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ganics. Vehicle tests also showed a reduction in noise levels, an unexpected bonus!

Semi-metallics are currently being produced for one domestic vehicle equipped with solid rotors. Combinations of organic and semi-metallic pads are being used on a domestic station wagon, luxury car and several light truck applications. The use of semi-metallics has also been expanded to the larger disc brakes currently released for heavy trucks.

## SMALL CAR SOLID ROTOR APPLICATIONS

As previously discussed, one of the prerequisites of a friction material is its ability to resist wear under various temperatures it will experience in service. We also have seen that smaller cars equipped with solid rotors will subject the friction materials to a wider range of temperatures than the materials used on larger cars equipped with ventilated rotors. It has been our experience that reasonably good predictions of durability life can be made knowing the wear versus temperature characteristics of any material.

The effects which rotor weight and brake configuration have on operating conditions can easily be observed or measured with a Full Brake Dynamometer. A procedure which has been used consists of a series of braking cycles at six different initial brake temperatures. Each cycle is comprised of 300 stops made from 50 mph at 12 fpsps deceleration. The time interval between stops is varied to maintain a constant initial rotor soak temperature. The initial rotor soak temperature is increased from 250° to 625°F in 75° increments. After the 625° cycle, a 250° cycle is repeated to establish the low temperature wear rate after severe usage. The linings are measured after each cycle and the incremental wear plotted. The total rotor wear experienced for the 2400 stop test is also recorded.

The data illustrated in Figure 7a, b and c, were accumulated using a 9" diameter solid rotor, 0.375" thick weighing 6 lbs. Wheel load used was 975 lbs.

The results clearly show the wear superiority of the semi-metallics over both the Class A and Class B organics. While the total rotor wear for both the Class A and Semi-metallic formulations were comparable, the Class B materials showed considerably higher opposing surface wear.

Another inertia dynamometer wear procedure used by some European manufacturers to screen potential friction materials is a series of 4 cycles consisting of 250 snubs, from 50 to 17 mph (13 ft/sec$^2$ deceleration) in which the time intervals between applications is held constant at 95 seconds. Temperatures generated on this schedule are relatively low, usually peaking at about 250°F for the brake outlined above. As in the previously discussed wear versus temperature data, the semi-metallics showed distinct advantages over both the Class A and Class B organics (see Figure8).

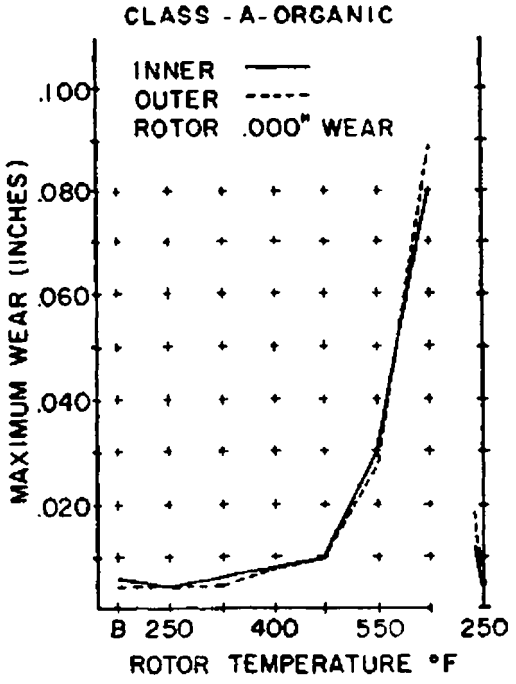



Fig. 7A-Wear versus temperature, inertia dynamometer, 975 lb wheel load, solid rotor

