# Replacing asbestos steam path gaskets

**Asbestos restrictions are tightening as deadlines draw near. Suitable substitutes for asbestos sheet gasket materials have been elusive, but one family of materials shows promise**

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Restrictions on the use of asbestos-containing materials continue to tighten. The federal Environmental Protection Agency (EPA) has established a policy for eliminating asbestos in non-critical applications (e.g., below 750 F) by August, 1993. Now, most engineers seek suitable substitute materials for applications where asbestos performed well over the years. In he case of sheet gasket materials, the earch for an asbestos-free substitute has een more complicated than anticipated.

During the mid-1980s, utilities began to replace asbestos sheet gaskets in low-pressure turbines (service temperatures below 750 F) with organic fiber/binder sheet gaskets. The substitutions were based on gasket supplier data and recommendations. As these asbestos-free gaskets accumulated service hours—normally about six months at temperatures above 550 F—they began to leak. The leakage was severe in most cases.

This experience prompted the initiation of a research program in 1986 to qualify an asbestos-free sheet gasket material. The key word here is "qualify," because experience showed that trials based on product literature and data were not satisfactory.

### Materials selection

Phase I of the program sought candidate materials. Suppliers of sheet gasket materials were given a requirements specification and asked to identify candidates that would meet the criteria. As a result, 33 asbestos-free sheet gasket materials entered the program and were classified into four groups: (1) inorganic fiber with a binder, (2) inorganic fiber with no binder and woven similar to cloth, (3) organic fiber (e.g. Kevlar) with a binder, and (4) flexible graphite with an insignificant amount of binder.

Fiber with binder and ceramic fiber with binder materials became available later in the program. These materials were subjected only to the constant displacement elevated temperature and long-term stress relaxation tests of Phase II, because of the timing of their release.

### Screening tests

All 33 candidate materials were subjected to a series of screening tests to determine which of them qualified for more rigorous testing. The screening tests consisted of exposing precut tensile specimens and compressibility buttons to three environments: 750 F/650 psig steam, 210 F water, and 250 F mineral oil. Exposures lasted for 240 hours with specimens supported so that the environment contacted all surfaces.

Materials were examined after they were exposed and Table 1 shows the results on the better materials. Results from the 750 F/650 psig steam exposures proved interesting. Specimens disappeared in the worst cases and others broke apart when touched. The better materials specimens remained intact and they could be handled and tested. The best materials appeared unaffected by exposure in 210 F

**Table 1. Summary of visual examination results of asbestos free samples.**

| Material tested | 750 F Steam | 210 F Water | 250 F Mineral oil |
|---|---|---|---|
| **Organic fiber/binder** | | | |
| Material 1 | Good condition | Good condition | Good condition |
| Material 2 | Good condition | Good condition | Good condition |
| Material 3 | Good condition | Good condition | Blistered/swollen |
| **Inorganic fiber/binder** | | | |
| Material 4 | Intact/brittle | Good condition | Good condition |
| **Inorganic fiber no binder** | | | |
| Material 5 | Torn* | Good condition | Good condition |
| **Flexible graphite** | | | |
| Material 6 | Good condition | Good condition | Good condition |
| **Asbestos control** | | | |
| White | Good/brittle | Good condition | Good condition |
| Black | Good/brittle | Good condition | Good condition |

* Cloth type material

**Table 2. Tensile, compressibility and recovery test data taken before and after exposure.**

| Material tested | 750 F Steam | | | 210 F Water | | | 250 F Mineral oil | | |
|---|---|---|---|---|---|---|---|---|---|
| | Tensile % change | Compressibility % change | Recovery % change | Tensile % change | Compressibility % change | Recovery % change | Tensile % change | Compressibility % change | Recovery % change |
| **Organic fiber/binder** | | | | | | | | | |
| Material 1 | -94.72 | Cracked | 41.4 | -1.1 | 0.0 | -1.10 | -5 2 | 0.0 | 19 6 |
| Material 2 | -95.26 | Cracked | Cracked | -4.4 | 0.0 | -4.39 | -23.0 | 12.5 | 26.9 |
| Material 3 | Fractured | -10.0 | -8.1 | 10.5 | 6 3 | 10.49 | -83 4 | 3.2 | NATT |
| **Inorganic fiber/binder** | | | | | | | | | |
| Material 4 | Fractured | 33.3 | 44.4 | 3.3 | 7 7 | 3.33 | 11.24 | 20.0 | 32.7 |
| **Inorganic fiber no binder** | | | | | | | | | |
| Material 5 | No test | No test | No test | No test | No test | No test | No test | No test | No test |
| **Flexible graphite** | | | | | | | | | |
| Material 6 | 11.27 | -2.5 | -4.0 | 16.1 | -7.5 | 16.10 | 4 4 | 24 5 | NATT |
| **Asbestos control** | | | | | | | | | |
| White | NATT | 25.7 | -4.3 | -59.0 | 10.8 | -59.0 | 215.1 | 0.0 | -7.2 |
| Black | NATT | 29.0 | -6.4 | -54.6 | 26.1 | -54.6 | -29.5 | -10.9 | 1.1 |

