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WEAR AND RELATED CHARACTERISTICS OF AN AIRCRAFT TIRE DURING BRAKING

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16. Abstract

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SUMMARY

An experimental investigation was conducted to evaluate the wear and related characteristics of friction and temperature developed during braking of size 22 × 5.5, type VII, aircraft tires. The testing technique involved gearing the tire to a driving wheel of a ground vehicle to provide operations at constant slip ratios on asphalt, concrete, and slurry-seal surfaces. Data were obtained over the range of slip ratios generally attributed to an aircraft braking system during dry runway operations. The results show that the cumulative tire wear varies linearly with distance traveled and the wear rate increases with increasing slip ratio and is influenced by the runway-surface character. Differences in the wear rates associated with the various surfaces suggest that runways can be rated on the basis of tire wear. The results also show that the friction coefficients developed during fixed-slip-ratio operations are in good agreement with those obtained by other investigators during cyclic braking, in that the dry friction is insensitive to the tire tread pattern or to the runway surface, whether grooved or ungrooved. In addition, the tread temperature is shown to increase with increasing slip ratio and, at the higher ratios, to be greater during braking on asphalt and slurry seal than on concrete. Tread temperatures are apparently more dependent upon surface material than upon surface texture since the temperatures are observed to be essentially insensitive to transverse runway grooving.

INTRODUCTION

Tire wear is of major economic concern to commercial and military aviation since tire replacement accounts for approximately half the overall landing-gear maintenance costs of present-day jet airplanes. Tire wear is associated with all phases of the normal ground operations of an airplane but principally in the touchdown, roll-out, and taxi phases. Runway rubber deposits attest to the wear which occurs in the touchdown phase; however, this wear is generally considered to be less significant than that due to the braking and cornering required during the roll-out and taxi phases. This paper presents

the results from an experimental program directed towards an examination of the tire-tread-wear effects attributed to braking.

The extent of braking is generally considered in terms of the wheel slip ratio which is a nondimensional relationship involving the braked and unbraked wheel angular velocity and equals 0 when the wheel is unbraked or freely rotating and equals 1.0 when in a locked wheel skid. The life of a tire tread at a slip ratio of 1.0 can be measured in terms of meters along the runway since the wear is limited to an isolated area of the tire. At a slip ratio less than 1.0, the wheel is rotating, and the tread wear is distributed around the tire periphery which thereby increases the tire life, until at a slip ratio of 0, tire life is measured in thousands of kilometers. The variation of tire wear with slip ratio between the freely rotating and the locked wheel states is unknown. The purpose of the investigation reported in this paper is to examine the wear and the related character-istics of friction and temperature developed by an aircraft tire over the range of slip ratios generally attributed to an aircraft braking system during dry runway operations. The testing technique involved gearing size 22 × 5.5, type VII, aircraft tires to a driving wheel of a ground vehicle to provide operations at a constant slip ratio on asphalt, con-crete, and slurry-seal runway surfaces. The results from preliminary wear tests con-ducted with a smooth tread automotive tire and which employed this technique are pre-sented in reference 1.

SYMBOLS

Values are given in both SI and U.S. Customary Units. The measurements were made in U.S. Customary Units.

F_V nominal vertical load on test tire

N_b number of revolutions of braked wheel over a measured distance

N_0 number of revolutions of free-rolling (unbraked) wheel over a measured
              distance

p   tire inflation pressure

V   test speed of ground vehicle

APPARATUS AND TEST PROCEDURE

Tires

The tires of this investigation were size 22 × 5.5, 8-ply rating, type VII, aircraft tires which were obtained from three manufacturers. Figure 1 is a photograph of one tire from each source. As shown in the figure, tire A, the primary test tire since it was most readily available, had a 6-groove tread, as did tire B, whereas the tread of tire C had 4 grooves. Under normal test conditions, the tires were inflated to the rated pressure of 83 N/cm^2 (120 lb/in^2) and subjected to the rated vertical loading of 17.8 kN (4000 lb). For comparison purposes, several tests were conducted with the tires under a 8.9-kN (2000-lb) loading both at the rated inflation pressure and at 40 N/cm^2 (58 lb/in^2). Wear, friction, and temperature data were obtained for each test condition throughout the test life of each tire, that is, until most of the tread rubber was removed.

Test Surfaces

An active runway and the landing research runway at NASA Wallops Station provided the primary test surfaces for this investigation. The active runway had an abrasive slurry-seal asphaltic surface and the research runway consisted of concrete and asphalt sections, both grooved and ungrooved. A description of the surfaces of the research runway, upon which most of the testing was conducted, is given in reference 2. The grooves on the asphalt and concrete surfaces were 0.6 cm (0.25 in.) deep, 0.6 cm (0.25 in.) wide, and sawed on 2.5-cm (1-in.) centers transversely to the runway. In addition to these surfaces, a concrete taxiway was employed for limited testing to evaluate the effects of certain tire parameters on the tread-wear characteristics. All testing was performed on dry surfaces with the exception of one series in which the concrete and asphalt surfaces were wetted to an average water depth of approximately 0.08 cm (0.03 in.).

Ground Test Vehicle and Instrumentation

Figure 2 is a photograph of the powered ground test vehicle used in this investigation and shows the instrumented wheel test fixture which consisted of the tire and the loading cylinders. The test tire was chain-driven through sprocket wheels by a driving wheel of the vehicle, as shown, to provide operations at constant slip ratios effected by the relative sprocket wheel diameters. Vertical load was applied to the tire by means of two pneumatic cylinders and the effect of this loading on the vehicle attitude was compensated by ballast. The vertical load as well as the drag load on the tire was measured by strain gage beams in the wheel test fixture. An optical pyrometer was mounted on the fixture in a position to monitor tread temperature after the tire had rotated approximately 3/8 of a

revolution out of the footprint. This location was necessary to avoid contaminating the sensor element with dust and loose particles.

Test Technique

The testing technique involved driving the ground vehicle at a velocity of 17.4 knots (20 mph) over a known distance with the test tire operating at a fixed slip ratio and monitoring the number of test wheel revolutions, the tread wear, the vertical and drag loads, and the approximate tread temperature. Tread wear was obtained by weighing the tire and wheel assembly prior to testing and at frequent intervals during the tire test life. Since the vehicle had to be stopped and the tire and wheel assembly removed for weighing, testing on each surface was accomplished by making a number of passes over a carefully measured distance along the runway. In general, the pass lengths were set at 402 m (0.25 mile) but because of the length of the grooved test sections in the research runway, passes on those surfaces were limited to 213 m (700 ft). One series of tests was conducted on an ungrooved surface to evaluate the effect of pass length on tire-wear characteristics wherein the passes were extended to 1207 m (0.75 mile). At low slip ratios where the tread wear was slight, numerous passes were made between weighings whereas at higher slip ratios weighings were taken more frequently.

In the conduct of a typical test at one slip ratio, the tire was first lowered to the runway and loaded with the vehicle in a stationary position. The vehicle was then driven at 17.4 knots over the fixed distance, with the acceleration and deceleration phases as brief as practicable. During the pass an oscillograph recorded the number of test wheel revolutions, the outputs from the vertical and drag load beams, and the response of the optical pyrometer. Figure 3 is a reproduction of a typical oscillograph record, but does not include the output from the wheel revolution counter. At the conclusion of the pass, the vertical load on the tire was removed, the tire raised from the surface, and the vehicle was realined with the runway for another pass. If a tire-wear data point was desired, the tire and wheel assembly was removed and weighed at this time and subsequently reinstalled for additional passes. Tests at one slip ratio were concluded when most of the tread rubber had been removed from the tire and a wear rate had been established.

Before and after each test, the tire was uncoupled from the driving wheel of the ground vehicle and, while fully loaded, driven over the pass length in the free-rolling or unbraked state and the number of wheel revolutions recorded. A knowledge of the braked and unbraked wheel revolutions was necessary to define the test slip ratio of the braked tire.

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RESULTS AND DISCUSSION

General

The data from the tests included a revolution count of the free-rolling and driven (geared to a driving wheel of the ground vehicle) test wheel over the pass distance, tire weights at various distance intervals, and time histories of the vertical and drag tire loadings plus the output from the temperature sensor. These data defined the test slip ratio, the tire tread wear, the friction coefficient, and the approximate tread temperatures. The test slip ratio was computed from the relationship

$$\text{Slip ratio} = \frac{N_0 - N_b}{N_0}$$

where N_0 and N_b are the unbraked (free rolling) and braked test wheel revolutions, respectively, over the same distance along the runway. The tire tread wear was determined from the cumulative loss in tire weight as a function of distance. The friction coefficient was defined as the ratio of the measured drag load to the applied vertical load. These loads together with the output from the temperature sensor were monitored during every pass as typified by the reproduced oscillograph record of figure 3. The oscillations noted in the force-gage response of this figure are attributed to runway roughness, to motions in the wheel test fixture and vehicle, and to the elastic behavior of the tire. These oscillations occurred about faired levels which were observed to remain essentially constant throughout each pass. The friction coefficient for a pass was computed from the ratio of the faired drag load to the faired vertical load. As also noted in the figure, the temperature of the tire tread generally increased during the early stages of the constant-velocity phase of each pass until a quasi-steady temperature was reached and essentially maintained for the remainder of that phase. It is this temperature which is referred to as tread temperature in the discussions to follow.

Data which typify the results from the tire wear tests are presented in figure 4 for three slip ratios, where the tire wear, steady-state friction coefficient, and tread temperature are plotted as a function of distance traveled on a dry concrete runway surface. Each slip ratio identifies a separate tire and, of course, a different set of sprocket wheels in the drive assembly. The tire wear was obtained from weighings at distance intervals commensurate with the wear rate, hence, the number of passes which ensued between weighings decrease with increasing slip ratio. Since the friction coefficient and tread temperature were generally obtained during every pass, values of those characteristics are plotted in the figure at distances which represent the midpoint of each pass. The data of this figure illustrate the linear relationship which exists between the tire wear

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and the traversed distance. Tire wear over a given distance is shown to increase with increasing slip ratio. The figure also shows that, over the range of slip ratios considered, the friction coefficient increases with increasing slip. It will be shown later that the friction level at a slip ratio of 0.144 is slightly below the maximum available with the test tire on this surface. The friction coefficient is also shown to increase slightly with distance. The reason for this increase is unknown, but may be attributed to slight increases in the slip ratio associated with a reduction in tire size due to tread wear and also may possibly be attributed to tread-temperature effects. Figure 4 also points out that an increase in the relative slip between the tire and the pavement is accompanied by a corresponding increase in the tread temperature.

