File - N28.1

Memorandum

Engineering Department
San Francisco, California
December 30, 1983

NON-ASBESTOS GASKETS & PACKING
INFORMATION & TEST PROPOSAL
File: N28.10 and N28.13

TO: DISTRIBUTION

Health hazards associated with asbestos products have resulted in the development of non-asbestos gaskets and packing materials. Product manufacturers have developed some asbestos substitutes, though none are fully interchangeable with asbestos. Several manufacturers have reported they may eventually phase out asbestos completely. This has spurred interest throughout the Company on non-asbestos gaskets and packing.

The attached report summarizes current Company practice, identifies potential use of non-asbestos products, and evaluates standard tests for gaskets and packing. Currently-available non-asbestos materials are not fully interchangeable with asbestos and are not yet proven to be functionally satisfactory. Also, OSHA regulations on asbestos do not require the use of non-asbestos gaskets or packing and there is no technical need to use non-asbestos products right away. OSHA does have regulations on handling of asbestos and monitoring of asbestos exposure levels. The use of non-asbestos products would eliminate the need for these precautions. We believe there is enough interest and potential use of non-asbestos products to justify Materials Laboratory testing, and we have proposed a test program for 1984.

This survey was completed with funds from the Corporate Overhead Technical Program (Engineering Department-sponsored). The testing planned for 1984 will be done under the CRC-sponsored Materials Research Program. Comments will be appreciated and should be directed to R. D. Sweeney, Materials Laboratory, P.O. Box 4012, Richmond, CA 94804.

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NON-ASBESTOS GASKETS AND PACKING INFORMATION SUMMARY AND TEST PROPOSAL

DECEMBER 30, 1983
FILE: N28.10 AND N28.13

BACKGROUND

Prolonged exposure of employees to airborne asbestos fibers can result in the chronic lung disease asbestosis and in some cases may result in special types of lung cancer. OSHA has developed regulations on asbestos which require employee exposure levels to be controlled to below a specified exposure limit and require precautions when handling or using asbestos-containing materials or products.(1) In addition OSHA has issued an Emergency Temporary Standard reducing allowable levels by a factor of 4; however, this is presently under appeal by the Asbestos Information Association.

Exposure to airborne asbestos can occur during the use of asbestos-containing gaskets or packing. However, exposure levels associated with handling or using these products are generally low, normally well below the OSHA exposure limits. When employee exposure levels are below the exposure limit, some of the OSHA regulations on asbestos do not apply; however, OSHA still requires proper handling of asbestos products and periodic monitoring of asbestos exposure levels. Although the use of non asbestos products is an effective means of controlling employee exposure to asbestos, current Company practice does not require the use of non-asbestos products. However, asbestos product manufacturers are developing alternative materials to eliminate asbestos exposure among their employees. Eventually, asbestos gaskets and packing may not be readily available. Also, many Company locations are seeking asbestos substitutes and are asking the Materials Division for help in choosing non-asbestos products. This report was written to document what is available and to determine what, if any, further work is needed to establish acceptable products.

Information Survey

Information on non-asbestos gaskets and packing, and gaskets and packing in general was obtained from several sources. Literature was reviewed, manufacturers were consulted and Company personnel were contacted. We looked for information in four areas:

* Current Company Practice

* Asbestos and Non-Asbestos Products

* Gasket and Packing Selection

* Standard Tests

1. CURRENT COMPANY PRACTICE

In order to identify the potential for non-asbestos products, current Company use of gaskets and packing was studied. We wanted to define the types of materials being recommended and used, and the types of services to be encountered. Corporate standards were consulted, and we talked with Company personnel in refining, chemical, and producing divisions. We concentrated on gaskets for piping and packing for valves and reciprocating and rotating equipment. Results of this study are described below.

CORPORATE STANDARDS

Gaskets - Corporate recommendations for piping gaskets are given in the Piping Manual, in standard drawing GB-135169-7. This drawing recommends gasket (and piping) materials for each of several service classes. For most services, compressed asbestos (white or blue) or spiral wound asbestos gaskets are recommended.

Packing - Recommendations for packing are separated by equipment: valves, rotating equipment, and reciprocating equipment. Valve packing is covered in standard drawing GC-L99771-0. Pump, compressor, and turbine packing standards are given in drawing GC-G99710-1. As with gaskets, most of the packing is asbestos. Only the packing lubrication and configuration vary.

REFINERY STANDARDS

We contacted personnel at Richmond, El Segundo, Perth Amboy, Pascagoula and El Paso to identify what gaskets and packing materials are used in these refineries.

Gaskets - Most refineries reported that they follow the Corporate piping standards for piping gaskets. Some have their own piping classes and material recommendations, but these are similar to the Corporate classes. Most of the recommended gaskets are asbestos. Compressed asbestos sheet and asbestos-filled spiral wound gaskets are used most commonly. Blue asbestos is sometimes specified, for severe acid service.

Packing - Most refineries have their own written standards for packing materials. They are similar to the Corporate standards but there is more variation than there is with gaskets. Table I gives Corporate and refinery packing recommendations. The refineries' recommendations are grouped together. If half or more of the refineries recommended the same material for a given service, it is the only one reported. Otherwise, all recommended types are listed. The key to the packing material codes is at the bottom of the table.

Although most refineries are trying some non-asbestos products, a lot of asbestos is still being used. Pascagoula recommends all non-asbestos products.

CHEMICAL PLANTS

We consulted personnel from three of the Company's Chemical plants: Fort Madison, Kennewick, and Oak Point.

