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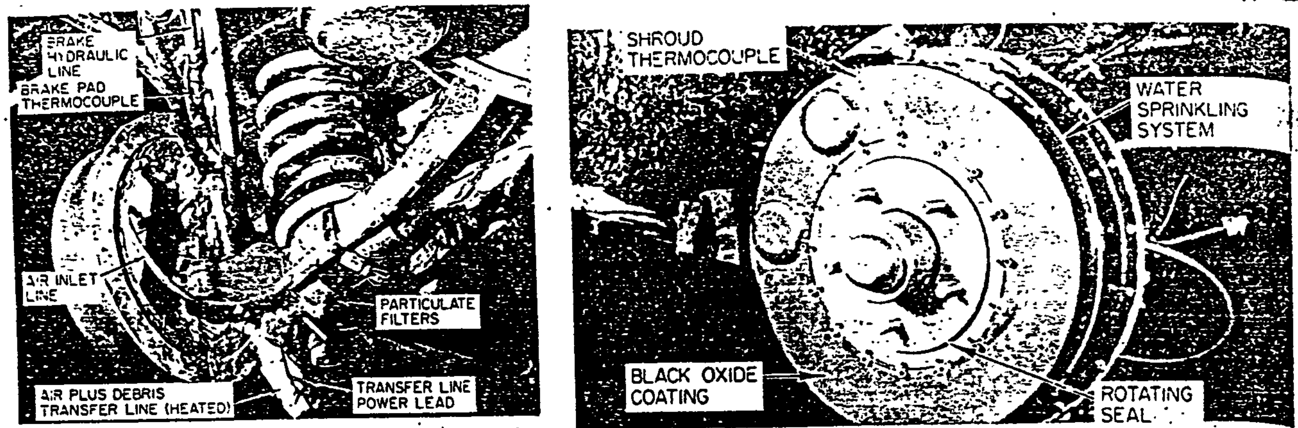


1. Disc brake emissions collector (left) from back, showing instrumentation; (right) showing thermal control aids.

HOW MUCH ASBESTOS DO VEHICLES EMIT?

EXHIBIT NO. 10
Betty Browning

Most of asbestos emitted from vehicle brakes and clutches is converted to other products, with only 3.2% of total asbestos emitted entering the atmosphere, according to Bendix researchers.

A comprehensive investigation of gas and particulate emissions from automotive brakes and clutches during actual vehicle operation shows that, on the average, more than 99.7% of the asbestos emitted is converted to other products. The contribution to the atmosphere is estimated to be 5060 lb per year for the whole country — or 3.2% of the total asbestos emitted.

These figures were obtained with a medium-weight (4850-lb test weight), high-volume passenger car with a 3-speed manual transmission, ventilated cast-iron disc brakes in front, cast-iron drum brakes in the rear, and a dry clutch. A front disc brake collector (Fig. 1) and a rear drum brake collector (Fig. 2) installed on the right side of the vehicle collected the wear debris and separated it into three fractions:

- Sump samples, including the wear debris on lining surfaces, in rivet holes, and on the brake drum.
- Surfaces samples, including wear debris on brake and collector shroud surfaces.
- Airborne samples, collected on membrane filters.

The clutch was sealed by closing the remaining few holes in its casing. The left wheel brakes were kept in their normal configuration. They were used to monitor the operation of the shrouded brakes. Wear debris was taken from the left brakes as well as from those on the right. The amounts of debris formed and the compositions were used to demonstrate that the brake shrouding did not significantly affect operation of the right-hand brakes.