The results of tests to define the effects of runway surface material and condition as well as certain test parameters on tire wear, developed friction, and tread temperature are presented separately in the sections which follow.

Runway-Surface Effects

Surface material.- The results of tests to evaluate the effects of various runway surfaces on the wear and related characteristics of the three test tires are presented in figures 5, 6, and 7. The data of figure 5 relate the tire-wear rate to slip ratio, where the rate is defined by the slope of the wear/distance curves such as those presented in figure 4. The figure shows that the tire-wear rate is influenced by the nature, or texture, of the runway surface. The wear on the asphalt test surface is shown to be significantly less than that on the slurry-seal or on the concrete surfaces, particularly at the higher slip ratios. Tire wear on the slurry seal was quite similar to that on the concrete at low slip ratios; however, at the higher ratios the tires began to experience severe chunking on the slurry seal which greatly magnified the rate of rubber removal. Tire A proved to be particularly susceptible to this damage which generally occurred during the second or third pass at a slip ratio as low as 0.08. Figure 5 includes the wear rates for this tire both before and during tread chunking. The inflection in the curves for all surfaces at the low slip ratios may be attributed to the elastic behavior of the tires which would tend to reduce the relative slippage at the tire-pavement interface and, hence, result in a lower wear rate. The data of this figure are not intended to imply that tire wear on all asphalt runways is less than that on all concrete or slurry-seal surfaces, or that tread chunking is inherent on all slurry seals, because of the wide possible variation in the texture of those surfaces. However, differences in the wear rates associated with the various surfaces do suggest that runways can be rated on the basis of tire wear.

The variation of friction coefficient with slip ratio for the different tire and runway combinations is presented in figure 6. Each plotted value of friction coefficient represents the average value measured over the life of the tire at each slip ratio. The figure

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shows that the developed friction coefficient is essentially independent of both the tire and the surface since one curve fairs the data from free rolling to beyond the maximum. These data, obtained at fixed slip ratios, corroborate the cyclic-braking results reported in reference 3 where it was shown that the tire tread pattern has very little effect on dry-runway braking, and similarly corroborate the results of reference 4 where it was observed that the friction coefficient is generally insensitive to the character of the runway surface when dry. Furthermore, the magnitude of the maximum friction coefficient, approximately 0.83, is in agreement with that predicted (0.80) from the empirical expression developed in reference 5 at very low ground speeds.

Figure 7 summarizes the approximate tire tread temperatures measured during constant slip-ratio operations on the different surfaces with the three test tires. These temperatures are the average of those recorded over the test distances and, again, each data point defines a separate tire. The figure shows that the tread temperature is essentially independent of the surface material from free rolling to a slip ratio of approximately 0.08, with the temperature increasing from about 36° C at free rolling to 70° C. At slip ratios higher than 0.08, the tread temperatures continue to increase, but those generated on the asphalt and slurry-seal surfaces are higher than those on concrete. The thermal conductivity of asphalt and slurry seal is less than that of concrete; therefore, more heat is dissipated to the latter surface and, as a consequence, the tire tread runs cooler. It is of interest to note that during the course of tests at slip ratios greater than approximately 0.18, the tread temperature was sufficiently high to melt the bitumin in the asphalt surface and leave a visible trail on the runway. Tests at lower slip ratios on asphalt and at all test slip ratios on concrete left rubber dust particles which did not adhere to the surface.

Transverse grooving.- Tire wear and related test results for fixed slip-ratio operations on dry grooved asphalt and concrete surfaces are presented in figure 8. For the purposes of comparison, the figure also includes the curves which fair the data from figures 5, 6, and 7 for the corresponding ungrooved surfaces. The tire-wear data of this figure corroborate the results from similar tests conducted on a smooth-tread automotive tire (ref. 1) in that the tire wear rate appears to be unaffected by runway grooving at low slip ratios (up to approximately 0.10 in ref. 1). However, the figure shows that the wear rate at higher slip ratios is greater on the grooved surfaces than on the ungrooved.

Figure 8 also shows that the dry friction coefficient is insensitive to runway grooving which confirms the results presented in reference 2. The figure further shows little effect of runway grooving on measured tread temperatures, thus it would appear that the tread temperature is more dependent upon the runway surface material than the texture of the surface.

Surface wetness.- In an attempt to obtain an indication of the effect of the lubrication provided by surface wetness on tire wear characteristics, one series of tests was performed on both concrete and asphalt surfaces following artificial wetting of those surfaces. The wet condition (average water depth of 0.08 cm (0.03 in.)) was obtained from two passes of a water truck and was approximately 3 m (10 ft) wide and extended the length of each test section. The results from these tests are presented in figure 9 together with the results from corresponding tests on each surface when dry. The data of the figure include the average measured friction coefficient (fig. 9(a)) and the tire wear (fig. 9(b)). No data are presented for tire temperature since the heat measuring device measured the temperature of the water on the tire which remained essentially at the ambient value throughout each test.

Figure 9(a) shows that the friction developed on the wet surfaces was only slightly less than that developed on the dry surfaces which is not surprising in view of the low test speed and the coarse texture of the two surfaces. The 17.4-knot test speed was well below the dynamic hydroplaning speed of 99 knots computed for the tire.

It is of interest to note that although the gearing arrangement in the drive-wheel assembly was the same for tests on both surfaces, slippage in the driving wheel of the ground vehicle on the more slippery wet concrete resulted in a lower test slip ratio on that surface. Therefore, to evaluate tire-wear effects (fig. 9(b)), the results obtained from the wet surfaces are compared with those from the dry surfaces at corresponding slip ratios. The data of figure 9(b) indicate that on the basis of these tests, tire wear on the wet surfaces was approximately 60 percent less than on the same surfaces when dry. Thus, these data suggest that for low-speed braking operation, there appears to be a sizable reduction in tire wear on a lightly wetted surface as compared to that on a dry surface with but a slight loss in friction coefficient.

Test Parameter Effects

Limited tests were conducted to study the effects on tire-wear data attributed to variations in parameters associated with the testing technique and the test tire loading conditions. These parameters included the pass length and speed of the ground test vehicle, and the tire applied vertical loading and inflation pressure. The results from these tests are discussed in the paragraphs which follow.

Pass length.- A pass is defined as the distance traversed by the ground vehicle at one runway heading from start to stop, after which the test wheel is raised from the surface and, depending upon the wear, possibly removed for weighing prior to the next pass. At the high test slip ratios where the tire wear is high, pass lengths were necessarily short to provide sufficient weighings to establish a wear rate. At low slip ratios, however, a considerable distance was generally required to obtain meaningful tire-wear

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characteristics. The results from tests to examine the effect of variations in pass length on tire wear and related characteristics are presented in figure 10. These tests considered pass lengths of 402 m (0.25 mile) and 1207 m (0.75 mile) and were conducted on slurry seal at a nominal slip ratio of 0.048, which was necessarily low to provide sufficient data over the longer pass length. The figure shows that the tire wear, the developed friction, and the tread temperature are essentially independent of these pass lengths. The slightly higher tire wear and friction coefficients noted for the shorter pass may be attributed to the slightly higher slip ratio associated with that tire. Even with the same gear arrangement in the test wheel drive assembly, as was the case for these tests, different tires from the same manufacturer were observed to yield slight differences in slip ratio, perhaps due to minor differences in the tire diameter.

Test speed.- The nominal ground speed for the tests of this paper was 17.4 knots, however, the wear data also include that which occurred during the acceleration and deceleration phases. The effect of the test speed on tire wear, friction, and temperature is illustrated in figure 11 which presents the results obtained on slurry seal at nominal ground speeds of 8.7, 17.4, and 26.1 knots and at a nominal slip ratio of 0.048. The data of this figure show no discernible influence of vehicle ground speed on the tire-wear rate. Differences in the tire wear associated with the three test speeds may be at least partially explained on the basis of slight differences noted in the wheel slip ratio. The figure further shows that the friction coefficient is insensitive to the speeds investigated. The tread temperatures, however, are shown to increase with increasing test speed which would be expected since at the higher speeds, less time is available for the heat to be dissipated from the free periphery of the tire.

Tire vertical loading.- The results from tests to evaluate the effects of applied vertical loading on the tire wear and related characteristics are presented in figure 12. Two cases are considered. In the first, figure 12(a), the drive gears were fixed to provide a slip ratio of 0.049 under the nominal tire loading and inflation pressure of $F_V = 17.8$ kN (4000 lb) and $p = 83$ N/cm^2 (120 lb/in^2). In the second case, figure 12(b), the slip ratio was 0.084 under the nominal test conditions. In both cases, the tire was tested first under the nominal conditions and then with the vertical load reduced by 50 percent. As indicated in the keys to the figure, a reduction in the vertical load on the test tire resulted in a slight decrease in the wheel slip ratio because of the reduced tire deflections.

Figure 12 shows a considerable improvement in tire life with reduced vertical load. Although there is a slight increase in the friction coefficient associated with the lighter loading, the magnitude of the drag force is much less and thus the work being done by the tire per unit distance is correspondingly less than that associated with the tire under its

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nominal loading. This reduced workload perhaps accounts for both the lower tire wear and the somewhat cooler tread temperatures noted for the lighter loaded tire.

Tire inflation pressure.- An additional test was conducted with the tire under the 50-percent lighter loading condition wherein the inflation pressure was reduced until the resulting tire deflection (and hence, footprint) was identical to that of the tire under the nominal loading and inflation pressure. It was necessary to reduce the inflation pressure from 83 to 40 N/cm^2 (120 to 58 lb/in^2) to provide identical deflections. The results from this test are presented in figure 13 and indicate that at essentially the same slip ratio, a change in the tire inflation pressure alone decreases the tread wear rate but has little or no effect on either the developed friction coefficient or the tread temperature.

