R. S. POTTER
FEB 13 REC'D

The Engineering Resource For Advancing Mobility
400 COMMONWEALTH DRIVE WARRENDALE, PA 15096

[redacted]

SAE Technical Paper Series

830218

Performance and Reliability of Non-Asbestos Gasketing Materials

Douglas H. Tracy and Bruce M. Arnio
Rogers Corp.

International Congress & Exposition
Detroit, Michigan
February 28 - March 4, 1983

10000002

The appearance of the code at the bottom of the first page of this paper indicates SAE's consent that copies of the paper may be made for personal or internal use, or for the personal or internal use of specific clients. This consent is given on the condition, however, that the copier pay the stated per article copy fee through the Copyright Clearance Center, Inc., Operations Center, 21 Congress St., Salem, MA 01970 for copying beyond that permitted by Sections 107 or 108 of the U.S. Copyright Law. This consent does not extend to other kinds of copying such as copying for general distribution, for advertising or promotional purposes, for creating new collective works, or for resale.

Papers published prior to 1978 may also be copied at a per paper fee of $2.50 under the above stated conditions.

SAE routinely stocks printed papers for a period of three years following date of publication. Direct your orders to SAE Order Department.

To obtain quantity reprint rates, permission to reprint a technical paper or permission to use copyrighted SAE publications in other works, contact the SAE Publications Division.

ISSN 0148-7191
Copyright 1983 Society of Automotive Engineers, Inc.

10000003

830218

Performance and Reliability of Non-Asbestos Gasketing Materials

Douglas H. Tracy and Bruce M. Arnio
Rogers Corp.

ABSTRACT
Some non-asbestos gasketing materials have proven to be equal to (and some superior to) asbestos reinforced gasketing materials under severe service conditions. Proper selection of materials for performance/cost considerations given the service requirements is essential. Data comparing non-asbestos gasket materials to conventional products over a wide range of simulated application parameters will be presented. Emphasis will be placed on data and test conditions that can be used to predict functionality and reliability of gasket materials.

THE PURPOSE OF THIS PAPER is to present data comparing conventional asbestos reinforced gasket materials to non-asbestos gasket materials utilizing new or modified test procedures with parameters commonly found in many applications.

Non-asbestos gasket materials have been commercially available for a very short period of time as compared to asbestos reinforced gasket materials. Compressed asbestos (CA or CAF) has been used in gasketing applications for more than 80 years. Beater addition (BA) asbestos gaskets have been around for approximately 30 years. Both these materials have been proven functional and reliable during many years of use in numerous applications.

Since the advent of non-asbestos materials (January 1979), numerous products have been advertised as replacements for asbestos reinforced gasket materials. These products range from paper to steel in composition and solid to liquid in form. Some even exhibit basic properties similar to certain types of asbestos gasket materials. Although these basic properties, i.e., tensile strength, compressibility and recovery, fluid resistance, etc., are useful for categorizing materials, they do not reflect the functionality or reliability of the material.

DEFINITIONS(1)

The type of gasket materials addressed in this article are those defined by ASTM F118 as "a deformable material, which when clamped between essentially stationary faces, prevents the passage of matter through an opening or joint". Although in one sense it is a static seal, all flanges (joints) undergo a certain degree of movement. Joints expand and contract with changes in temperature, thus the gasket is exposed to changing compressive forces. Vibration also exists in many gasketed assemblies.

CREEP RELAXATION - one of the most important properties of a gasket material on which functionality is dependent is defined as: "a transient stress-strain condition in which the strain increases concurrently with the decay of stress". Lower creep relaxation results in higher retained com-

---

*Numbers in parentheses designate references at end of paper.

0148-7191/83/0228-0218$02.50
Copyright 1983 Society of Automotive Engineers, Inc.

pressive loading, thus better sealability.

SEALABILITY - although not as yet defined by ASTM, is basically the ability of a gasket material to prevent the passage of fluids and/or gasses from one point to another.

COMPRESSIVE STRENGTH - another important property of a gasket material. At this time, both a definition and a test method are under development by ASTM. Our definition is "the load at which a gasket material begins to yield under compressive loading". This differs from "crush resistance", which is the ability of a gasket material to continue to function, i.e., does not flow, creep, extrude or break, at a given compressive load.

CREEP/SEAL PERFORMANCE - testing performed on a material to determine its sealability characteristics after a standard creep relaxation test has been performed. This is a new test method we are investigating.