How the tests were run

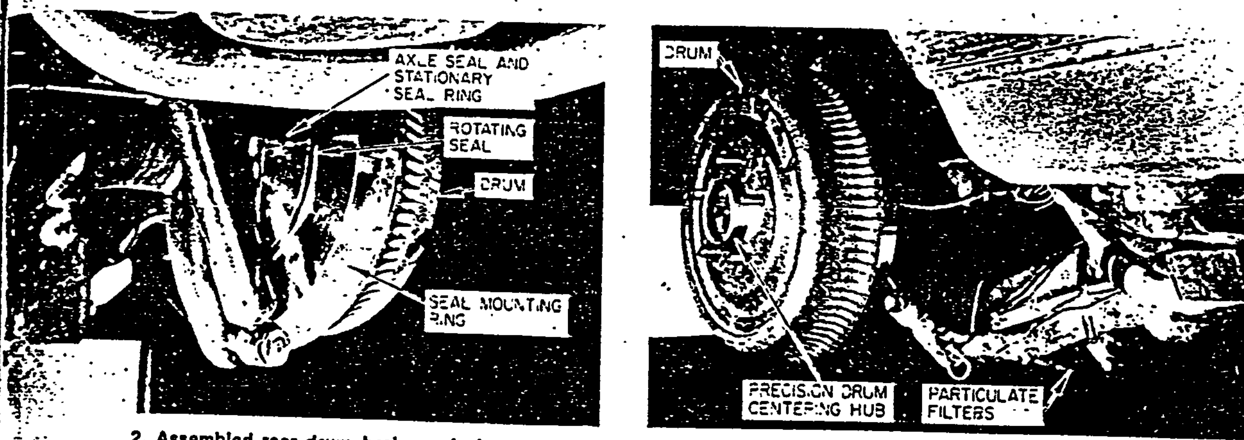
Three vehicle tests were run: the first with original equipment friction materials; the second simulating a partial reline — fronts only were relined, with the rears retained as is to give a replicate test, and an indication of emissions trends for friction materials with continued use. The third vehicle test simulated a complete brake reline, including turned discs and drums.

All friction materials contained asbestos, and were representative of those supplied by the industry. Materials from Abex, Bendix, Raybestos-Manhatten, Thiokol, and Worldbestos were used for original equipment and aftermarket disc pads and drum linings, selected in part because of their high-volume usage.

Collecting the emissions

Fig. 3 shows a cross-sectional view of the disc brake emissions collector. The rubbing seal is located at the hat or hub section of the rotor. The seal is a spring-loaded, graphite-filled Teflon seal of commercial manufacture. The main portion of the shroud was coated with black oxide. A water cooling system was added, and an open "mag" wheel was used to aid in cooling the enclosed brake.

A cross-sectional view of the drum brake emissions collector is shown in Fig. 4, along with details of the rubbing seal, which is the same type as that on the disc brake emissions collector. The axle hub used to attach the drum was modified with a pie



2. Assembled rear drum brake emissions collector (left) shown from inboard; (right) shown from outboard.

that was concentric to the axle bearings within 0.001 in. (0.0025 cm). A tapered lead facilitated drum mounting. Close tolerances were necessary on the concentricities to obtain reasonable seal life.

Seven test vehicle driving schedules were used. Each was followed by a measurement procedure that included taking emissions samples, measuring wear, inspecting systems, and replacing worn-parts, if necessary.

First, three low-temperature tests were run Burnish, Afterburnish Baseline, and Detroit Traffic. These were followed by the high-temperature tests — 10-stop Fade, Afterfade Baseline, 15-stop Fade, and Final Baseline.

Measuring asbestos content

Each of the samples was analyzed for asbestos content by optical and electron microscopy.

For vehicle test 1, asbestos content of brake emissions ranged from 1.65% down to 0.5%. Of the 47 analyses reported, only two were above 1.00%. For test 1, the overall average was 0.38%.

For test 2, the asbestos content ranged from 1.42% down to 0.03%. Of the 43 analyses reported, only one was above 1.09%, and only three were between 0.50 and 0.96%; all others were less than 0.50%. The overall average was 0.25%.

For vehicle test 3, the range of asbestos content in brake emissions varied from 0.51% down to 0.003%. Of the analyses reported, three were between 0.20 and 0.51%; all others were less than 0.20%. The overall average was 0.07%.

For all three vehicle tests, the overall average of asbestos content in the brake emissions was 0.23%.