It is of interest to compare the data derived from the tire under nominal test conditions (circle symbols, fig. 12(b)) with that for a similar tire having the same deflection (and footprint) but under a reduced vertical load and inflation pressure (square symbols, fig. 13). The tread wear associated with the latter test condition is considerably less than that associated with the nominal since the effect of reducing either vertical load or inflation pressure is to decrease the wear rate. The comparison does suggest, however, that the friction coefficient and tread temperature are essentially the same for the two test conditions.

Remarks on Tire-Tread-Wear Behavior

Tire A was the primary tire selected for these tests, but some tests were conducted with tire B which, like tire A, had a 6-groove tread and with tire C which was equipped with a 4-groove tread (see fig. 1). The wear characteristics of tires A and B were observed to be similar but, on the basis of tests on slurry seal, the wear performance of tire C was somewhat better. This difference in tread wear between tire C and the other two tires may be attributed to differences in the tread rubber compound or to the lower net bearing pressure of tire C as a result of having fewer grooves which, on the basis of data presented in figure 13, would suggest less tire wear.

At slip ratios greater than approximately 0.08 on slurry seal, tire A experienced severe tread chunking whereas the tread of tire B developed a number of transverse superficial cuts with slight chunking which appeared to become more pronounced with increasing slip ratio. Tire C did not appear to be susceptible to unusual tread wear at slip ratios up to approximately 0.10, the maximum tested on slurry seal. No chunking was observed in the tread of any tire on the asphalt and concrete test surfaces although some superficial cutting was noted during high slip ratio operations on the grooved surfaces. Figure 14 presents photographs that illustrate typical tire-tread-wear behavior as well as wear which involved cutting and chunking.

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CONCLUSIONS

An experimental investigation was conducted to evaluate the wear and related characteristics of friction and temperature developed during braking of size 22 × 5.5, type VII, aircraft tires. The testing technique involved gearing the tire to a driving wheel of a ground vehicle to provide operations at constant slip ratios on asphalt, concrete, and slurry-seal runway surfaces. Data were obtained over the range of slip ratios generally attributed to an aircraft braking system during dry runway operations. The results of this investigation suggest the following conclusions:

1. Cumulative tire wear (tread rubber removed) varies linearly with distance traveled and the wear rate (mass removed per unit distance) increases with increasing slip ratio and is influenced by the runway surface character. The wear on the asphalt test surface was significantly less than that on the slurry-seal or on the concrete test surfaces, and transverse runway grooves increased the wear rate, particularly at the higher test slip ratios. Differences in the wear rates associated with the various surfaces suggest that runways can be rated on the basis of tire wear.

2. The friction coefficients developed during fixed-slip-ratio operations are in good agreement with those obtained by other investigators during cyclic braking in that the dry friction is insensitive to the tire tread pattern or to the runway surface, whether grooved or ungrooved.

3. Tread temperatures increase with increasing slip ratio and, at the higher test slip ratios, the temperatures measured during braking operations on asphalt and slurry seal are higher than those measured on concrete. This difference is attributed to differences in the thermal conductivity of these surfaces. The tread temperatures on a given surface are essentially insensitive to grooving, thus it appears that the temperature is more dependent upon surface material than upon surface texture.

4. The lubrication provided by wetting the runway reduces the tire wear rate but, at the low speeds of this investigation (17.4 knots), with only a slight loss in traction.

5. Tire wear and friction are insensitive to variations in the test distances from 402 to 1207 m (0.25 to 0.75 mile) and in the test velocity from 8.7 to 26.1 knots. However, tread temperatures generally increase with increasing test velocity since less time is available for the heat to be dissipated from the tire free periphery.

6. A reduction in the vertical loading on the tire decreases the tread wear rate and temperature and produces a slight increase in the friction coefficient.

7. A reduction in the tire inflation pressure results in decreased wear rate and essentially no change in either friction coefficient or tread temperature.

8. Under heavy braking on an abrasive runway surface, the tread of some tires is more susceptible than others to such undesirable wear behavior as cutting and chunking.

Langley Research Center,
    National Aeronautics and Space Administration,
        Hampton, Va., October 30, 1972.

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Tire A Tire B Tire C
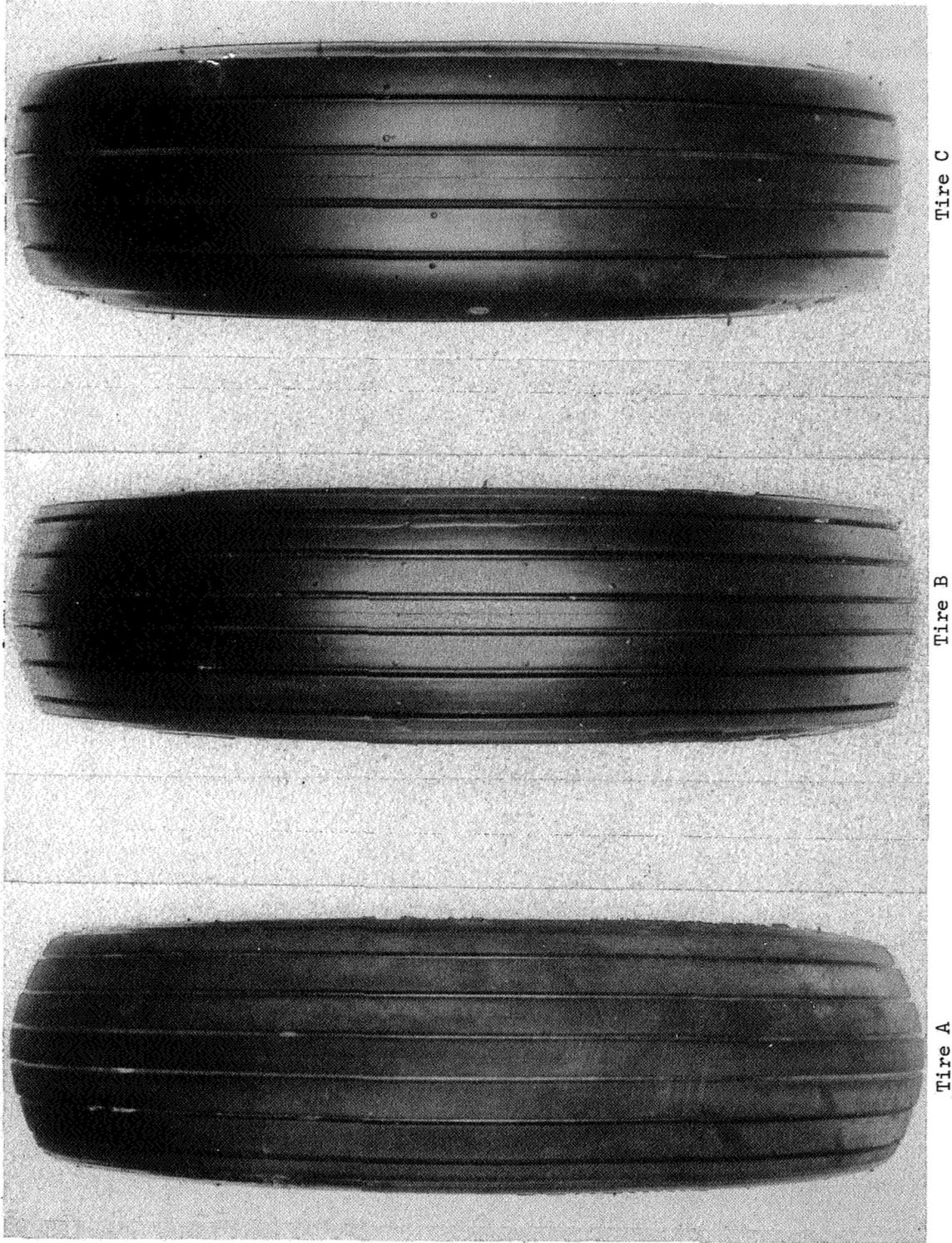
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Figure 1.- Photographs of 22 × 5.5, type VII, aircraft test tires.

Figure 2.- Ground test vehicle.

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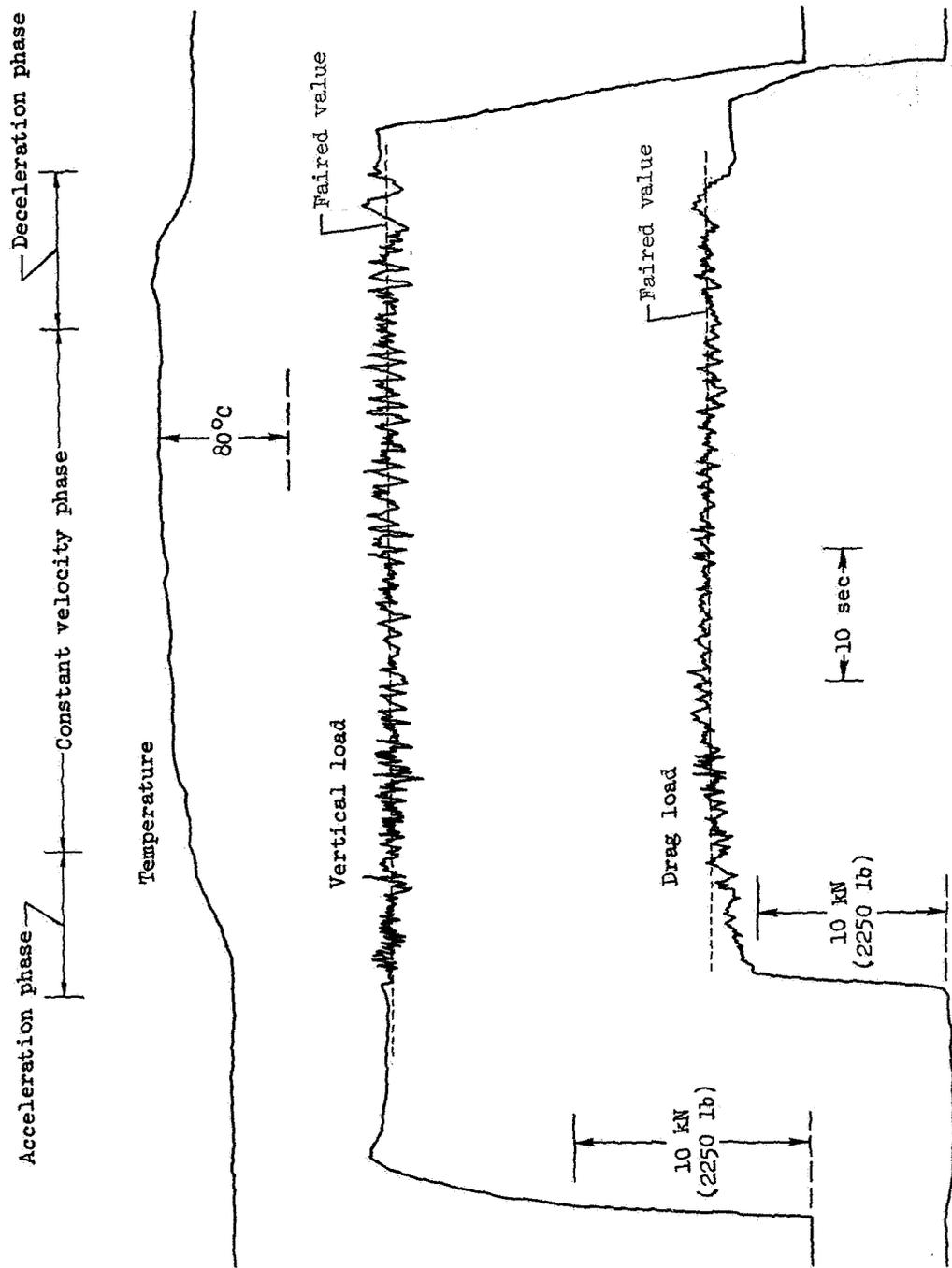
Figure 3.- Reproduction of a typical oscillograph record showing instrumentation response. Concrete runway; Slip ratio = 0.102.