APPLICATION PARAMETERS

Every gasket application has a given set of application parameters. The design engineer and/or maintenance repair man must have a basic understanding of these parameters in order to select a gasket material which will be both functional and economical. Parameters which must be considered are:

a. media to be sealed
b. maximum temperature (minimum not normally critical)
c. maximum and minimum load on the gasket
d. maximum media pressure
e. surface finish of the flanges
f. bolt spacing
g. composition of flanges (type of metal, glass, plastic,etc.)
h. thermal cycling
i. vibration

As can be seen from this list, an infinite number of application parameters can exist, which is the reason why there is no one universal gasket material.

GASKET MATERIAL FACTORS AFFECTING PERFORMANCE

There are many different types of gasket materials used today. Both the composition and method of manufacture influence their performance characteristics. The non-asbestos gasket materials (those designed specifically to replace asbestos reinforced gasket materials) of today are composed of fibers, fillers, and binders. Cellulose, glass, aramid, phenolic and acrylic fibers are used, depending on the temperature of the application. Clay, mica, wollastonite, vermiculite, tremolite, talc, barium sulfate are a few of the fillers used. The binders are the same as those used in the asbestos gasket materials, i.e., nitrile (NBR), chloroprene (CR), styrene butadiene (SBR), and acrylics (PA).

For any of these gasket materials, the following can, and do affect the performance characteristics:

Type of fiber(s)
Fiber form (length, size, amount of fibrillation)
Fiber content
Type of filler(s)
Particle size distribution of the fillers
Filler content
Type of binder(s)
Binder content
Type of antioxidants and vulcanizing agents
Amounts of antioxidants and vulcanizing agents
Degree of vulcanization of the gasket material
Density of the gasket material at time of vulcanization
Density of the gasket material when installed in an application.

With a knowledge of the application parameters and the resultant effect of the above variables on the gasket materials performance, the manufacturer can design materials suited specifically for the application. However, because the cost to manufacture gasket materials is highly dependent on the volume produced[2], the manufacturer designs and develops gasket materials with the goal of fulfilling the requirements of many applications so the cost of gaskets to the end user will be reasonable.

TYPES OF MATERIALS

Asbestos gasketing materials are composed of two primary ingredients: asbestos fibers and a rubber binder. In non-asbestos materials, a combination of fibers and fillers and a rubber binder are used. As in asbestos materials, non-asbestos materials may differ from one another by the

quantity and types of components used. Generally, the fiber content of most non-asbestos materials is 10-30%. It is the fiber which provides the reinforcement within the material. The filler is the least expensive portion of the material, and is usually the major constituent comprising 40-80%. The filler is also the most thermally stable component which increases the thermal stability of the material as a whole. The binder may be any one of a number of natural or synthetic polymers and normally constitutes 10-30% of the product. The binder, as the term implies, bonds all the components together giving flexibility and some degree of elasticity to the material.

METHOD OF MANUFACTURE

The majority of asbestos and non-asbestos materials are produced using one of two methods: beater addition and compressed sheeter process. In the beater addition method, the fibers and fillers are dispersed in water at very low concentrations of 0.5 to 3.0%. To this water slurry, an emulsion of rubber (latex) is added and subsequently deposited onto the fiber and filler particles. The resulting stock is then run on conventional paper machines usually of the cylinder or Fourdrinier type. The wet paper is then dried, calendered, and trimmed. In the compressed sheeter process, a rubber dissolved in solvent or a latex is combined with fibers, fillers, and additives, and mixed together at relatively high concentrations in excess of 50%. The resulting paste-like mixture is fed into the nip between two rotating rolls of a sheeter (mill) and the sheet thickness is gradually built up on one of the rolls. This roll may be heated to vaporize the solvents and/or vulcanize the rubber. When the desired thickness is obtained, the sheet is cut off the roll and trimmed.

A major difference between the two methods of manufacture is homogeniety of the end product. In the beater addition process, because all components are well dispersed in a large amount of water, the resulting paper is very uniform in composition. In the compressed sheeter process, the amount of water or solvent in the mix is much less than in the beater



Figure 1: Photos of the internal portion of non-asbestos gasket papers

addition process which results in a sheet in which the components are not as well dispersed. Extremes of this are seen as fiber and rubber clumps within the sheet.