As a check on Bendix results, independent asbestos analyses were also made, which gave slightly different results. For example, Battelle Columbus Laboratories, which analyzed 24 samples generated during the program, obtained an average of 0.171%, which is 69% of the Bendix average of 0.24% for the same 24 analyses.

The explanation for the higher Bendix values is as follows: all larger fibers (bundles of fibrils) found were assumed to be cylinders of projected diameter and length, and a fiber with an elliptical cross-section was actually smaller in volume than reported. In addition, all fibers were assumed to be 100% asbestos (partially degraded asbestos or olivine fibers were weak and mechanically reduced to nonfibrous material by the other analytical technique used, hence, only the remaining asbestos fibrils were counted).

To compare emissions properly, it was necessary to calculate the asbestos emissions factors for each sample in micrograms/mile. Values of these factors were obtained by multiplying the weights of brake debris generated by the appropriate asbestos percents, then dividing by miles per test schedule. Thus, either a high asbestos content or a large sample gave a high factor.

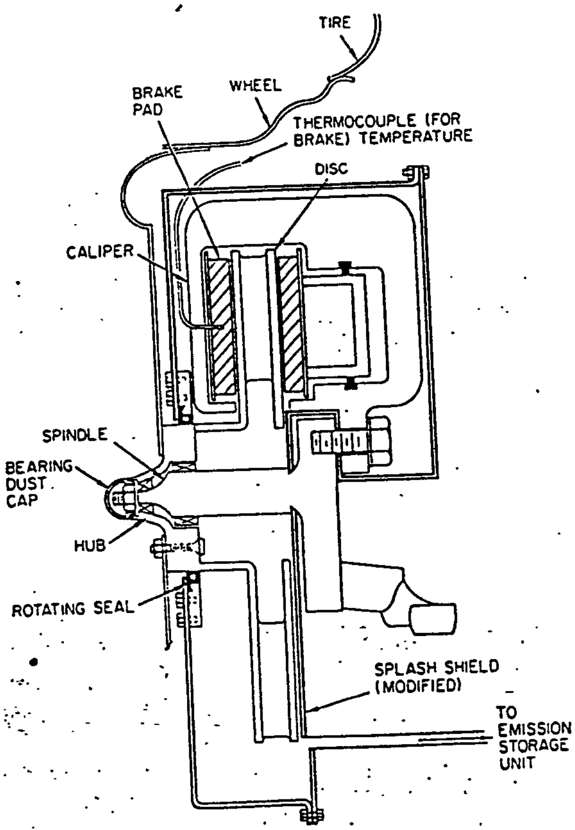
The trends in asbestos emissions can be summarized as follows:

- Asbestos emissions are higher for new friction surfaces and decrease with use.
- The drum brake produces more asbestos emissions than the disc brake initially, but the difference decreases as the friction materials continue in use.
- Heavy (abusive) duty do not necessarily give a higher per cent asbestos; the large amount of debris produced, however, give a significant rise is asbestos emissions.
- Asbestos emissions from brakes decrease from fade or heavy-duty stops (highest) to burnish to moderate braking (lowest).
- For the disc pads only, there is an increase in asbestos emissions with increased asbestos content in the friction material. (There was no such trend for the drum brake materials.)
- Both front disc pads and drum linings of vehicle test 3 had wear rates comparable to those found in the other two vehicle tests, yet the asbestos emissions were significantly lower. (Both pads and secondary linings contained brass chips, which may have been in part responsible for the more complete conversion of the asbestos in brake emissions.)
- For both disc and drum brakes, the surfaces sample was the largest of the three (about 92%), the sump sample was next (about 7%), and the airborne sample was smallest (about 1%).