Gaskets - The chemical plants also reported that they follow the Corporate piping standards for gaskets. Kennewick has tried many non-asbestos products and have found gaskets made of ceramic fibers to be the most promising. However, these still are not entirely satisfactory as compressed asbestos replacements because they are less stiff. The ceramic products are also much more expensive.

Packing - The chemical plants contacted do not have written standards for packing. They either go by the equipment manufacturer's recommendation or by the recommendation of their own experienced personnel. Manufacturer's recommendations are evaluated on an individual basis. The plants reported that they are using some non-asbestos packings for trial applications but didn't have specific data on materials and services.

PRODUCING

Western, Central, and Eastern Region personnel were called. We also talked to Chevron Standard in Calgary, Canada. Main services discussed were gas, oil and water. In general, temperatures are not that high, 200-300F max., as compared to some refinery and chemical applications.

Gaskets - The producing divisions follow the Corporate piping standards for gaskets, namely compressed asbestos, or asbestos-filled spiral wound gaskets.

Packing - There is variation in what the producing regions use for packing. Eastern Region and Chevron Standard follow equipment manufacturer's recommendations and evaluate these individually. Western Region reported that they have nothing written, but avoid using asbestos. They say this isn't difficult because of the low service temperatures. Central Region uses Kevlar and teflon packing only.

2. ASBESTOS AND NON-ASBESTOS PRODUCTS

ASBESTOS[2,3]

Asbestos is a name given to a group of fibrous hydrated silicates. There are several types of asbestos fibers. The most commonly used fiber is chrysotile, $Mg_3 (Si_2 O_5) (OH)_4$. A more scarce and less widely used fiber is crocidolite or blue asbestos, $3Na_20 \cdot 6Fe0 \cdot 2Fe_20_3 \cdot 16Si0_2 \cdot H_20$. Both of these asbestos fibers are used to make gaskets and packing. The fibers can be compressed to form sheets for gaskets or woven into different configurations for packing.

Asbestos fibers as a group are known for their fineness, high strength, flexibility, heat resistance and chemical resistance. There are significant differences between chrysotile and crocidolite fibers, given below:

Chrysotile - This fiber has the best combination of strength and flexibility of all the asbestos fibers. Its tensile strength is in the range of 80,000 to 200,000 psi. This strength is retained for long exposures up to 700F. Chrysotile or white asbestos, has good resistance to mild caustics, but is not as resistant to acids as other asbestos fibers.

Crocidolite - Crocidolite, or blue asbestos is stronger than chrystotile, but less flexible. The tensile strength of crocidolite fibers is 100,000 to 300,000 psi. However, at about 400F, the tensile strength begins to drop. The main use of crocidolite gaskets and packing is in acid service. Crocidolite is much more resistant to acids than chrysotile, and has about the same resistance as chrysotile to caustics. A comparison of the chemical resistance of these two asbestos fibers is given in Table II.

NON - ASBESTOS PRODUCTS

There are several types of gaskets and packing that do not contain asbestos. Some of these have always been around; some have recently been developed as substitutes for asbestos. Common non-asbestos gasket and packing materials are described below. Table III summarizes recommended temperature and pH limits for asbestos and non-asbestos products. Note that the temperature limits given in Table III are manufacturer's recommendations and may be optimistic. For example, we usually consider 500F too hot for Teflon.

Graphite Fiber - Several manufacturers are using graphite fibers for gaskets and packing. Graphite is a crystalline form of carbon. For gaskets, graphite fibers can be used in a tape form or as a filler in spiral wound gaskets. No graphite substitutes for compressed asbestos gaskets have been developed. Graphite packing comes in many configurations including tape, braid, and die-formed rings.

Graphite products are rated to high temperatures: 650F in oxidizing environments, 1200F in steam, and 3000F in neutral or reducing environments. Graphite also has very good chemical resistance: it is recommended for 0-14 pH services. Graphite is desirable in packing, due to its self-lubricating, low friction characteristics. There are reports that graphite packing, being relatively soft, tends to extrude.

Carbon - Carbon is used as a packing material. Carbon has similar temperature and chemical resistance to graphite, although some manufacturers rate it lower in both areas. Generally, carbon packing is cheaper than graphite fiber packing. Carbon is made in the same packing configurations as graphite fibers.

Ceramics - Alumina or silica fibers are used to make some gaskets and packing. Kennewick reported using a compressed ceramic sheet for gaskets but didn't give more details. Ceramics are used in braided and woven packing. The ceramics have temperature resistance up to 2300F and good chemical resistance, except to hydrofluoric and phosphoric acids, and severe caustics. Ceramics fibers have higher strength than asbestos.

Fiberglass - Fiberglass can be woven to make some types of packing. It is reportedly good to about 1000F, has higher strength than asbestos, and has good chemical resistance (but not to strong caustics).

Chlorite - One company, Flexitallic, is using chlorite fibers as a spiral wound gasket filler material to replace asbestos. The fibers are a mineral said to be similar to mica. The gaskets are called Flexite and Flexite Super depending on the binder (nitrile vs. graphite). They are rated to 1050F. Both are claimed to have good resistance to many services including caustics and mild acids.

Teflon - Many manufacturers make TFE and PTFE gaskets and packing. The gaskets sometimes have a filler material for strength. Packing usually is pure Teflon and comes in several configurations. Teflon has excellent chemical resistance and moderate temperature resistance (to about 500F). Pure teflon has a tendency to flow under pressure ("cold flow"). Some manufacturers add fillers which reportedly reduce cold flow without affecting chemical resistance. Teflon products have low friction coefficients. Teflon is often used as a lubricant for other packing.