NATT - Not able to test

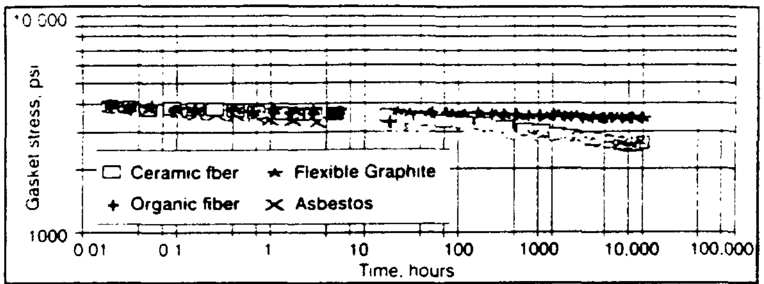


**Figure 1. Room temperature stress relaxation data.**

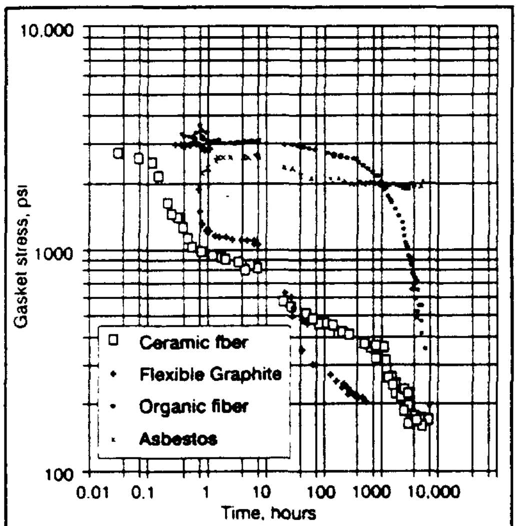


**Figure 2. 750 F stress relaxation test data.**

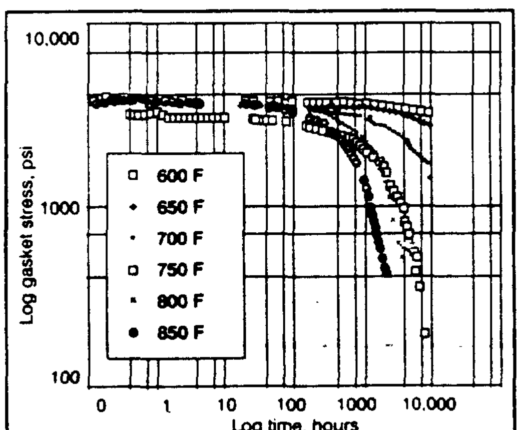


**Figure 3. Flexible graphite stress relaxation test data.**

water. Only two materials appeared to be affected by the oil in 250 F mineral oil exposures.

Tests for tensile strength, compressibility and recovery also were conducted after exposure and the resulting data were compared to unexposed properties. See Table 2 for the percentages of change in the better materials.

More details of these test results can be found in the paper "Evaluation of Asbestos Free Gasket Materials" by W. F. Jones and B. B. Seth, presented during the ASME/IEEE International Joint Power Generation Conference, October 21-25, 1990 (90-JPGC/Pwr-58).

The screening results identified the best materials for Phase II qualification tests. Primary criteria for selection, in this case, were based on the materials' appearance after the screening exposures. This was because very few of the 33 materials survived the 750 F/650 psig steam exposure. The flexible graphite materials survived intact with no visible evidence of degradation. A few of the organic fiber/binder materials also survived these screening tests based on appearance.