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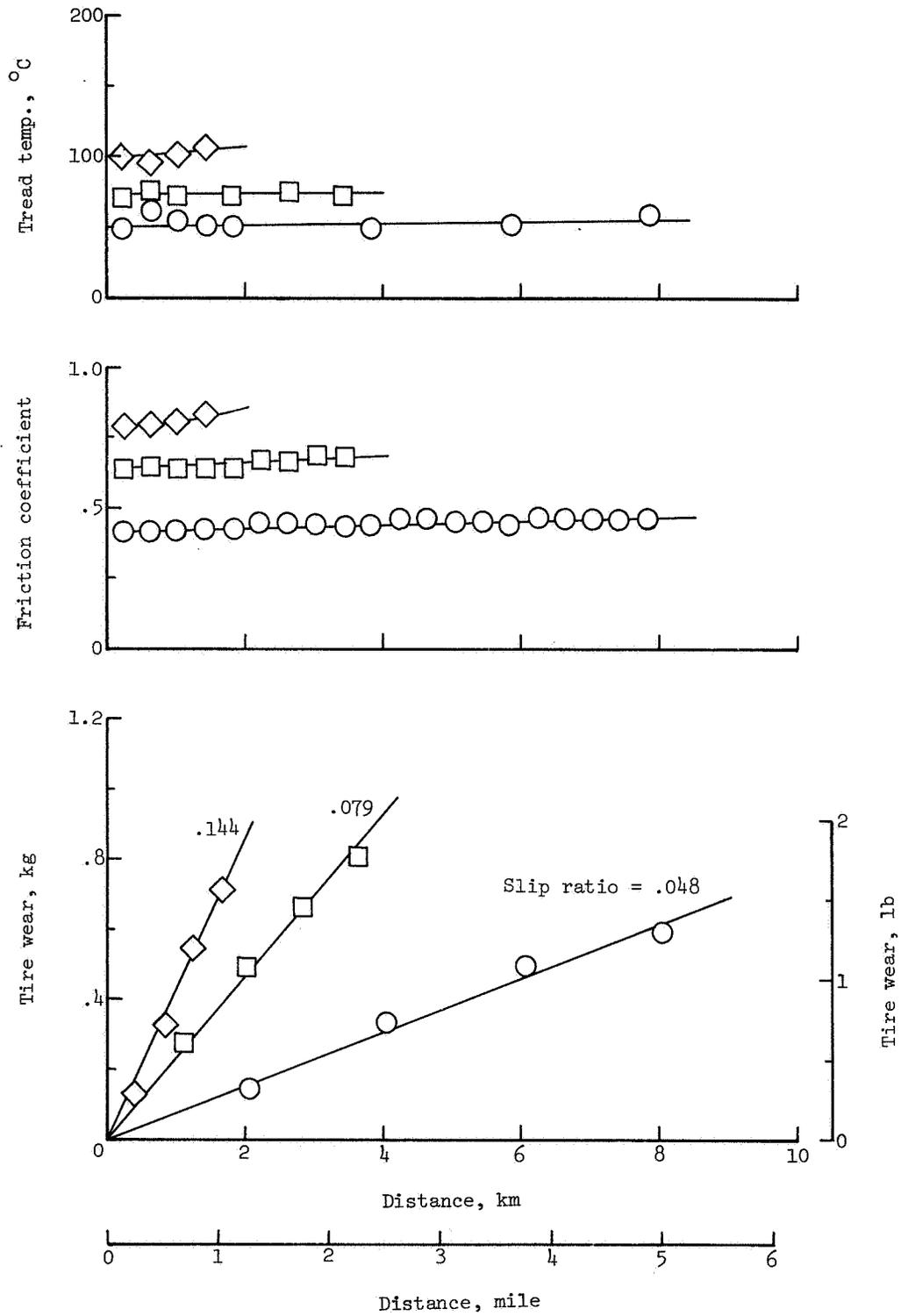
Figure 4.- Typical test results obtained on a concrete runway.

Tire-wear rate, lb/mile

Surface	Tire A	Tire B	Tire C
Asphalt	○	◐	◆
Concrete	□	◧	◆
Slurry seal	◇	◈	◆

Tread chunking

Slip ratio
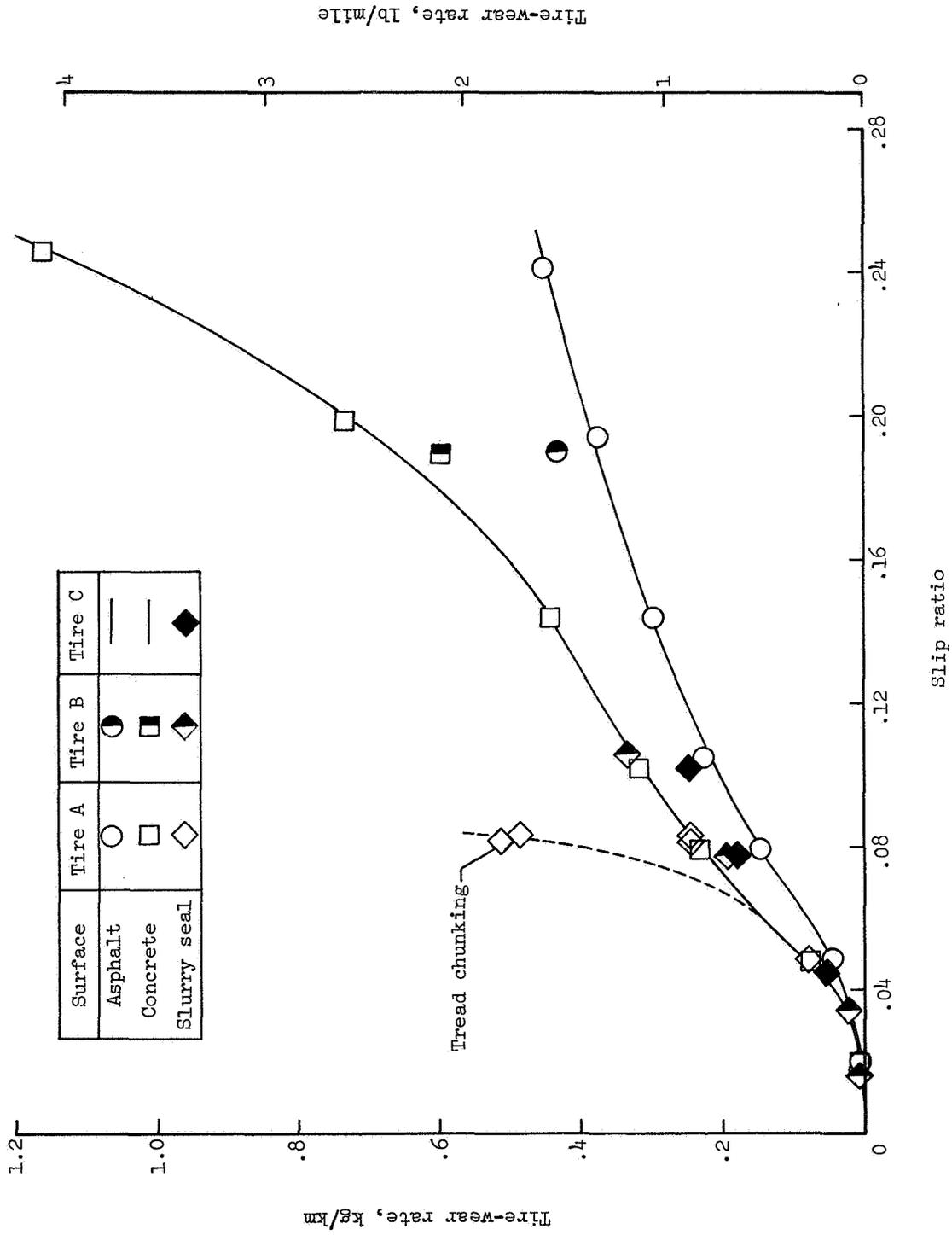
Tire-wear rate, kg/km

Figure 5.– Variation of tire-wear rate with slip ratio on test runways.

