, aliphatic hydrocarbons and chlorine gas.

- Nitrile Rubber (NBR) Hard Rubbers
  The resistance of these linings to some organic compounds is better than that of other hard rubbers.

NOTE: The letters in parentheses following the heading for each rubber are the symbols used to identify the generic type. See ASTM D1418.

III SELECTION AND TESTING OF ELASTOMERS FOR USE IN PROCESS PLANT

Process conditions for which elastomeric linings are known to be suitable are many and varied. Where possible, selection of an elastomer(s) for a particular duty should be made on the basis of previous experience. Most producers of elastomers and manufacturers of sheet rubber provide tables indicating the chemical resistance of their products. Such tables offer guidance but do not necessarily give the complete information required. Process plant requirements are seldom simple and testing may be required to provide assurance that a rubber lining will perform satisfactorily in the given conditions.

If possible, samples of rubber should be placed in process streams, e.g., in a pilot plant. When this is not possible, service conditions should be simulated. The test liquor should represent the process stream as closely as possible. It is important that when organic chemicals are present in the process, even in trace quantities, they are added to the test liquor and the test liquor changed at frequent intervals. Rubber can preferentially absorb chemicals and the effect over a period of time may be cumulative.

If appropriate, samples of rubber should also be placed in the vapour space. All rubber samples should be identified by type and manufacturer's reference.

It is sometimes useful to test in two ways. The simplest method of assessing suitability is to expose sheet samples of the rubber to the test conditions and measure volume swelling, effect on hardness, change in weight, tensile strength and elongation. Test methods covering these properties are well established in various national standards. The results of such tests will give a fairly clear indication of the chemical resistance of the rubber. The second method is to expose a sample of rubber lining bonded to the substrate (normally steel) to the test conditions. By exposing one side of a lined test panel, the method closely approximates the service conditions including the temperature differential between the external and internal surfaces of a tank, which may accelerate permeation of the lining by the medium. In addition, this test will give an indication of whether the rubber will remain bonded to the substrate in the service conditions. The samples should be examined for evidence of surface cracking, blistering and delamination.

It is important that the samples of rubber used for test purposes are representative of the rubber to be used for lining. Therefore, they should be taken from sheet produced for that purpose which has been vulcanised in a manner similar to that which will be used for lining equipment. The properties of moulded samples of the rubber are not necessarily representative of the finished rubber lining.

The simplest test to do is to measure weight change after exposure to the test liquor(s). If possible, the change in weight should be determined after more than one period of exposure and continue to be measured until there is no significant change over succeeding periods. Interpretation of test results is to some extent a matter of experience and judgement. Changes in weight up to 5% are not incompatible with successful use. The acceptable limit is generally between 5% and 10% depending upon other effects and the application.

All rubbers can absorb liquids to some extent. The absorption of liquid causes the rubber to increase in volume. The amount of volume swelling and the rate of swelling varies with both rubber and liquid. It is important that volume change is determined after several periods of immersion and the percentage increase plotted against time.

A typical curve is illustrated in Figure 1. The total test time should extend beyond the point of maximum absorption. The methods of test are described in ANSI/ASTM D471.

Samples should be examined for any marked surface effect. It is not possible to state precise limits for the amount of swelling considered acceptable. For most applications, a volume change of 10% will not be a reason for rejection and higher test results will not necessarily exclude a rubber from service.

In the process of swelling, liquids do penetrate the full thickness of the rubber and the adhesive bond may be attacked. The testing of samples bonded to steel, as detailed in ANSI/ASTM D3491, is very useful for assessing effect on adhesion. The method of determining adhesion is described in ASTM D429 (Method B).