Final selection of Phase II materials was based on tensile, compressibility and recovery test data. Those with the least loss in tensile strength after exposure held the most promise. Consideration also was given to those materials that were not affected by the mineral oil tests.

Flexible graphite materials and three organic fiber/binder sheet materials were selected for testing. The organics were selected instead of the inorganic fiber cloth materials because the cloth-type materials would not seal vacuum applications. Further, the organic fiber/binder materials most closely duplicated asbestos sheet in handling and size availability.

Phase II testing was considered the qualification portion of the program. The candidate materials were subjected to more extensive evaluations and simulated service conditions. Materials were subjected to standard compression, flammability and y and m factor tests, as well as specially designed tests. Data from these standard tests indicated that the materials would perform adequately.

It was the special tests that began to reveal the problems that account for the leaky service experience of asbestos-free materials. Long-term stress relaxation tests showed expected performance at room temperature (Figure 1), but all except asbestos sheet exhibited significant load reductions at 750 F (Figure 2). The organic fiber and ceramic fiber materials showed the fastest load drops. However, the flexible graphite came closer to matching the performance of asbestos sheet.

**Special tests reveal leak causes**

Constant displacement elevated temperature tests also offered insight to the leaky service experiences of the organic fiber/binder materials. In these tests, samples were loaded to typical flange conditions (3000 psi) at room temperature. Room temperature displacement was held constant while the specimens were heated to 750 F. Load was monitored during heating. In all cases, gasket stress increased rapidly, but some behaved unexpectedly.

The carbon fiber/binder material smoked and oozed out of the test fixture. Two of the organic fiber/binder materials pulverized and melted, a condition leading to leakage in service. The third organic fiber/binder material appeared to survive, but it was held together merely by its wire mesh insert. Only the asbestos sheet and the flexible graphite materials survived the test with satisfactory results. Table 3 summarizes the maximum stresses and visual conditions for materials subjected to these tests.

In the final part of Phase II, asbestos sheet and flexible graphite were subjected to simulated service tests that varied temperature and pressure of the gasket environment. The tests were run, but fixture difficulties prevented precise leak rate determinations. However, the asbestos sheet leaked more than the flexible graphite sample.

The results of the asbestos-free gasket qualification program through Phase II indicated that the flexible graphite material appeared to be the only candidate capable of substituting for asbestos sheet. However, the long-term stress relaxation behavior of the flexible graphite (Figure 2) indicated that leakage could be expected at 750 F in less than five years. As a result, Phase III of the program was initiated to develop data to predict usable service for flexible graphite sheet. Usable service in this context is defined as the time required for the flange load to relax to the minimum flange clamping load. This is calculated in accordance with ASME Section VIII Man-

**Table 3. Constant displacement elevated temperature test data for materials tested.**

| Material | Maximum stress reached stress (psi)/ temp F | Stress after 5 min at temp stress (psi)/ temp F | Visual condition of test sample after test |
|---|---|---|---|
| Asbestos sheet | 12,000 / 705 | 13,040 / 750 | Intact, no distress |
| Organic fiber/binder | 8480 / 714 | 8480 / 750 | Pulverized and melted |
| Carbon fiber/binder | 8475 / 729 | 12,550 / 750 | Extremely brittle** |
| Ceramic fiber/binder | 11,100 / 746 | 11,100 / 750 | Brittle |
| Organic fiber/binder wire insert | 13,120 / 745 | 13,120 / 745 | Intact, no distress |
| Flexible graphite | 10,200 / 750 | 10,200 / 750 | Intact, no distress |

** Smoked and oozed out of fixture during heating.

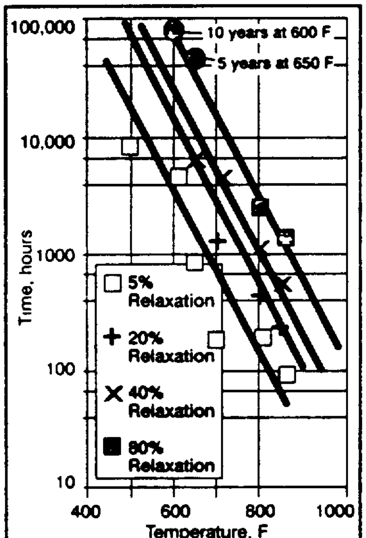


**Figure 4. Flexible graphite usable service prediction curves.**

datory Appendix 2.