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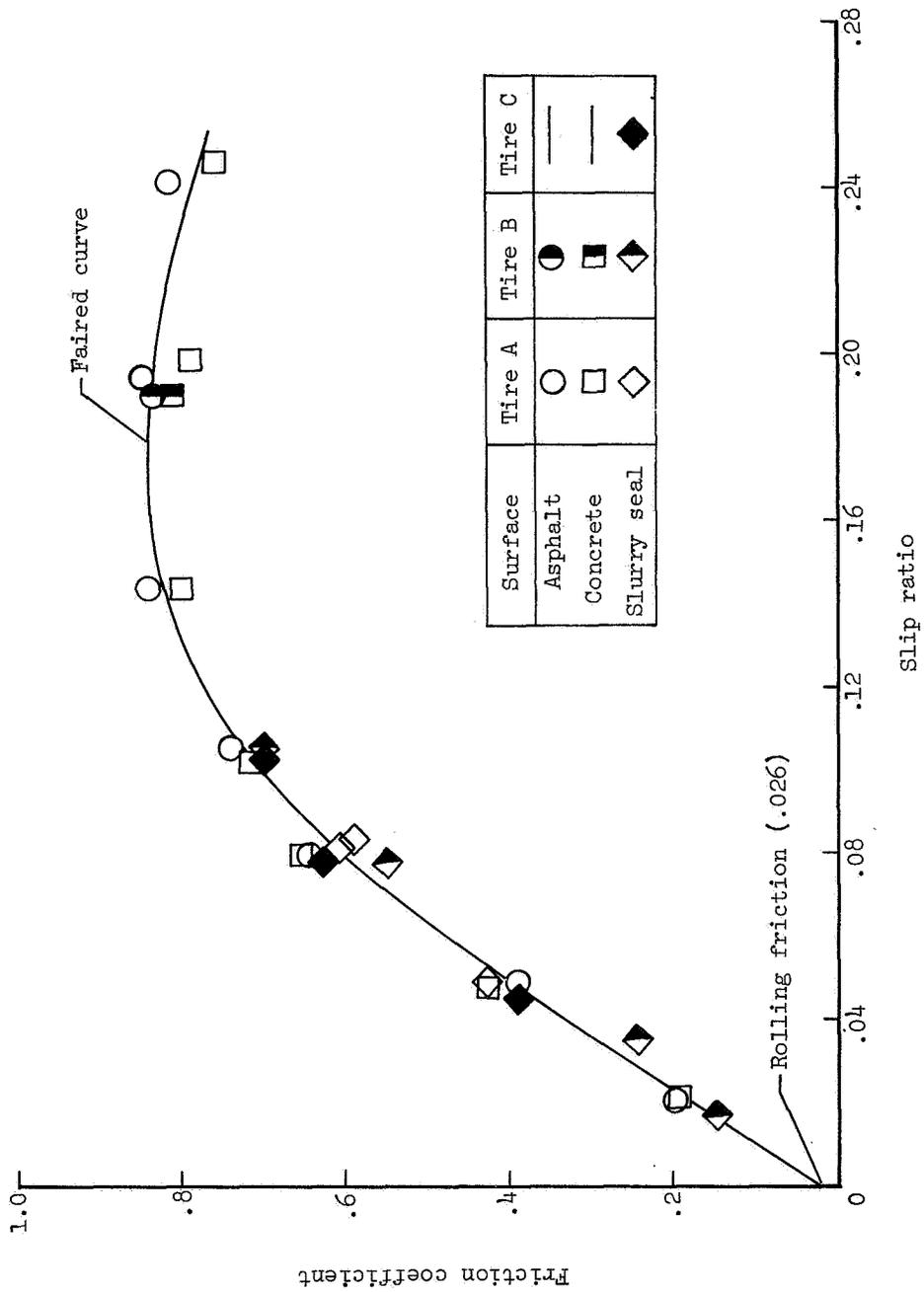
Figure 6.- Variation of friction coefficient with slip ratio for different tire/runway combinations.
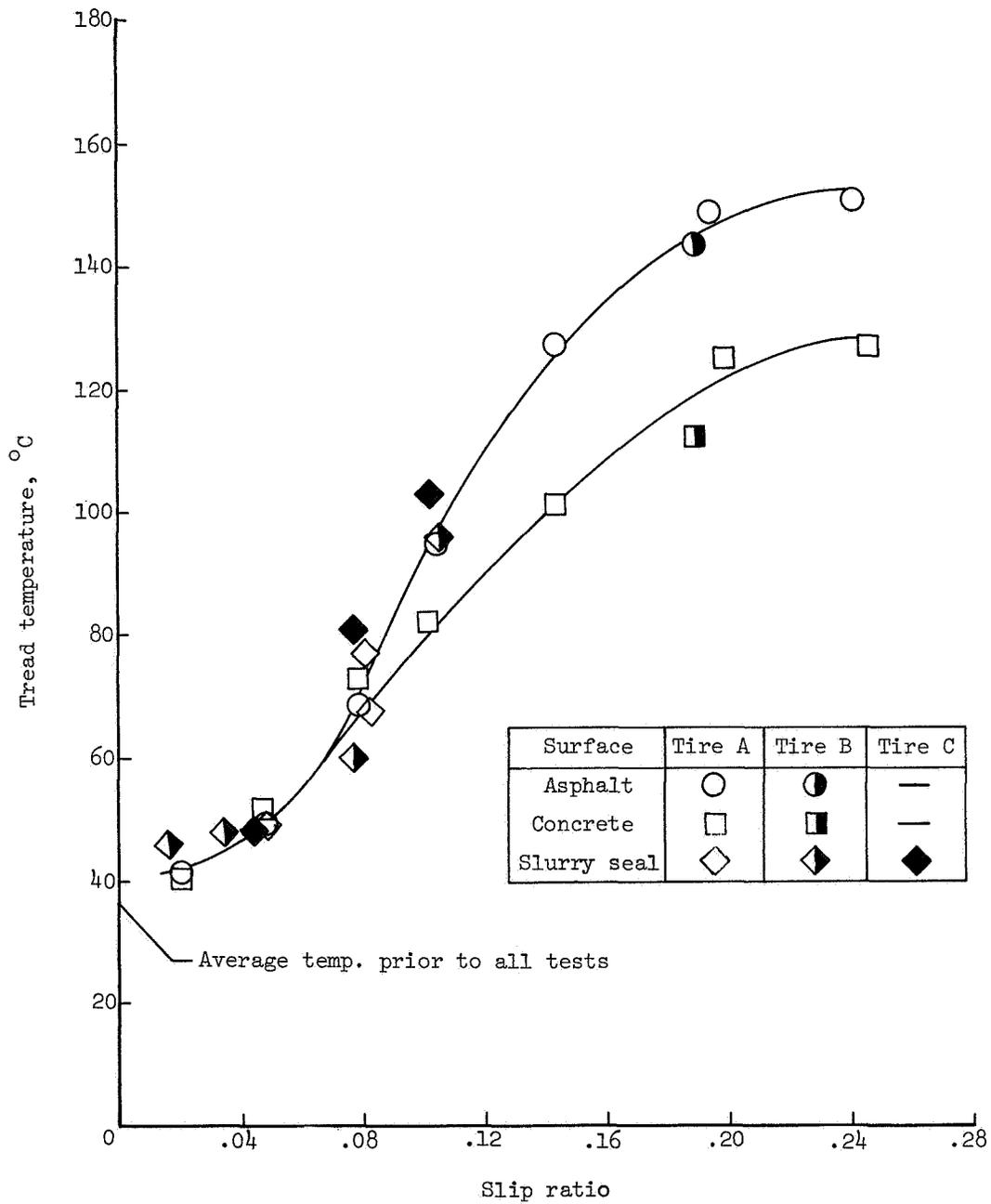
Figure 7.- Tire-tread temperatures measured during constant slip-ratio
operations on the test runways.
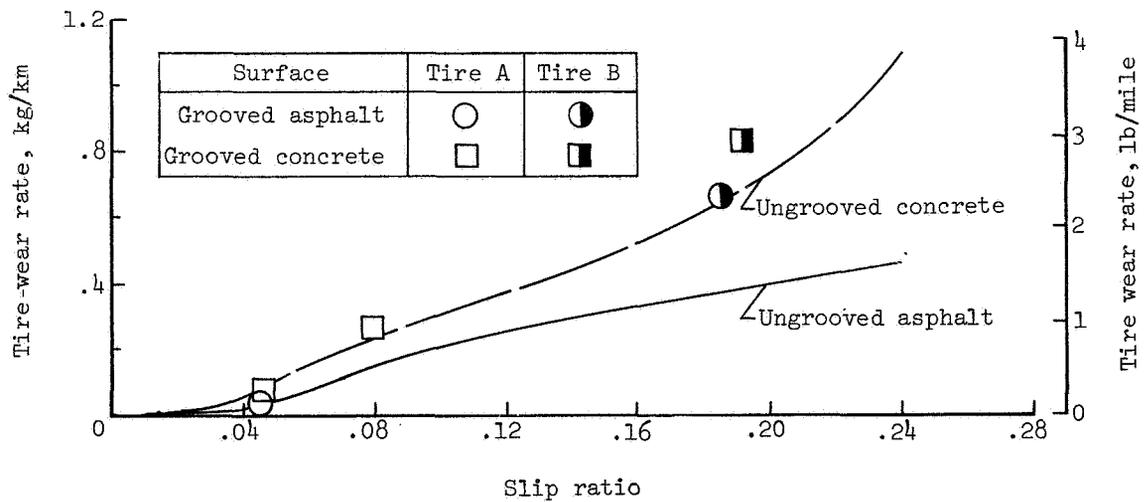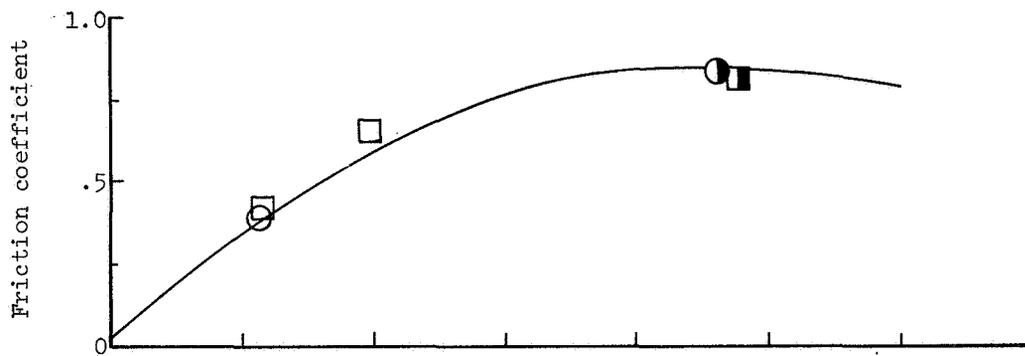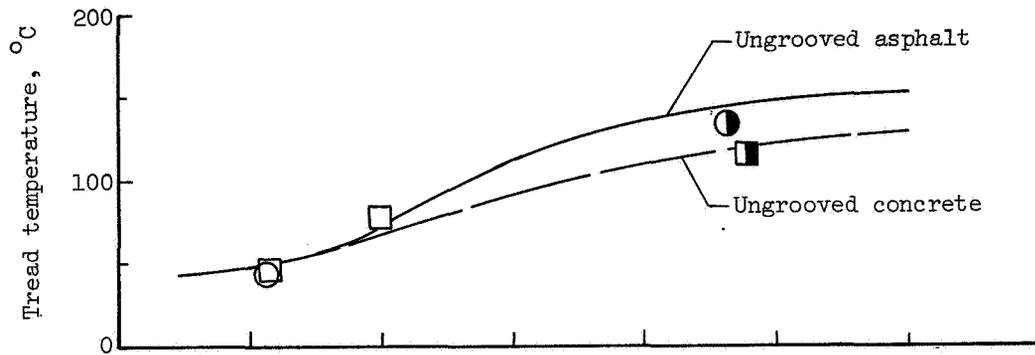
Figure 8.- Effect of runway grooving on tire-wear test results.
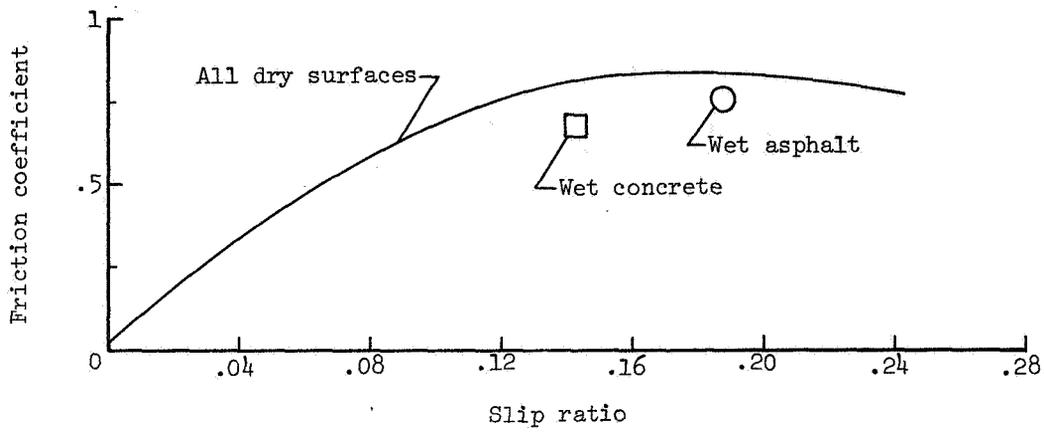
(a) Friction coefficient.
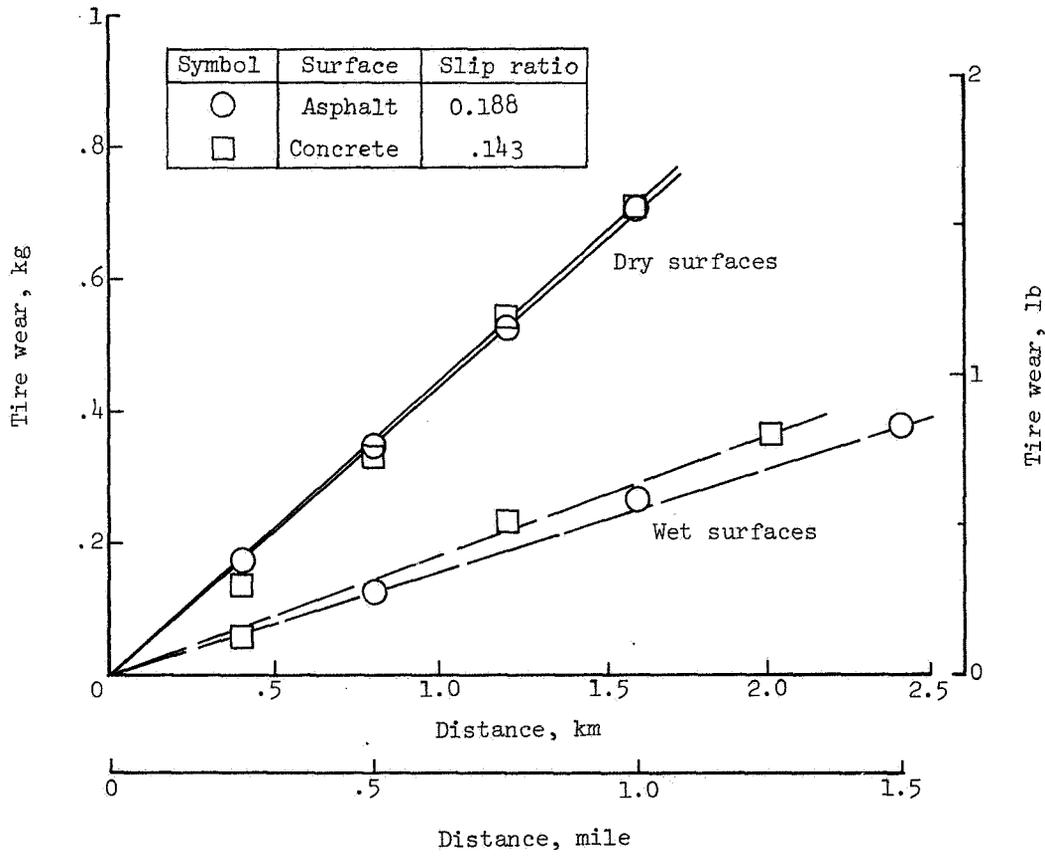
(b) Tire wear.