Kevlar/Aramid - Kevlar is an aramid fiber, developed by DuPont, with temperature resistance to about 500F, and good chemical resistance (3 to 10 pH). Kevlar can be woven to form packing or compressed to form a substitute for compressed asbestos gaskets.

Flax - Flax is a plant fiber that is woven to make packings. Flax packings are not new but have been used in cold water service for years. Flax is only rated to about 150-200F. The strength of flax increases when the packing is wet.

Ramie - Ramie, a plant fiber, is similar to flax. It is used in cold water service, its strength increases when it is wet, and its temperature limit is 150-200F.

Cotton - Cotton, often referred to as "duck" fiber, is used as a cold water packing and is rated to 200F.

Rubbers - Rubbers are used for o-rings and gaskets. Neoprene and nitrile are the most common. Viton is used in more severe services. The elastomer products are generally recommended to temperatures of 200-400F.

Rubber is also a common binder in compressed asbestos sheet gaskets.

Metals - Metals are sometimes used as packing in foil form, but their largest use is in spiral wound gaskets as the inner and outer rings and the windings. Spiral wound gaskets can be made with virtually any metal. The packing foils are usually aluminum alloys, copper alloys, or babbitt. Metals are used in high temperature applications.

3. GASKET AND PACKING SELECTION

GASKETS

Characteristics of a "Good" Gasket

A gasket is used to maintain a pressure-tight joint between two static surfaces. There are several characteristics of a gasket which to some degree determine how well it will perform its function. Some important characteristics of a "good" gasket are:

a. It should be relatively impermeable to the fluid or gas being sealed. It must also be resistant to attack by the fluid. Changes in volume, especially shrinkage, can dramatically affect the gaskets' performance. Finally, the gasket should not contaminate the fluid it is sealing.

b. When flammable materials are being handled, the gaskets used must be fire resistant. This requirement eliminates several potential non-asbestos products, including Teflon, Kevlar, flax, ramie, cotton, and rubbers. These materials are candidates for non-flammable services.

c. The gasket should be compressible, yet resilient. As the gasket is compressed, the bolting load is distributed over the entire gasket. Compressibility also allows the gasket to conform to irregularities in the surfaces being sealed. Resiliency allows the gasket to maintain a seal throughout small movements from changes in pressure and temperature, and vibration.

d. There should be friction between the gasket and the sealed surfaces to prevent gasket "blow-out". The gasket can not be lubricated. Surfaces to be sealed should be neither too rough nor too smooth. Very smooth surfaces can lead to blowouts; some "tooth" is needed for friction. Rough surfaces are difficult to seal and can result in seepage.

e. The gasket should be easy to install and remove.

f. The gasket should be able to withstand the service temperature encountered.

g. The gasket should not flow or creep over time.

Methods of Gasket Selection

There are no widely accepted criteria by which to judge the performance of a gasket. The purpose of a gasket is to seal, but since several factors influence the gasket's ability to seal, there are several methods to select gaskets. Most are not based on test results, but rather on actual experience. Two methods were referred to most frequently in the literature.

a. PxT Ratings - Many manufacturers report maximum pressure x temperature ratings for gaskets, to be used as a "rule of thumb" for initial gasket selection. The PxT products are based on experience - what works in what service. Along with PxT values, a maximum temperature limit for the gasket is given. Table IV gives PxT values for some gaskets (Garlock). These values are used in gasket selection as follows:

   1) Candidate gaskets must be compatible with the fluid being sealed.

   2) The service temperature must not exceed the recommended temperature limit for the material. Gasket manufacturers often overrate the temperature resistance of their gaskets. We recommend staying at least 50-100F below the manufacturer's rating. Divide the PxT rating by the service temperature to get an idea of what the maximum sealable internal pressure is. Check this against the expected service pressure to narrow down the candidates.

b. ASME Boiler and Pressure Vessel Code - "m" and "y" Factors - The ASME Boiler and Pressure Vessel Code Section VIII Division I outlines Rules for Bolted Flange Connections in Appendix 2. In the appendix, two gasket factors, "m" and "y", are defined. These factors and the gasket thickness are the gasket parameters used in flange design calculations. Table 2-5.1 of the appendix, attached as Table V here, reports "m" and "y" values for several gasket materials and thicknesses. Reportedly the values originated from trial and error: "m" and "y" values for each type of gasket were changed until they most accurately reflected service performance of that gasket. ASME recommends use of their factors in the calculations, but states that other factors should be used if they are found to be more representative of the actual behavior of the gasket.

   The origin of the "m" and "y" factors is sketchy, but the ASME Code is widely used, so "m" and "y" are the most commonly used parameters in gasket selection. A brief outline of the ASME flange design method will clarify what the factors are and how they are used.

compatibility to limit the candidates. "m" and "y" factors are gotten from the ASME table, the gasket manufacturer, or experience.

2) Calculations are made to determine bolt loading, size, and spacing and flange moments stress, and thickness. Two cases are considered in the calculations; this is where "m" and "y" come in.

Operating - Here the bolt loading must be enough to withstand the hydrostatic end force (from internal pressure), yet still provide enough compression to seat and seal the gasket. "m" is defined as the ratio of residual gasket pressure to internal pressure. Residual gasket pressure is the residual compressive force on the gasket contact area. For the gasket to seal, this must still be greater than the internal pressure after the compressive force has been relieved by the hydrostatic end force.