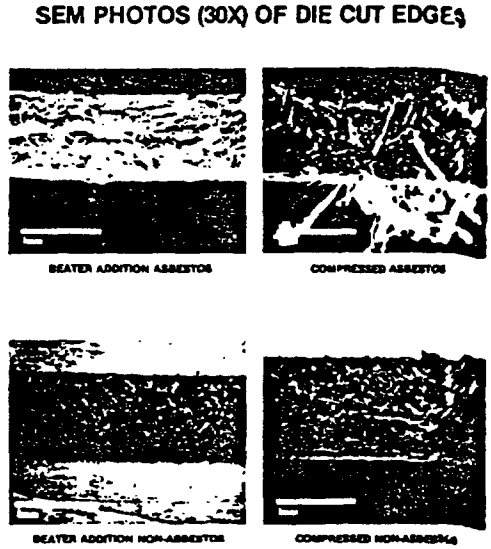


Figure 2: SEM photos (30X) of die cut edges

ASBESTOS VERSUS NON-ASBESTOS

Asbestos fibers are unique they possess a combination of properties not found in other inorganic materials. They have good heat resistance (up to 800°C), a high degree of resistance to most chemicals, are flexible and resilient, and magnesium ion chemically reacts

carboxillated rubbers in the processing steps and contributes to the cure, or vulcanization reactions. Until recently, asbestos was one of the lowest cost minerals.

As there is no one known material that can directly replace asbestos, combinations of materials must be used. Combinations of fibers (organic and/or inorganic) and fillers (inorganic) of various shapes and particle size distribution result in a matrix which can yield properties similar to all-asbestos containing materials.

Basic properties such as tensile strength, compressibility and recovery, and fluid immersions are used for quality control purposes and classification (F104). However, these properties do not predict how a material will function in end use applications.

In our opinion, there are three properties of a gasket material which can be used to help predict performance. They are:

1. Torque retention at the application temperature.
2. Sealability of the media after the gasket has relaxed in the application.
3. Compressive strength at yield when exposed to the temperature and media.

Torque Retention - because relaxation of total systems occurs at elevated temperatures (tempering of metals, compression set and flow of gasket materials), it is imperative that the gasket material exhibit a high degree of resistance to creep in order to retain a compressive load sufficient to continue sealing. Since the creep, or relaxation of any organic containing material increases with increasing temperature, and at differing rates dependent upon composition, no one temperature test can be used to predict performance at other (higher) temperatures.

Numerous creep relaxation tests have been conducted at various temperatures[3] on both asbestos and non-asbestos gasket materials. These results were plotted on linear graph paper to show the relationship between the types of materials and rate of change (shape of curve) of the materials. As can be seen from this graph, some non-asbestos gasket materials compare very well with asbestos reinforced gasket materials. Creep relaxation is a direct indicator of the ability of a gasket material to retain the compressive force required to maintain a seal.

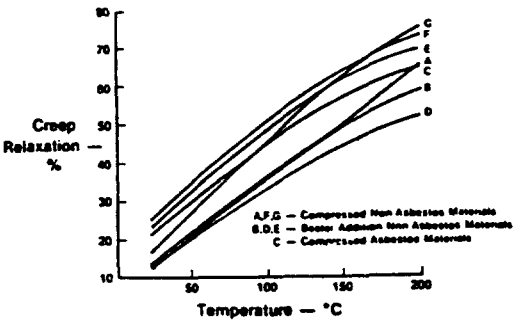


Figure 3: Creep-relaxation versus temperature

Sealability - a gasket is used in an assembly to seal matter in (or out). The ASTM F37 sealability test method is designed to comparatively evaluate materials. By expanding this test procedure to include various fluids, gasses, flange loads, and internal pressures, tests can be performed to closely simulate the intended application. Figure 4 shows the sealability to Fuel A of asbestos versus non-asbestos gasket materials as flange loading varies.

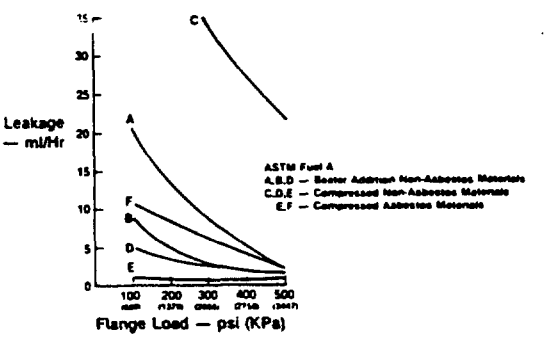


Figure 4: Sealability versus flange load

As stated earlier, this test method is used to compare materials and/or classify materials, but is not indicative of the in-service performance characteristics due to the effects of the other variables such as heat, creep, compression set, etc.