Figure 9.- Effect of runway wetness on tire friction coefficient and wear.
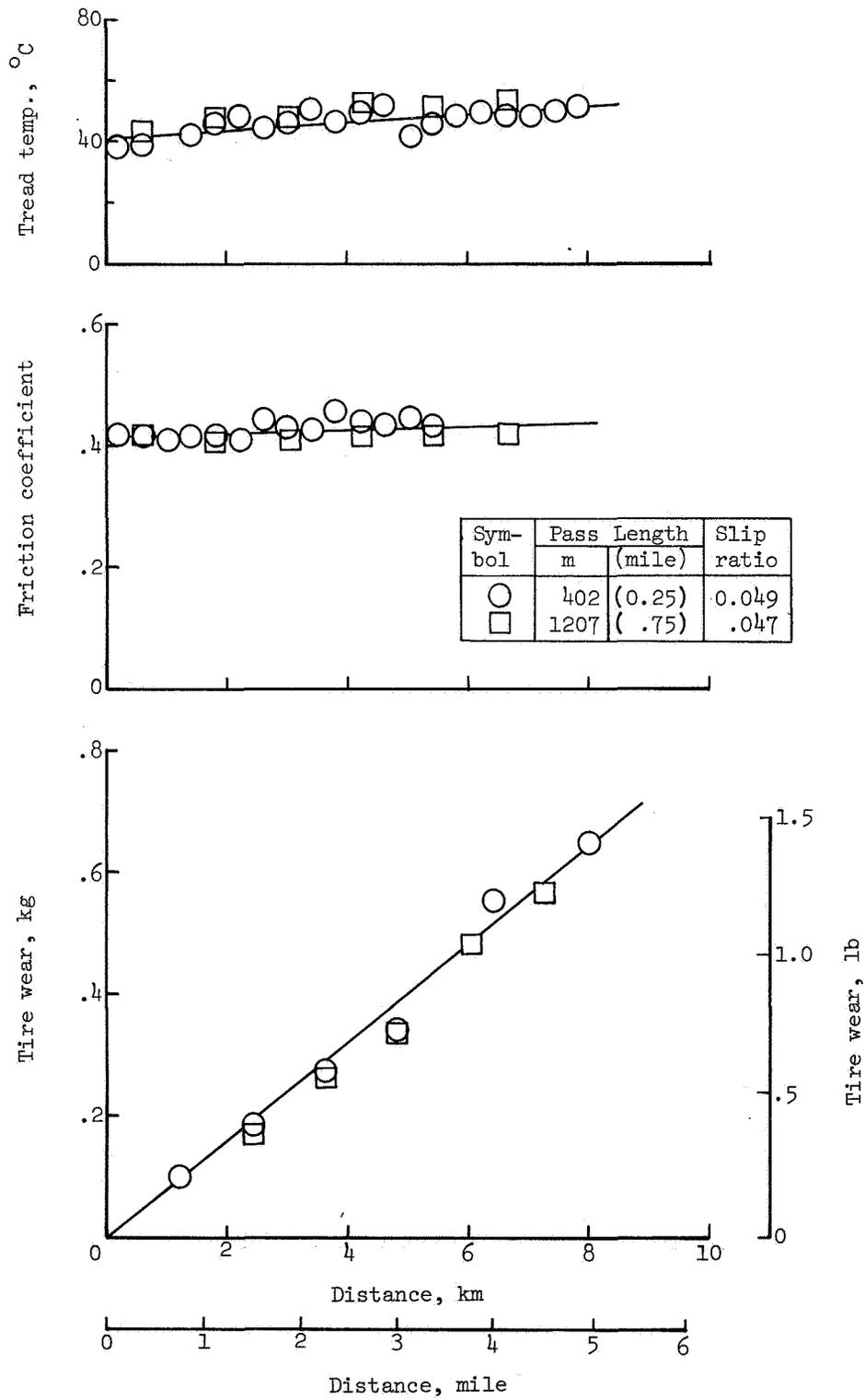
Figure 10.- Effect of pass length on tire-wear test results.
Slurry-seal surface.
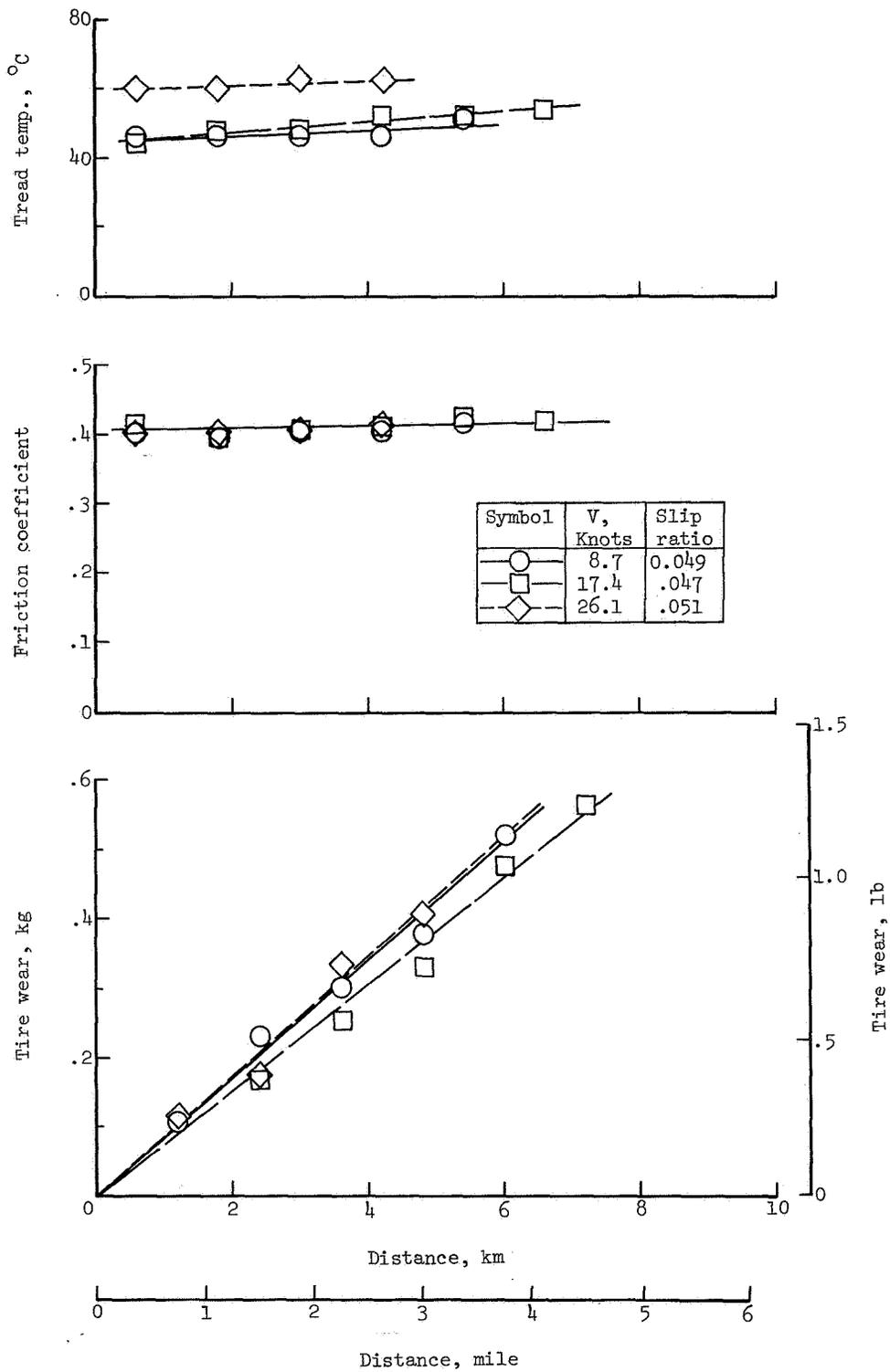
Figure 11.- Effect of test speed on tire-wear test results.
Slurry-seal surface.
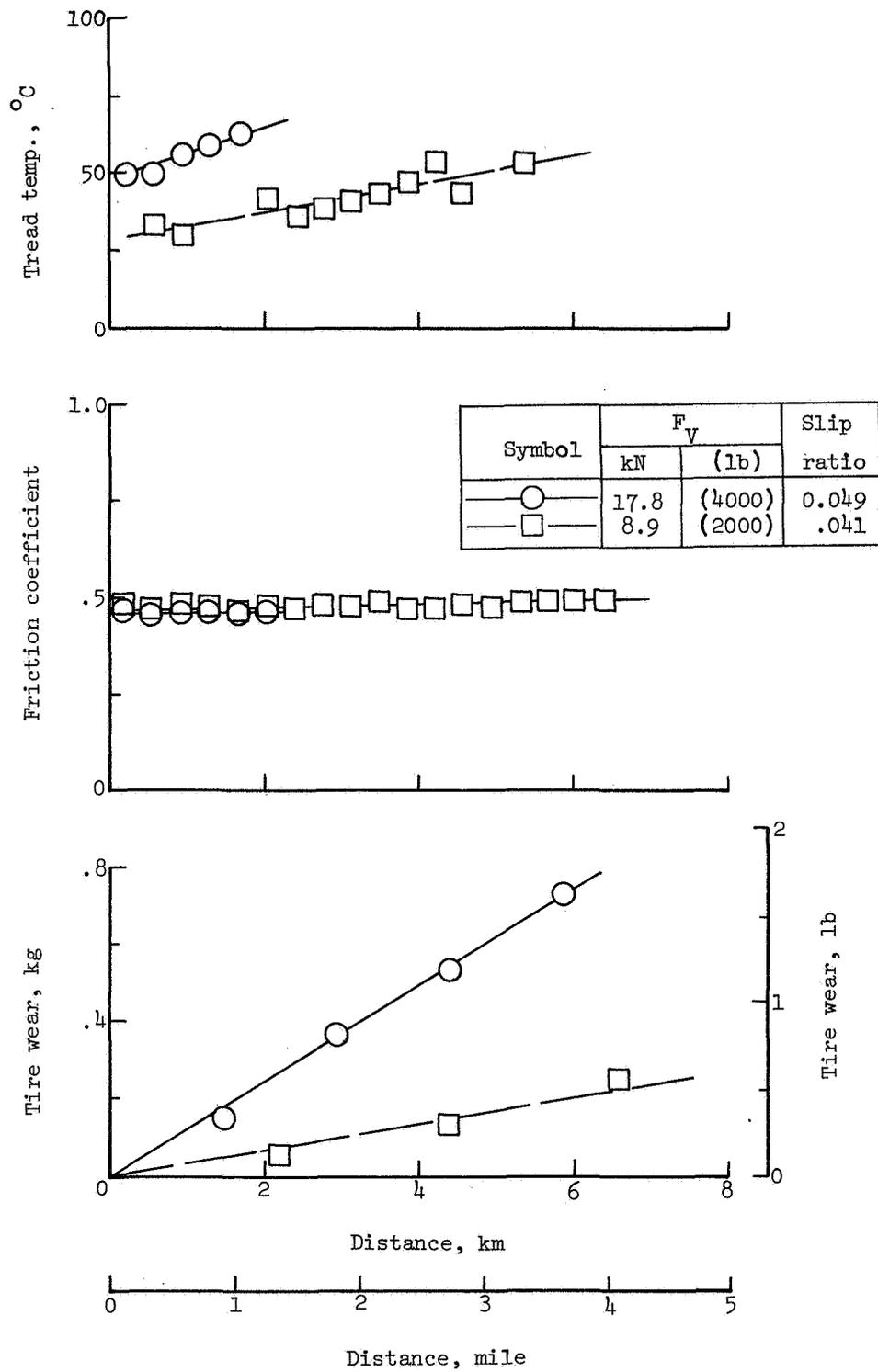
(a) Slip ratio = 0.049 under nominal test conditions.