Gasket Seating - Before internal pressure is applied, the bolts must be loaded enough to compress and properly seat the gasket. This bolt load calculation involves "y", which is defined as the stress necessary to seat the gasket.

3) Both cases are considered until flange moments are calculated, where the higher moment value is then used to calculate the stresses on the flange and the necessary flange thicknesses.

4) If a gasket is being selected for an existing flange, these calculations can be run backwards to determine a range of "m's" and "y's" needed. Then a replacement gasket can be selected. An easier method is to replace the old gasket with a new gasket that has similar "m" and "y" factors. But, neither manufacturers nor the literature gave a clear idea of how close is close enough.

We asked several manufacturers about the origin and usefulness of "m" and "y" factors. None could tell exactly how they were originally chosen, but we found they are dependent on the leakage rate, the temperature, and the internal and external pressure. Currently, ASTM F-586 outlines how "m" and "y" versus leakage rate can be determined for a given temperature and internal pressure. Some manufacturers run these tests. Many have simplified versions of the ASME code that they use for flange design. However manufacturers reported that the code is widely used, so "m" and "y" values are useful.

PACKING

Characteristics of "Good" Packing

Packing is often called a "dynamic" seal as opposed to stationary seals (gaskets) because its purpose is to seal between moving equipment surfaces. Packing is most commonly used in pumps, compressors, and valves. The purpose of the packing is to seal, but some leakage must be allowed to cool the packing and lubricate moving surfaces. Characteristics of "good" packing are:

1. It should be chemically compatible with the fluid or gas being sealed.

2. The packing must be fire resistant if it is to be used in a flammable service. As with gasket materials, many potential non-asbestos products are eliminated by this requirement.

3. It should be able to withstand the service temperature.

4. Unlike gaskets, there should be little friction between packing and the sealed surfaces. This is most often accomplished with lubrication and "slippery" packing texture.

5. The packing should be resistant to extrusion from internal pressure. Often stiff packing is used in conjunction with softer packing to prevent extrusion of the softer packing.

6. The packing should be compressible enough to seal against the surfaces, yet resilient and durable enough to allow for movement.

7. The packing should be of the proper geometry or configuration for the service. The right configuration is determined by the type and speed of motion (rotating or reciprocating), temperature, pressure, availability of lubrication, and clearances. Some common configurations are twisted, braided, braid over braid, lattice braid, die-formed rings and tape.

Packing Selection

There is no clearly defined method to select packing. The packing material is chosen on the basis of temperature and chemical resistance. The packing configuration is primarily a matter of experience - manufacturers recommend what they've found to be suitable. As stated before, the proper configuration depends on several factors, most of all the type of movement encountered.

4. STANDARD TESTS

There are several ASTM standard tests for gasket materials. There are none specifically for packings, but the ASTM index refers to the gasket tests for packing also. Although there are many tests, there are no criteria or standards by which to judge the acceptability of results of the tests. Also, there is reportedly much variation in results from different laboratories. The ASTM test standards and their significance are discussed below.

A. ASTM F-36 COMPRESSIBILITY AND RECOVERY OF GASKET MATERIALS

Procedure - Sheet gaskets are loaded and released. The change in thickness is recorded as a measure of the gaskets' compressibility and recovery. The tests are conducted at room temperature.

Significance - The compressibility and recovery of a gasket are important factors in it's ability to seal. This test could be incorporated in a sealability tests (F-586) by measuring thickness before and after loading.

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B. ASTM F-37 SEALABILITY OF GASKET MATERIALS

Procedure - This test can be run at room temperature and elevated temperature on sheet gaskets. The gasket is loaded in a simulated flange with a fixed internal pressure, external load, and temperature: leakage is measured over time to determine leakage rates for the gaskets.

Significance - This is a good test for gaskets because it quantitatively measures their ability to seal. Unless many tests are run, the effects of temperature, external load, and internal pressure will not be measured. The test can be used to rank gasket materials.

C. ASTM F-38 CREEP RELAXATION OF GASKET MATERIALS

Procedure - This test can be run at any temperature. A gasket is loaded externally. Bolt strain is measured with time. As the gasket creeps, bolt strain is released. Tests are up to 24 hours long.

Significance - Creep relaxation is an important factor in gasket performance. However, in order to be significant this test would need to be run longer than 24 hours. Also, the effect of internal pressure is not measured.

D. ASTM F-146 FLUID RESISTANCE OF GASKET MATERIALS

Procedure - Gaskets are immersed in fluids and the effects on thickness, weight, volume, tensile strength, compressibility, and flexibility are measured. Exposures can be at any temperature.

Significance - Although a gasket in service is only exposed to the fluid at its edge, the chemical resistance of the material is important. The most important effect is on the gasket volume. If the gasket shrinks very much in the thickness direction, leakage is almost certain. Swelling is not as harmful but a large change does indicate a breakdown of the gasket material. Other properties also change with chemical exposure. We usually measure changes in weight and volume and sometimes hardness. So many tests may be excessive, especially the tensile strength and flexibility tests, since these aren't directly related to performance.

E. ASTM F-152 TENSION TESTING OF NON-METALLIC GASKET MATERIALS

Procedure - Gaskets are pulled in tension and the ultimate strength and elongation are measured.

Significance - This test is not related to gasket performance. In service, gaskets are not loaded in tension, but in compression. The test may have significance when used as a monitor of quality control.