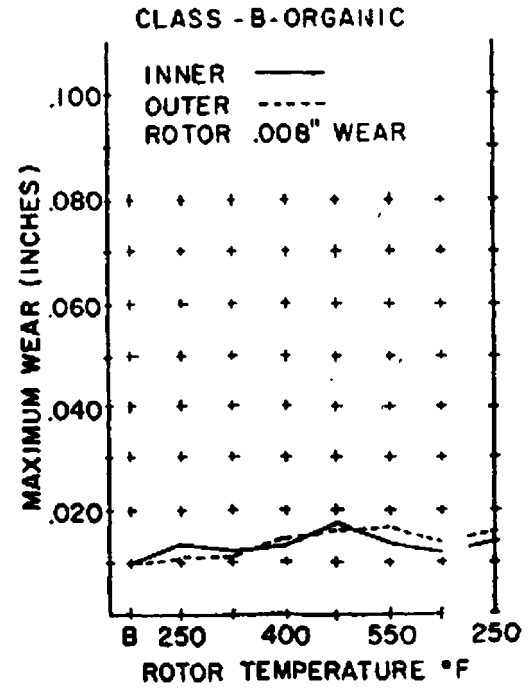



Fig. 7B-Wear versus temperature, inertia dynamometer, 975 lb wheel load, solid rotor

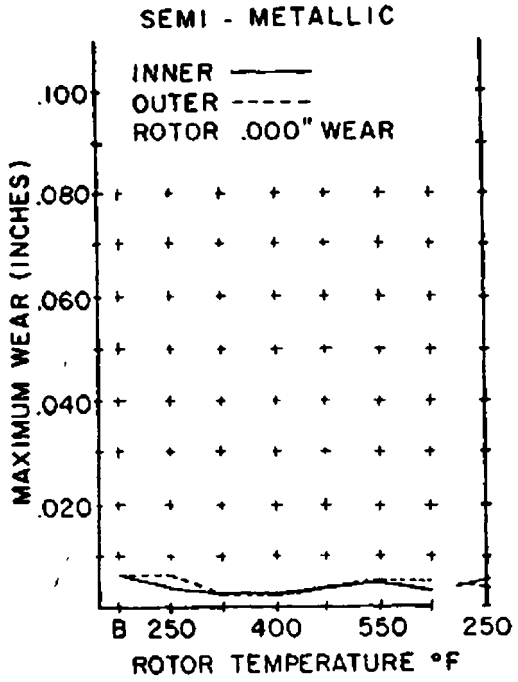



Fig. 7C-Wear versus temperature, inertia dynamometer, 975 lb wheel load, solid rotor

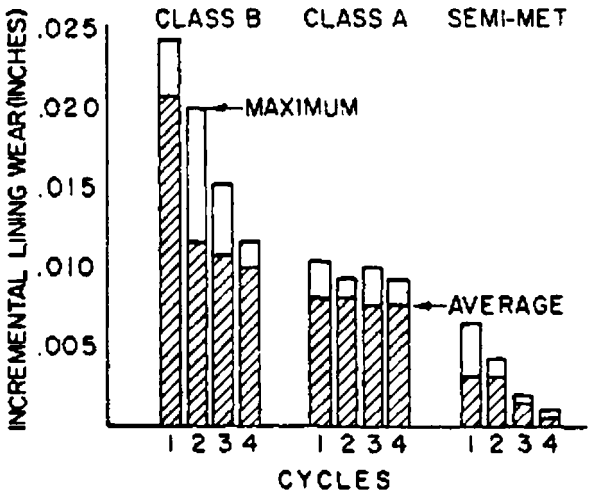



Fig. 8-Incremental lining wear, inertia dynamometer simulation of 2800 lb G.V.W., sedan running low temperature durability

In the introduction, front brake temperature profiles were outlined (Figure 2) for a durability test of a vehicle equipped with solid rotors having a brake test weight of 2800 lbs. Tests conducted on Class A, Class B organics and semi-metallics using this vehicle procedure have repeatedly verified that semi-metallics offer distinct improvements in lining life. The results illustrated in Figure 9 confirm the incremental wear rates previously found in full brake dynamometer tests. The differences between front and rear brake mileage projections are due to the differences in operating temperatures and lining availability. Rear brake operating temperatures were approximately 100°F below the front brakes thereby drastically improving the wear rates of the Class A organic. In the case of the Class B organic and semi-metallics, the lower rear brake mileage projections are the result of differences in available lining thickness.