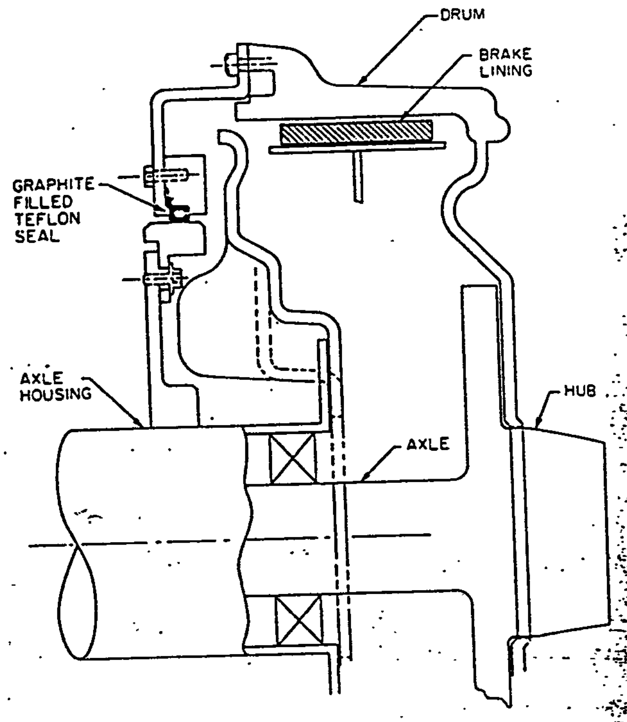
How asbestos emissions add up

An estimate of the total emissions from brakes and clutches is given in Table 1.

Values for the number of vehicles in use are based on estimates from the National Highway Traffic Safety Administration, the Federal Highway Administration, and other sources.



3. Disc brake shroud shown schematically.



4. Drum brake shroud shown schematically.

Total asbestos emissions per year were calculated by multiplying the weight of emissions per vehicle-mile by the number of miles the vehicle was driven per year and the number of vehicles in use.

For example, for passenger cars, the following estimates were used:

- Total asbestos emissions per vehicle: 28.51 μg/mile, which was obtained by averaging the values from the three vehicle tests.
- Average annual mileage for passenger cars was estimated at 9978 miles.
- Number of passenger vehicles: 96,400,000.

Substituting these values in the equation gives:

$$\frac{28.51\ \mu g}{\text{vehicle-mile}} \times \frac{10^6 g}{\mu g} \times 9.978 \times 10^3 \frac{\text{miles}}{\text{year}} \times \frac{1}{454\ g} \times 96.4 \times 10^6 \text{ vehicles}$$

$$= 60.400 \text{ lb per year}$$

The asbestos from the test vehicle friction materials was calculated to end up as follows: 81.9% deposited on the ground, 14.4% retained in the brake and/or disposed of during service, and 3.7% emitted to the atmosphere. These percentages were used to determine the distribution of emissions for passenger cars.

Truck brakes usually are heavier than passenger-car brakes and tend to operate at higher temperatures. In addition, the clutch is used more often. When these differences are taken into account, total asbestos emissions per light truck are calculated at 87.51 μg/mile.

Distribution factors had to be modified because the truck drum brake is more open than the car drum brake and, in many instances, has no splash shields. It was estimated, therefore, that only about 25% as much debris remains in a truck drum brake as in a passenger-car drum brake. The distribution of emissions for trucks was, therefore, calculated to be: 87.9% road dropout, 2.9% airborne, and 9.2% retained in the brakes.

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Based on SAE paper No. 730548, "Brake and Clutch Emissions Generated during Vehicle Operations," presented at the SAE Automobile Engineering Meeting, May 1973, Detroit.

Table 1 Summary of All Brake and Clutch Emissions (lb per year)

	Number of Vehicles	Total Asbestos Emissions	Distribution: Dropout	Distribution: Airborne	Distribution: Brake Retention
Passenger Cars	96,400,000	60,400	49,470	2,230	8,700
Light Trucks	17,100,000	32,300	28,420	940	2,940
Medium Trucks and Buses	2,600,000	16,300	14,330	470	1,500
Heavy Trucks	1,200,000	32,900	28,920	950	3,030
Miscellaneous[a]	6,615,000	16,300[a]	14,330	470	1,500
Totals		158,200	135,470	5,060	17,670
% of Total			(85.6)	(3.2)	(11.2)

[a]Estimated equal to medium trucks as weights of friction material used for both categories are almost equal. Includes motorcycles, trailers, and the like.