F. ASTM F-586 LEAK RATES VERSUS y STRESSES AND m FACTORS FOR GASKETS

Procedure - Gaskets are loaded in a simulated flange. Leak rates are measured at a fixed temperature and internal pressure, at different external loads. "m" and "y" are calculated and plots of "m" vs. leak rate and "y" vs. leak rate are made. The internal pressure is different for the "m" and "y" tests.

Significance - This test simulates actual service and yields results that can be used in gasket selection and flange design. It provides the same information as F-37 but also measures the effect of load on leakage rate. Without a lot of tests, the effect of temperature is not measured. Some indication of the effect of internal pressure can be gained.

DISCUSSION

There are several gasket and packing products that have been developed as substitutes for asbestos. Some are being used by the Company and are reported to be doing well. But, for the most part, the Company is still using asbestos. The most difficult product to find a suitable substitute for is compressed asbestos gasketing. Products are available to replace most other asbestos products, but are more expensive and not proven.

There is not enough information available from literature and manufacturers to choose suitable asbestos substitutes and have good confidence of their likely success. Field trials would provide the best data, but it would be difficult to get quantitative results in a reasonable amount of time. Materials Laboratory tests can help narrow down the possibilites. Although OSHA and Company practice don't require switching to non-asbestos products, we believe lab tests are justified for the following reasons:

* The Materials Division gets repeated requests for recommendations on non-asbestos products, and currently we don't know enough to give definitive answers.

* Our survey showed that many Company locations are trying and have been trying non-asbestos products. These locations asked for any guidance the Materials Laboratory could give them.

* Our survey also showed that most gasket and packing manufacturers have developed non-asbestos products. Many have said they will eventually phase out their asbestos products. Eventually, we may not be able to get asbestos products.

We believe the following tests will provide the most useful information.

1. Packing

   For packing, we recommend chemical resistance tests and extrusion resistance tests. We do not know enough about the different packing configurations to judge what is suitable for a given service. This can be obtained from past experience and/or manufacturers. Temperature limits are dependent on the material and are fairly consistent in the literature and manufacturers' data. Manufacturers may overrate their products, so we recommend staying at least 50-100F below their limits.

   A. Chemical Resistance

      The chemical resistance testing we suggest is outlined below. We believe these tests are needed because manufacturers gave only pH limits for their products. pH limits are too general to use for choosing a packing for a specific service. The appendix gives cost estimates for this testing.

      1. Use the same packing configuration for all the materials.

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2. Immerse samples in the following fluids at room temperature for at least three time periods, eg. 1 day, 1 week, 1 month.

   a) weak acid, pH 2-3
   b) sulfuric acid, pH $<$ 1
   c) crude oil
   d) low aromatic hydrocarbon
   e) high aromatic hydrocarbon
   f) caustic, pH $>$ 14

3. Test at least the following materials:

   a) chrysotile (white) asbestos
   b) crocidolite (blue) asbestos
   c) Teflon
   d) graphite
   e) carbon
   f) Kevlar
   g) ceramic
   h) fiberglass

4. Measure weight and volume before and after each time period. Plot $\%\Delta W$ and $\%\Delta V$ versus time on a log-log scale. Check to see if changes level out with time. Rank materials by $\%\Delta V$ and $\%\Delta W$ at 30 days (extrapolated or actual). Use chrysotile asbestos as the acceptance standard for all fluids except sulfuric acid, where crocidolite asbestos should be the standard. Those materials that have lower $\%\Delta V$ and $\%\Delta W$ than the standard should be judged as passing. By this means identify possible asbestos substitutes for each fluid service class.

B. Extrusion Resistance Tests

Although there is no standard test for extrusion resistance of packing, we believe this is an important parameter to define. We did find a brief description of an extrusion resistance test that Rockwell developed for valve stem packing(6). We recommend a similar test be included in the test program. The test is described below, but it must be further defined before tests are started.

Rockwell designed a test fixture which simulated cycling of a valve under presssure. The valve was cycled every 90 seconds for up to 2500 cycles. Tests were first run at room temperature, then at elevated temperature. Those packings which sealed for 2500 cycles, with minimal gland adjustments, were designated as passing.

For the Materials Laboratory tests. the procedure must be more well-defined. The following recommendations should be considered when developing the test procedure.

1. The same packing configuration should be used for all materials.

2. All tests should be run at the same pressure. Tests should be at room temperature only, unless there is time and money for elevated temperature tests.

3. Use the same type of valve for all tests.

4. Run the tests as closely as possible to Rockwell's procedure. Cycle until leakage occurs. Tighten the gland and see if leakage subsides. If so, continue cycling, up to 2500 cycles. If not, discontinue test. Record the number of cycles at which leakage first occurs and the number of times the gland must be tightened before 2500 cycles is reached. Use these two parameters to rank the packing materials.
5. Test the following materials. Run at least two tests per material.

   a) chrysotile (white) asbestos
   b) crocidolite (blue) asbestos
   c) Teflon
   d) graphite
   e) Carbon
   f) Kevlar
   g) ceramic
   h) fiberglass

2. Gaskets

We believe the two most important parameters for gaskets are chemical resistance and sealability. Manufacturers don't have sufficient data, so we recommend two tests, one for each of these parameters. The chemical resistance test is similar to that suggested for packing. The second is ASTM F-586 to determine "m" factors versus leak rates and "y" stresses versus leak rates. ASTM F-586 can be used to measure compressibility and recovery also. If there is time, ASTM F-586 can be run at a higher temperature to provide data on the effect of temperature. Recommended procedures are outlined below.