**Stress relaxation tests**

In Phase III, long-term stress relaxation tests were started at 500 F, 600 F, 650 F, 700 F, 800 F and 850 F and allowed to run until minimum usable service load or 10,000 hours of exposure were reached. The 500 F, 600 F and 650 F tests continued to run to 10,000 hours. Figure 3 shows the long-term stress relaxation curves. The 500 F data are not plotted, because they show no relaxation. Usable service prediction curves (Figure 4) were generated from the data in Figure 3 by picking different amounts of stress relaxation.

**Utility survey**

Parallel with the long term stress relaxation tests, a utility survey was initiated to determine industry experience with asbestos-free gasket materials. Thirty-three utilities representing 90 units responded to the survey. Of these 90 units, 46 continue to use asbestos sheet gaskets. The remaining 44 units had tried or were currently using asbestos-free materials in some locations. The asbestos-free sheet gasket materials identified in this survey included types made up of seven different organic fiber/binders: one carbon fiber/binder; four different flexible graphite types; one spiral-wound flexible graphite filled gasket and one spiral-wound Teflon-filled gasket.

Three of the materials mentioned in the survey responses were packings and not considered. In addition, seven were unknown materials and their use was in locations at less than 550 F. They met with little success in applications at temperatures above 300 F.

Success in the use of organic fiber materials was mixed, according to reports. One unit reported successful operation at 750 F, yet others reported failures of the same materials at 630 F and 700 F. Other materials failed at temperatures as low as 550 F. Failure times were short, generally in one to three months.

Reports of operation for the carbon fiber/binder material ranged up to 1000 F. It operated successfully at 750 F and 850 F, but had one confirmed failure at 690 F. The user indicated that this material tended to leak in operations above 590 F, especially after a system disturbance.

The use of flexible graphite sheet was limited. Although one utility reported its successful use at 950 F, the service time was only three months. Higher temperature applications (to 1150 F) of flexible graphite were in the form of spiral wound gaskets.

Although the results of the utility survey were not quantitative, they did confirm the laboratory test results. Tests of asbestos-free gasket materials confirmed that flexible graphite is the best material for replacing asbestos sheet in applications with temperatures above 300 F. Flexible graphite sheet equaled or outperformed asbestos sheet in all except the high temperature stress relaxation tests.

This behavior of flexible graphite is adequate for use up to 650 F. However, the service life drops to less than five years in applications above this temperature. As a result, the use of flexible graphite sheet gaskets in Westinghouse steam turbines is based on the usable service curves shown in Figure 4. The following guidelines are used for all applications eliminating asbestos:

- Use the time vs temperature curves for applications needing less than five-year usable service.
- Use at 650 F maximum to get five years of service.
- Use at 600 F maximum to get 10 years of service.
- Use metal or flexible graphite filled spiral wound gaskets for application at temperatures higher than 750 F.
- Flexible graphite spiral wound gaskets also should be used for special or critical applications.

**Field tests**

To correlate the laboratory test data with actual service, use of flexible graphite gaskets in operating turbines is being evaluated. Flexible graphite sheet gaskets currently are in service in several locations and are operating without incident. As more units begin to use flexible graphite we expect to verify its adequacy as a substitute for asbestos sheet gaskets in steam turbines.

**Conclusions**

No single material was found during the research that could substitute for asbestos sheet gaskets. However, flexible graphite is a satisfactory replacement for application at temperatures up to 650 F.

As for organic fiber/binder sheet gaskets, they are not capable of performing effectively at temperatures above 350 F.

Elevated temperature testing (i.e., at least operating temperature) is required on any material that is intended to be used as a replacement for asbestos. Further, long-time stress relaxation testing at projected operating temperatures are required as part of qualifying any asbestos free material. END

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# FIELD NOTES

APPLICATIONS OF NEW TECHNOLOGY
AT POWER GENERATING PLANTS
MONA REYNOLDS, Special Projects Editor

## Central controls balance district cooling system

Automated control of part of a cogenerated district heating and cooling system in Trenton, N.J. has provided an investment payback of less than six months because of an increase in efficiency compared to manual operation.