A new test method is being investigated to incorporate both the F-38B creep relaxation and F37 sealability test methods (Figure IV). By modifying the ASTM F38-B creep relaxation fixture, and the specimen shape (keeping the load bearing surface area at 2.0 square inches, (2581 mm^2), a gasket specimen can be tested for creep relaxation at prescribed loads, temperatures, and times, and then can be tested for sealability on the same specimen using fluids or gasses.

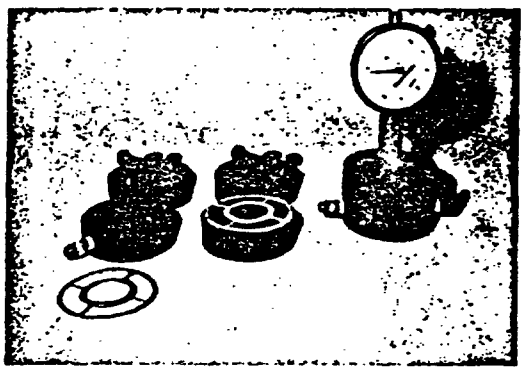


Figure 5: Modified creep relaxation fixtures for measuring sealability

Because a number of factors affect the initial sealability of a gasket material, i.e., type of binder and state of cure, density, type of fiber and fillers, amount of each ingredient present, some materials may not seal well when tested in the as-received state but once exposed to elevated temperatures, these same materials normally exhibit lower rates due primarily to the gasket being compacted in the flange. Some sealability results on various materials after such exposure are listed in Table I.

	A	B	C
Beater Addition	32	33	27
Non-Asbestos	23	40	7
Materials	148	33	112
	94	39	36
	255	56	74
Compressed	1550	58	242
Non-Asbestos	28	57	6
Materials	5	42	4
	11	45	10
	16	47	4
	13	43	5
Compressed	58	40	20
Asbestos	81	36	53
Materials			

A = Leakage before oven exposure mL/hr.

B = Creep relaxation 22 hours at 100°C, %

C = Leakage after oven exposure mL/hr.

Table 1: Combination Creep Relaxation-Sealability Testing. Initial flange load-3000 psi (20.7 MPa), Media-N2 gas, 100 psig (690 KPa) internal pressure

Compressive Strength - because gaskets are sometimes subjected to extremely high compressive loads, the compressive strength of gasketing materials is another very important property. Non-uniform flange loading, heat, and media to be sealed all have detrimental effects on the compressive strength of the gasket material.

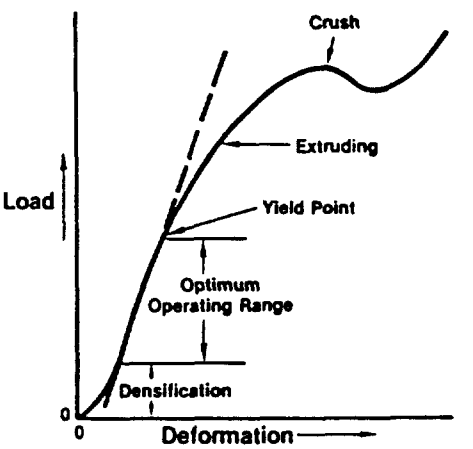


Figure 6: Typical stress/strain curve

Figure 6, showing atypical stress/strain curve, depicts what happens to a compressible gasket material while being subjected to a constantly increasing compressive force. The exponential change in slope at the low end of loading results from compaction of the material. Once the material has reached its compaction density, the curve becomes linear. The slope of the curve in the linear portion is dependent upon the composititon of the gasket material and its hardnes, i.e., harder gasket materials yield a steeper slope.

When a gasket material begins to creep (deformation due to flow of the material), we have a load which we define as the compressive strength of the material. Given any stress beyond the yield load, the gasket material may not function due to separation of internal bonds (rupture), excessive torque loss, etc.

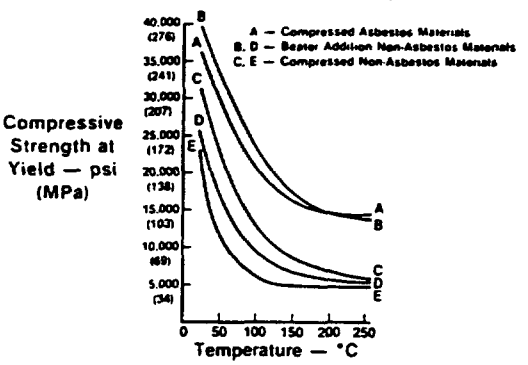


Figure 7: Compressive strength versus temperature

Figure 7 depicts the compressive strength relationship between asbestos and non-asbestos gasket materials. Because there are so many brands and types of asbestos gasket materials, only a limited number were tested due to the time and cost involved. Those tested were representative of the very high strength, general purpose, and controlled swell types.