A. Chemical Resistance

1. Use sheet gasket materials. All gaskets should have the same thickness.

2. Immerse samples in the same room temperature fluids recommended for packing. Run tests for at least three time periods.

3. Test at least the following classes of materials:

   a) chrysotile (white) asbestos
   b) crocidolite (blue) asbestos
   c) Teflon-pure or filled
   d) Kevlar
   e) ceramic
   f) graphite ribbon

4. Measure changes in thickness, weight, and volume, and plot as described before. Rank materials and judge performance against white asbestos, except use blue asbestos for sulfuric acid. Identify possible substitutes for each service class.

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B. Sealability (ASTM F-586)

1. Use sheet gaskets, all of the same thickness.

2. Follow ASTM F-586. Use 6 tests for each "m" versus leak rate curve and 6 tests for each "y" versus leak rate curve.

3. Also measure the thickness before testing, 60 seconds after load application (bolt down) and 60 seconds after the gasket load is released (similar to F-36 procedure). This will give compressibility and recovery data.

4. Test the following materials:

   a) sheet gaskets
      1) chrysotile (white) asbestos
      2) crocidolite (blue) asbestos
      3) Teflon
      4) Kevlar
      5) ceramic

   b) spiral wound gaskets
      1) chrysotile (white) asbestos
      2) crocidolite (blue) asbestos
      3) Teflon
      4) graphite
      5) ceramic
      6) chlorite

5. Run tests at room temperature. If possible, run some at a higher temperature.

6. Compare test results for candidates to results for white asbestos and blue asbestos. Those substitutes with "m's" and "y's" closest to asbestos' will perform the most similarly. Some gaskets may have consistently lower leak rates for all values of "m" and "y". These gaskets will require lower bolt loads than asbestos to achieve the same leakage rate. Those gaskets with consistently higher leak rates may seal satisfactorily, but will require higher bolt loads than asbestos to achieve the same leakage.

   The candidate gaskets can also be ranked by the compressibility and recovery data. However, leakage rates are the most important parameter.

To initially identify possible substitutes for asbestos gaskets for a given service, temperature limits and chemical resistance tests can be used. The leak rate data will identify which candidates behave similarly or seal better than asbestos.

CONCLUSIONS AND RECOMMENDATIONS

There are several promising substitutes for asbestos gaskets and packing. However, currently-available non-asbestos materials are not fuly interchangeable with asbestos and are not yet proven to be functionally satisfactory. We recommend Materials Laboratory tests be run to narrow down the possible substitutes for several service classes. Tests we recommend are:

1. Packing - chemical resistance tests and extrusion resistance tests.

2. Gaskets - chemical resistance and ASTM F-586 for sealability.

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2. Conversations with D.H. Barber and H. J McDermott, Corporation Environmentl, Industrial Hygiene & Safety Staff, San Francisco.

3. Rosato, D.V., "Asbestos: Its Industrial Applications," Reinhold Publishing Corporation, New York 1959, pp. 37-62, 178-185.

4. Peters, George A. and Barbara J., "Handbook on Asbestos Diseases: Medical, Legal, and Engineering Aspects," Garland Publishing Co., 1980.

5. ASME Boiler and Pressure Vessel Code, Section VIII, Division I, Appendix 2, Table 2-5.1.

6. Goodman, D. A. and Schweitzer, R. L., "Asbestos-Free Stem Packing for High Temperature Valves", Rockwell Technical Article V-Rep 82-1.

APPENDIX

ESTIMATED COSTS OF RECOMMENDED TESTS

	Steps	Engineer Hours	Technician Hours	Materials $	Total $
1.	Gathering materials	50	20	--	2,685
2.	Packing chemical resistance tests	30	50	100	2,775
3.	Packing extrusion resistance tests - build and de-bug apparatus.	40	50	2,000	5,100
4.	Running extrusion resistance tests.	20	75	-	2,950
5.	Gasket chemical resistance tests	30	50	100	2,775
6.	Gasket sealing tests - build and de-bug apparatus	30	50	3,000	5,675
7.	Running sealing tests	20	150	--	5,050
8.	Writing report	60	--	--	2,550
	TOTALS	280	445	5,200	29,560

TABLE I

CURRENT RECOMMENDED PACKING: CORPORATE AND REFINERY STANDARDS

SERVICE CLASS	SOURCE	VALVES	ROTATING	RECIPROCATING
ACIDS	Corporate	weak (except H_2SO_4): A strong + H_2SO_4: B	weak: B, C, or G strong: B, C, or D	C, F, or Q*
	Refineries	C	C	C
CAUSTIC	Corporate	B	C	C
	Refineries	C	C	C
CHEMICAL	Corporate	A	G/E	F*
	Refineries	C	G/E or C	C or F*
GASES	Corporate	G	G/E	G/E or C
	Refineries	H	G/E or S	G/E or S
HF, HF + OIL	Corporate	F*	C	S
	Refineries	J*/B	—	—
LPG	Corporate	G	L*/E	M*
	Refineries	H	C, L*/E, or S	C, M*, or S
HEAVY OILS	Corporate	to 450F: A >450F: A	L* K* or N*	A, E, or L* K*
	Refineries	to 450F: H >450F: H	L* or N* K*	E or K* K*
LIGHT OILS	Corporate	A	L*/E	M*
	Refineries	H	G/E or C	C or M*
STEAM	Corporate	E	P*	G, L*, or T
	Refineries	H	K*, N*, O*, P*	C
WATER	Corporate	A or I*	Cold: C, G or Q* Hot (to 300F): C, L*/E, or R*	Cold: C or M* Hot (to 300F): C,G,or T
	Refineries	H	Cold: C Hot (to 300F): C, K*, N*, or O*	Cold: C or M* Hot (to 300F): C or K*