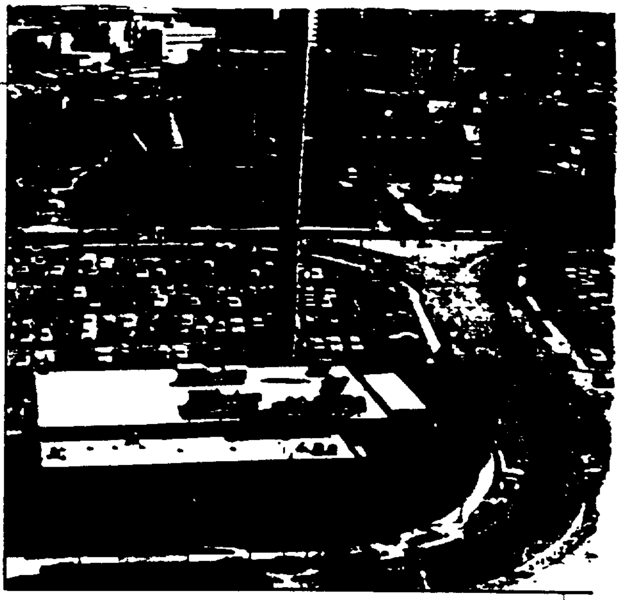
Trigen Energy Corp. installed the Honeywell Inc. system to govern the chilled water portion of a cogeneration project serving 18 buildings in downtown Trenton. Buildings served include the state capitol complex, offices, a hospital, a prison, and commercial structures. Control of hot water and electric power generation will be automated in the near future.

At Trenton, Trigen operates two diesel electric generators totaling 12 MW, three hot water loops and a chilled water loop. A maximum of 3.75 MW is drawn by the equipment; the remainder is sold to Public Service Electric & Gas Co.

"The 4.5-mile-long chilled water loop to the 18 buildings includes a 2.7-million gallon flow-through storage tank and pumphouse," according to Gary Fechter, Trigen director of operations. "The tank imports chilled water at night and exports it during the day....Loads can range to 11,000 tons."

When the chilled water storage tank was installed, control was manual. Efficient use of the new tank required that automated optimization strategies for tank import and export be developed. At the same time, it was determined that such automation could eliminate the need for operators to walk the several block distances between the generating plant and the pumphouse and chillers to start and stop and monitor equipment, adjust setpoints, and balance loads.

The new control system consists of loop-and-logic controllers in three locations to provide chiller and pump interlocking, sequencing, multiloop analog control, and status information. Compared to previous manual operation, the new system tightened control of chilled water production and distribution. But to obtain the full benefits of automation through coordinated control—and a reduction in the amount of walking required of operators—the controllers in the field were linked to a supervisory unit located in the generating plant control room.



**Cogeneration plant supplies chilled water for district cooling system in downtown Trenton, N.J.**

With the supervisory unit, "the operator can balance the entire chilled water system—storage, production, and distribution—from one location," said Fechter. The operator interface to the supervisory unit consists of two personal computers. In an emergency the PCs can access the controllers directly.

According to Fechter, typical optimization calculations performed by the supervisory unit are those employed to control the temperatures in the cooling tower that serves the absorption chillers. By establishing setpoints that approach wet bulb limits, and also by more tightly controlling chiller operation, the system reduces the amount of steam needed to produce a ton of cooling. Steam consumption has fallen from as high as 14 lb/ton to 9.0 lb/ton.

**Circle 206 on Reader Request Card**

## Switch to helium unit improves condenser leak detection

**Portable helium leak detector seeks out air inleakage into the condenser.**

Operators of Florida Power & Light's Manatee plant decided to stop using a chloro-fluorocarbon refrigerant to locate leaks because of its environmentally destructive nature. FPL also experienced problems with the product because it is heavier than air and drops to the bottom of the condenser, thus making detection of air inleakage difficult.

FPL personnel were first introduced to the use of helium as a tracer gas when they called in a contractor who used a mass spectrometer to find an air inleak they could not find with their equipment.

The mass spectrometer, however, is large and cumbersome, and FPL sought a portable instrument. Their search led to a helium detector manufactured by Mark Products, Inc., Sunnyvale, Calif., that can be strapped to a technician's waist or mounted on an equipment cart for testing.

Testing for air inleakage with the helium unit takes two people, one to "spray" the helium, and the other to remain with the instrument and watch for indicative displays. Helium is sprayed on the suspected leak areas for about 10 seconds. The technician then waits for the helium to permeate into the leak and register at the detector.

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