Figure 12.- Effect of tire vertical loading on test results at two slip ratios; p = 83 N/cm² (120 lb/in²); concrete surface.

		F_V		Slip
Symbol	kN	(lb)		ratio
○	18	(4040)		0.084
□	9	(2020)		.078
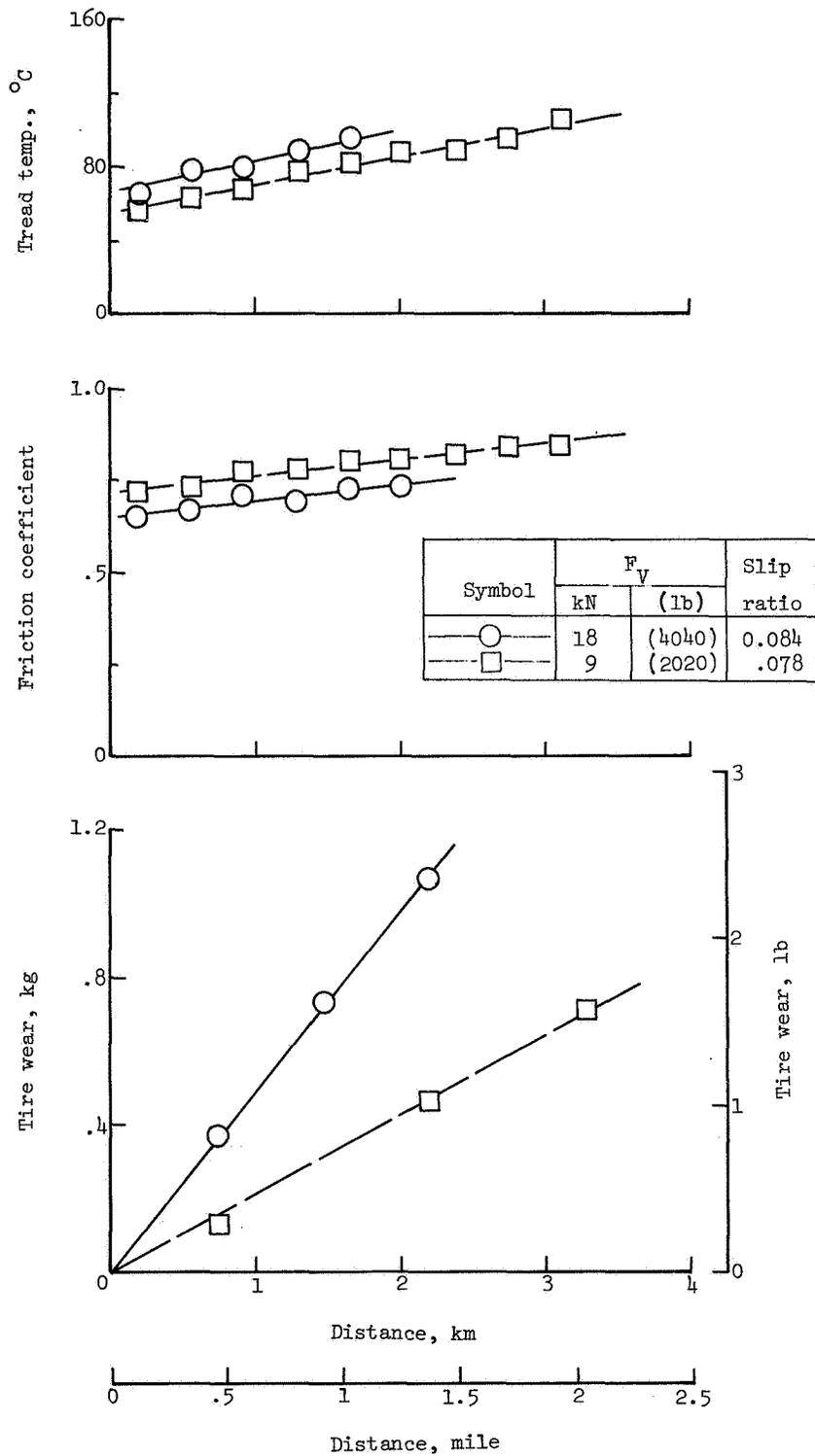
(b)   Slip ratio = 0.084   under nominal test conditions.