KEY:

PACKING TYPES

* = asbestos free
/ = combination of types

A = chrysotile asbestos
B = crocidolite asbestos
C = Teflon-impregnated asbestos
D = Teflon-impregnated blue asbestos
E = asbestos-jacketed plastic
F = Teflon
G = graphited asbestos
H = graphited asbestos w/wire core
I = flax
J = Cu foil
K = Al foil
L = Babbitt foil
M = cotton w/neoprene binder
N = graphite yarn
O = graphite ribbon
P = carbon rings
Q = rubber
R = plastic
S = mechanical seals
T = graphited blue asbestos

TABLE II

CHEMICAL RESISTANCE OF CHRYSOTILE VERSUS CROCIDOLITE ASBESTOS(2)

	% Change in Weight*				
	HCl	CH_3COOH	H_3PO_4	H_2SO_4	NaOH
Chrysotile	56.00	24.04	56.45	56.00	1.03
Crocidolite	3.14	1.02	3.91	3.48	1.20

*Exposure: 25% acid or caustic, 26°F, 528 hours.

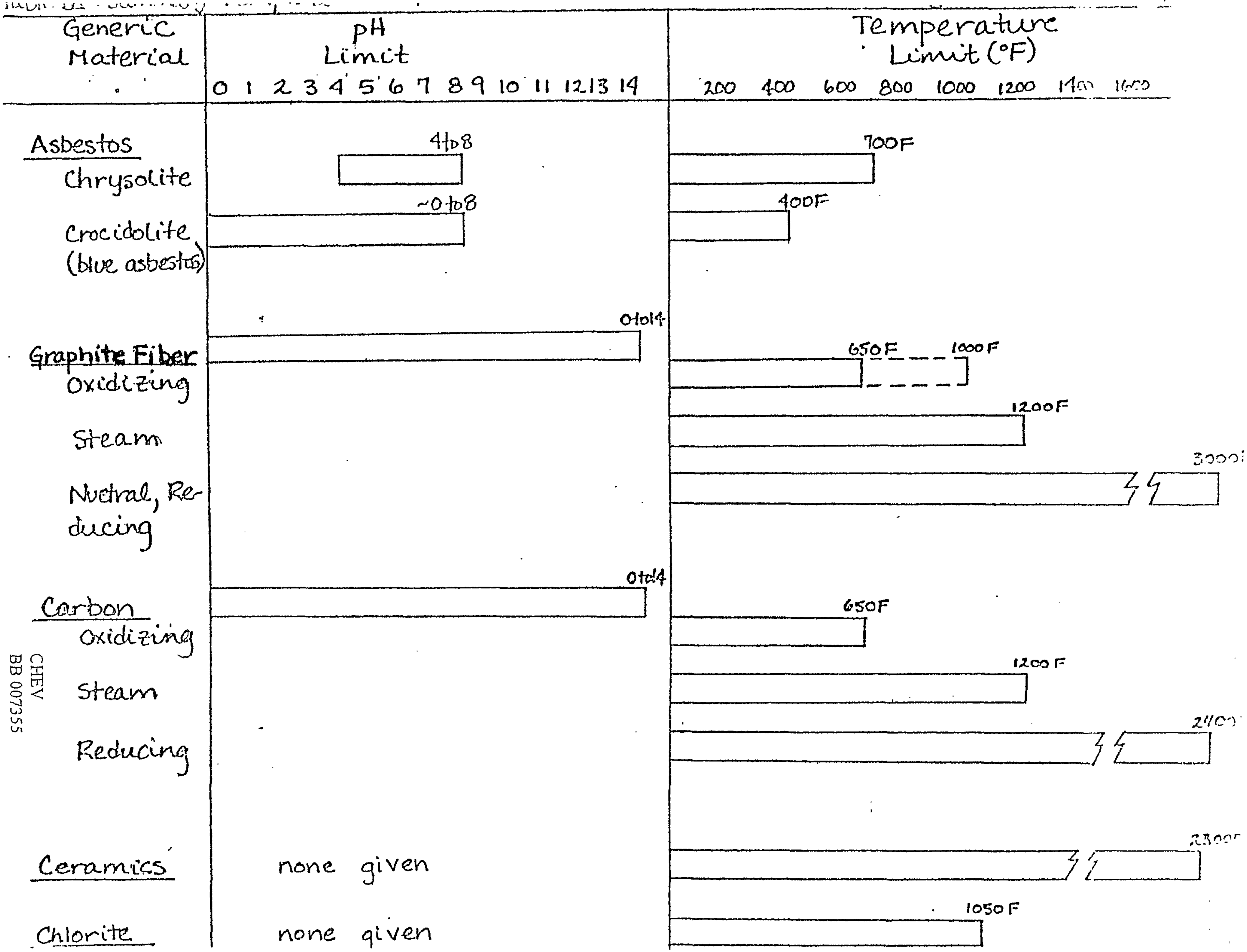
Generic Material
pH Limit
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Temperature Limit (°F)
200 400 600 800 1000 1200 1400 1600
Asbestos
Chrysolite
4 to 8
700F
Crocidolite (blue asbestos)
~0 to 8
400F
Graphite Fiber
0 to 14
Oxidizing
650F
1000F
Steam
1200F
Nuetral, Reducing
3000F
Carbon
0 to 14
Oxidizing
650F
Steam
1200 F
Reducing
2400
Ceramics
none given
2300F
Chlorite
none given
1050 F

Table III (cont.)