The hardness of the rubber both before and after immersion in the test liquor(s) should always be measured and recorded. The test methods are given in ASTM D1415 and ANSI/ASTM D2240. The hardness of the rubber as supplied is required for quality control when determining whether or not the lining has been vulcanised correctly. The hardness after immersion

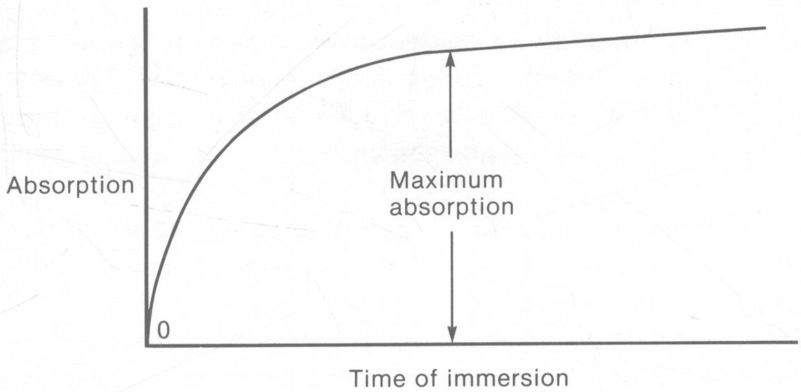

Figure 1

Time-Absorption Curve of Soft Vulcanised Rubber.

is vital information for monitoring the performance of the lining in service. Hardness tests can be done in situ and are non-destructive and therefore it is possible to compare hardness after a period of service with test results.

It should be remembered that some variation in results is to be expected in hardness testing. A scatter of $\pm 3°$ is not unknown.

Details of tensile testing for soft and hard rubbers are given in ANSI/ASTM D412 and D2707, respectively. The tensile strength of rubber for most lining applications is of less importance than for other applications of rubber. A loss of 20% in tensile strength is generally acceptable.

Attention is drawn to the danger of short-term testing. A minimum test time of three months is recommended.

Before selecting the rubber to be tested or used, due consideration should be given to the type of equipment to be lined, where the lining will be done and the method of vulcanisation. The compounds may be different depending on the method of vulcanisation used which, in turn, is dictated by the size of the equipment to be lined.

The methods available for vulcanisation are:

1. Placing the equipment in an autoclave
2. Using the equipment as its own autoclave
3. Steam or hot air vulcanisation at ambient pressure
4. Vulcanisation with hot water
5. Self-vulcanisation

Vulcanisation in an autoclave produces a lining with the lowest porosity and the best bond between rubber and substrate. However, the size of the equipment may be a dominant factor. When concrete, which has a large heat capacity, is to be lined or when large steel equipment is to be lined on site, there may be advantage in using pre-cured or self-vulcanising rubbers. Self-vulcanised rubbers do not have the same range of chemical resistance as steam vulcanised rubbers.

IV INFORMATION USEFUL FOR THE DESIGN OF A RUBBER LINING

Before a rubber is selected for lining, full information about the proposed duty (service) should be made available to those involved in the decisions. Depending upon the complexity of the equipment and the process duty, it may be necessary, and is always helpful, to have a consultation among the parties concerned with the design, use, fabrication of equipment and the application of the lining.

The following information should be established and notified to the parties concerned. If, after decisions have been made, any of the parameters change, then the interested parties should be notified. It is preferable that all information be exchanged in writing.

1. Design and fabrication details of the equipment and provision of drawings.
2. Details of the contents of the equipment including trace materials and any intermediate reaction products. Consideration should be given to the liquid and vapour phases.
3. The cycle of operation—whether batch or continuous.
4. The design and operating temperatures.
5. The design and operating pressures.
6. As soon as the basic process conditions are established, the question needs to be asked whether suitable grades of rubber are known or if testing is required.
7. The details of any solids to be handled and flow rates.
8. Methods to be used in any heating or cooling.
9. Any cleaning methods which may be employed with the equipment, e.g., water washing, solvent washing, boiling out or steaming.
10. Where the lining will be done and, in the case of site linings, conditions which may affect the lining operation.
11. Any special conditions which may obtain during the handling, transport, storage and insulation of the equipment, e.g., extremes of temperature.