Figure 8 compares the compressive strength relationship between asbestos and non-asbestos medium density/NBR materials after being subjected to various fluids. Because the media being sealed does migrate into the gasket material, it could soften the binder resulting in high torque loss and/or compressive failure.

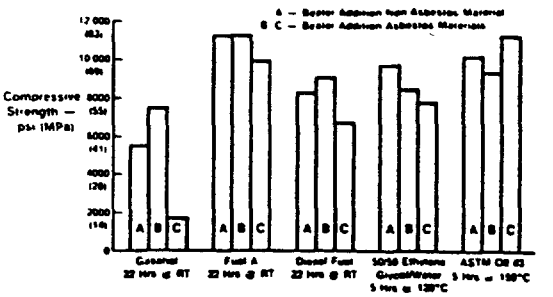


Figure 8: Compressive strength after exposure to fluids

Dynamic Blow Out Resistance - another new test method is being developed to measure dynamic blow out resistance of gasket materials. Using the same modified creep relaxation fixture mentioned earlier, the gasket is subjected to a pulsing internal fluid pressure. The magnitude of the peak pressure is increased until the material ruptures and/or severe leakage occurs. Variables affecting this test will be flange loading, type of media, temperature at time of testing, and preconditioning of the gasket.

RELIABILITY

As mentioned earlier, non-asbestos gasket materials are relatively new to the marketplace, and therefore, do not possess the demonstrated reliability with time like the asbestos gasket materials. However, during the past four years, non-asbestos gasket materials have been found to perform satisfactorily in more than 75% of the applications which had for years been serviced by the asbestos gasket materials.

The conversion to non-asbestos gasket materials to date has been relatively slow due to:

1. Higher cost of the non-asbestos materials.
2. Time and costs for evaluating and approving the materials.
3. Availability of asbestos gasket materials.
4. Easing of federal legislation pertaining to asbestos.

The tests described earlier have been utilized to predict the function ality of materials in specific applications. They have proven reliable on

numerous occasions by correlating extremely well with results obtained in actual field evaluations.

COST VERSUS PERFORMANCE

The cost to manufacture asbestos reinforced gasket materials is at present less than the cost to manufacture non-asbestos gasket materials. Since the asbestos fiber constitutes 70 to 85% of the gasket composition, and it is usually the lowest cost constituent, the direct material cost is normally less than 50% of the product's full cost. High performance non-asbestos gasket materials, although containing only 10-30% fibers, are more costly due to the high cost of the fibers used. The replacement of asbestos with fiber/filler combinations results in increased direct material costs of up to 4 times that of an equal asbestos product. This higher direct material cost, coupled with yield factors in manufacturing, results in a higher cost product in which the material costs can be as high as 85% of the full cost.

Since there are two basic fibers being used in non-asbestos gasket materials, i.e., cellulose and Aramid, the design engineer should be cautious not to over specify the gasket material, as cellulose containing non-asbestos gasket materials are considerably less costly than those containing aramid fibers. The only significant difference between the cellulose and aramid containing gasket materials is temperature resistance. Cellulose will function up to 350°F (177°C), aramid over 600°F (316°C).

FOOTNOTES

1. A number of new and/or modified test methods are presently under development by ASTM. Subcommittee F03.0, responsible for test methods, classifications, definition of terms, and specifications of gasket materials is attempting to develop test methods that will more precisely define the functional characteristics of gasket materials.

2. Gasket materials are manufactured by a number of different processes. Sheeter (CA and CNA), Beater (BA and BNA), molding (cork/rubber buns), saturating, to name a few. Some processes produce up to 20 tons of product per day.

3. Tests up to and including 200°C were performed using the ASTM F38-B test fixture. New F38-B test fixtures made of high alloy steel are being considered for use up to 400°C.

This paper is subject to revision. Statements and opinions advanced in papers or discussion are the author's and are his responsibility, not SAE's; however, the paper has been edited by SAE for uniform styling and format. Discussion will be printed with the paper if it is published in SAE Transactions. For permission to publish this paper in full or in part, contact the SAE Publications Division.

Persons wishing to submit papers to be considered for presentation or publication through SAE should send the manuscript or a 300 word abstract of a proposed manuscript to: Secretary, Engineering Activity Board, SAE.

Printed in U.S.A.

10000011