Generic Material	pH Limit	Temperature Limit (°F)
Fiberglass		1000F
Teflon	0/2 to 12/14	500F
Kevlar/Aramid	3 to 10	450F
Flax	4/6 to 8/10	150F
Ramie	4/6 to 8/10	150F
Rubber	6 to 8	200F 400F (depending on type)
Cotton	6 to 8	200F

TABLE IV

PxT VALUES FOR SOME GASKETS*

Gasketing Material	Maximum Pressure X Temperature, PSI x F	High Temperature Limit	
		°C	°F
Compressed Asbestos	1,200,000	400	752
Blueguard (Kevlar)	700,000	370	700
PTFE	75,000	260	500
Gylon (Filled PTFE)			
Fawn or Black	200,000	260	500
Blue	150,000	260	500
Woven Asbestos Cloth	125,000	205-540	401-1004
Reinforced Rubber	125,000	120	248
Beater-Saturated Cellulose	50,000	150	302
Vegetable Fiber	40,000	105	221
Natural Rubber and SBR	20,000	100	212
Neoprene and Nitrile Rubber	20,000	120	248
Viton Flouroelastomer	20,000	200	392
Silicone Rubber	20,000	260	500

*From Garlock Catalog.

Table V: ASME Boiler and Pressure Vessel Code m and y Values For Various Gaskets (4)

Gasket Material	Gasket Factor m	Min. Design Seating Stress y, psi	Sketches	Facing Sketch and Column in Table 2-5.2
Self-energizing types (O rings, metallic, elastomer, other gasket types considered as self-sealing)	0	0	...	...
Elastomers without fabric or high percent of asbestos fiber:				(1a),(1b),(1c),(1d), (4),(5); Column II
Below 75A Shore Durometer	0.50	0		
75A or higher Shore Durometer	1.00	200		
Asbestos with suitable binder for operating conditions:				(1a),(1b),(1c),(1d), (4),(5); Column II
1/8 in. thick	2.00	1600		
1/16 in. thick	2.75	3700		
1/32 in. thick	3.50	6500		
Elastomers with cotton fabric insertion	1.25	400		(1a),(1b),(1c),(1d), (4),(5); Column II
Elastomers with asbestos fabric insertion (with or without wire reinforcement):				(1a),(1b),(1c),(1d), (4),(5); Column II
3-ply	2.25	2200		
2-ply	2.50	2900		
1-ply	2.75	3700		
Vegetable fiber	1.75	1100		(1a),(1b),(1c),(1d), (4),(5); Column II
Spiral-wound metal, asbestos filled:				(1a),(1b); Column II
Carbon	2.50	10,000		
Stainless or Monel	3.00	10,000		
Corrugated metal, asbestos inserted, or Corrugated metal, jacketed asbestos filled:				(1a),(1b); Column II
Soft aluminum	2.50	2900		
Soft copper or brass	2.75	3700		
Iron or soft steel	3.00	4500		
Monel or 4–6% chrome	3.25	5500		
Stainless steels	3.50	6500		

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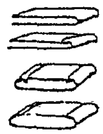
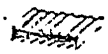
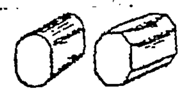
Table V (cont.)

Gasket Material	Gasket Factor m	Min. Design Seating Stress y, psi	Sketches	Facing Sketch and Column in Table 2-5.2
Corrugated metal:				
Soft aluminum	2.75	3700		
Soft copper or brass	3.00	4500		(1a),(1b),(1c),(1d), Column II
Iron or soft steel	3.25	5500		
Monel or 4–6% chrome	3.50	6500		
Stainless steels	3.75	7600		
Flat metal, jacketed asbestos filled:				
Soft aluminum	3.25	5500		
Soft copper or brass	3.50	6500		(1a),(1b),(1c),[2] (1d),[2] (2)[2]; Column II
Iron or soft steel	3.75	7600		
Monel	3.50	8000		
4–6% chrome	3.75	9000		
Stainless steels	3.75	9000		
Grooved metal:				
Soft aluminum	3.25	5500		
Soft copper or brass	3.50	6500		(1a),(1b),(1c),(1d), (2),(3); Column II
Iron or soft steel	3.75	7600		
Monel or 4–6% chrome	3.75	9000		
Stainless steels	4.25	10,100		
Solid flat metal:				
Soft aluminum	4.00	8800		
Soft copper or brass	4.75	13,000		(1a),(1b),(1c),(1d), (2),(3),(4),(5); Column I
Iron or soft steel	5.50	18,000		
Monel or 4–6% chrome	6.00	21,800		
Stainless steels	6.50	26,000		
Ring joint:				
Iron or soft steel	5.50	18,000		
Monel or 4–6% chrome	6.00	21,800		(6), Column I
Stainless steels	6.50	26,000		

NOTES:

(1) This Table gives a list of many commonly used gasket materials and contact facings with suggested design values of m and y that have generally proved satisfactory in actual service when using effective gasket seating width b given in Table 2-5.2. The design values and other details given in this Table are suggested only and are not mandatory.

(2) The surface of a gasket having a lap should not be against the nubbin.