Figure 12.- Concluded.

| Symbol | p | | Slip |
	N/cm^2	(lb/in.^{2})	ratio
◯	83	(120)	0.078
□	40	(58)	.074
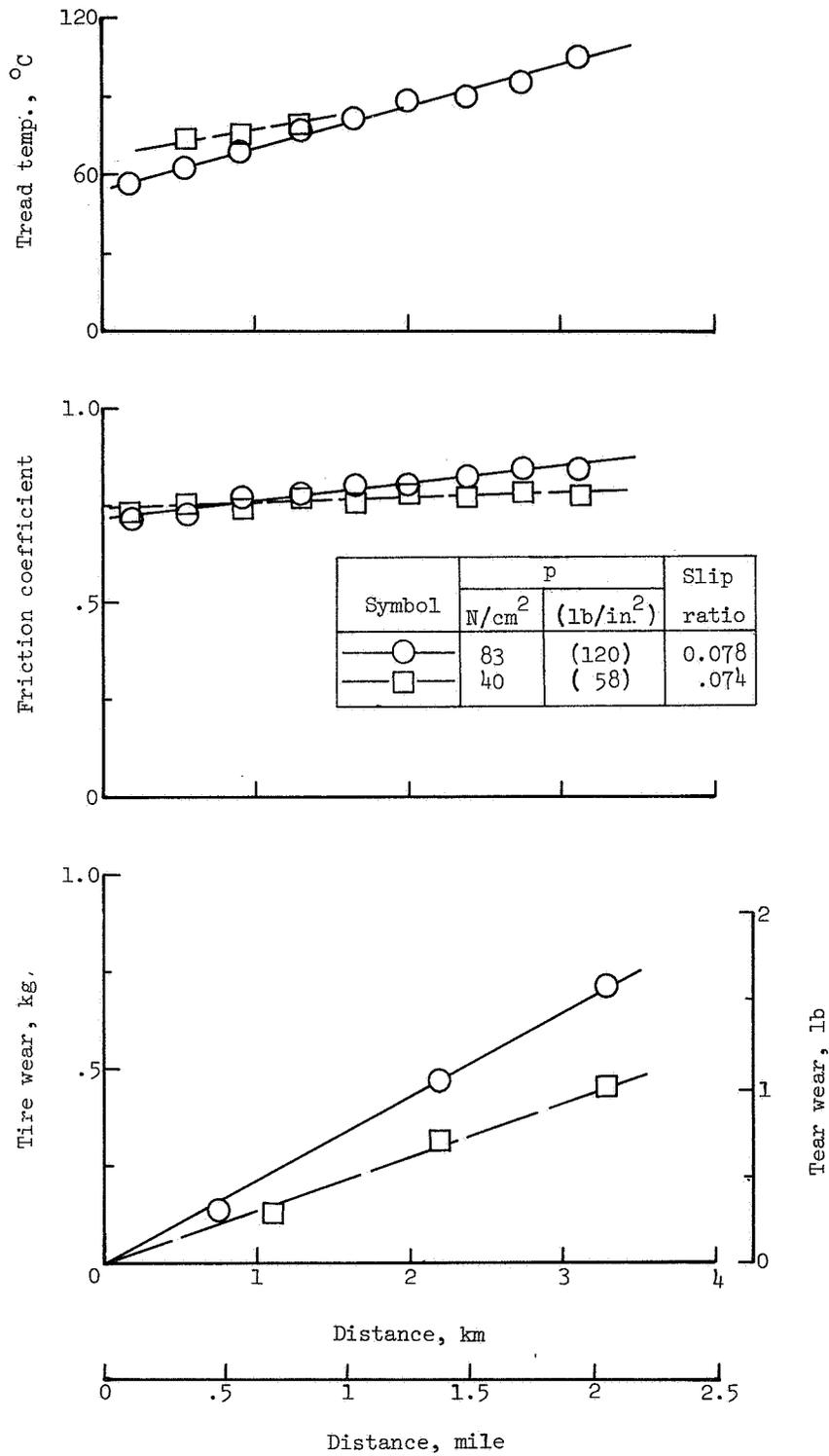
Figure 13.- Effect of tire inflation pressure on test results.
F_V = 9 kN (2020 lb); concrete surface.
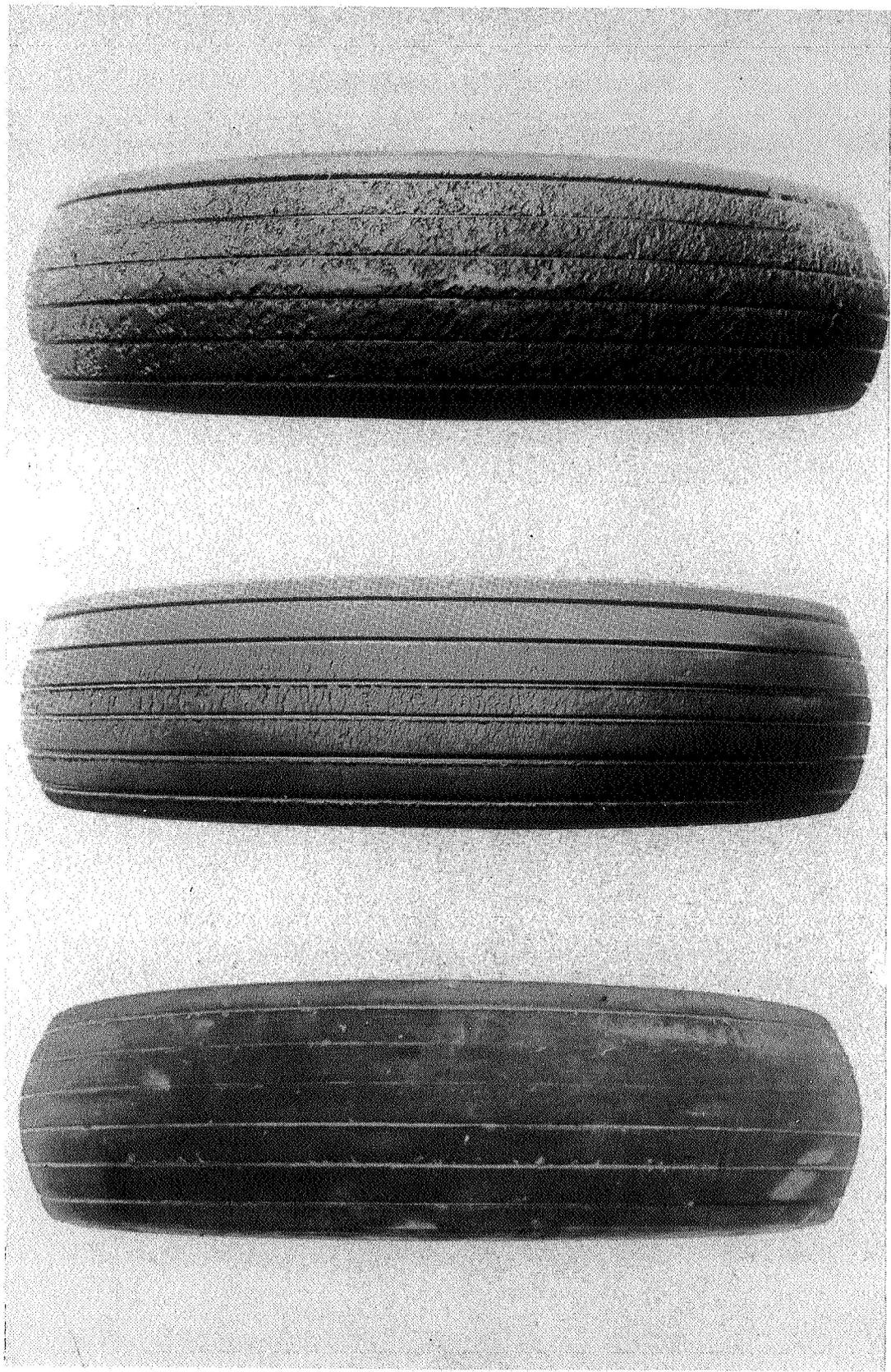
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NORMAL WEAR   SUPERFICIAL CUTTING   TREAD CHUNKING

Figure 14.- Typical tire tread-wear patterns.

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—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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