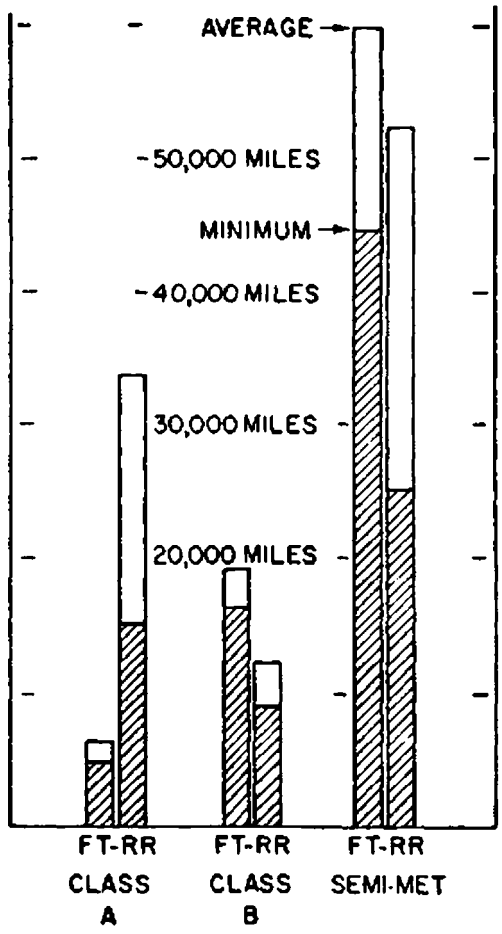



Fig. 9-Mileage projections, 2500 mile durability test, 1973 sedan, 2800 lb G.V.W.

The particular brake system evaluated utilized front brakes lined with pads 0.475" thick while the rear brakes had pads which were 0.185" thick. It is interesting to note that similar tests on larger cars equipped with ventilated rotors rarely show life projections over 30,000 miles.

Significant reductions in noise levels were noted when semi-metallics were compared to the Class B organics. While specific noise hunts detected brake noise ratings as low as "7" for the semi-metallics, the Class B organics showed unacceptable noise ratings as low as "4" (see SAE J1060). Further improve-

ment . in noise rating levels were achieved when typical U.S. type insulators were added to the back of the steel shoes.

A series of vehicle tests were initiated over a year ago in Europe in which a new semi-metallic formulation was installed on vehicles subjected to three different types of duty and were compared to a typical O.E. organic lining:

1. Taxi cabs having automatic and standard transmissions.
2. Rental cars.
3. Business travelers (described as country driving).

The estimated annual driving ranges from 12,500 miles (20,000 km) for rental cars to 25,000 miles (40,000 km) for taxi cabs and business travelers. The results tabulated below (Table 1) indicate the semi-metallics reduced lining wear rates significantly, showing 250 to 430% improvement.

With respect to rotor wear the semi-metallic offered similar advantages over the Class B organic (see Table 2).

## SUMMARY

The performance and wear advantages of semi-metallic linings over conventional organic types have previously been established. More recent development has made them more comparable for initial friction and low temperature or initial wear characteristics.

The high temperature wear capacity of semi-metallic linings enhances their potential for usage on smaller cars with solid rotor brakes. Actual vehicle comparisons have shown substantial improvements over Class B type organics for projected lining life, rotor life, and noise characteristics under a variety of usage conditions.

The gains in lining and rotor life offered by semi-metallics would appear to make them a most viable and cost effective candidate for use on small cars with solid rotor brakes and relative small lining pad areas.

## REFERENCES

1. F. William Aldrich, "Semi-Metallics: A New Type of Friction Material." SAE Paper #710591, June 7-11, 1971.

2. G. R. Wynne, "Development of Police Car Brake Standards." SAE Paper #750397, Feb. 24-28, 1975.

3. Seong Kwan Rhee & John P. Kwolek, U.S. Patent #3,835,118, Sept. 10, 1974.

Table 1 - Lining Wear Rates (MM/1000 Km.)

| | Taxi Cabs | | Car | Business |
|---|---|---|---|---|
| | Automatic | Manual | Rentals | Travelers |
| Class B Organic (O.E.) | 6.5 | 4.0 | 1.5 | 1.5 |
| Semi-Metallics | 1.5 | 1.5 | 0.5 | 0.5 |

Table 2 - Rotor Wear Rates (MM/10,000 Km.)

| | Taxi Cabs | | Car | Business |
|---|---|---|---|---|
| | Automatic | Manual | Rentals | Travelers |
| Class B Organic (O.E.) | 0.57 | 0.33 | 0.12 | 0.10 |
| Semi-Metallics | 0.02 | 0.02 | 0.06 | 0.04 |