State of Illinois
DEPARTMENT OF PUBLIC WORKS AND BUILDINGS
Division of Highways

SAFETY OF METAL-STUDDED TIRES ON BARE PAVEMENT SURFACES

By
Donald R. Schwartz
Assistant Engineer of Research and Development

and
Philip G. Dierstein
Engineer of Pavement Research

A Study Conducted by the
Illinois Division of Highways
Bureau of Research and Development

March 1967

State of Illinois
DEPARTMENT OF PUBLIC WORKS AND BUILDINGS
Division of Highways
Bureau of Research and Development

SAFETY OF METAL-STUDDED TIRES ON BARE PAVEMENT SURFACES

SUMMARY

Following their introduction a few years ago, metal-studded tires have been given wide publicity as a safety feature for driving under icy conditions. This safety aspect appears to be reasonably well documented. Studded tires have been suspected, however, of having disadvantages as well as this advantage, but adequate information has not been available either to allay or to confirm the suspicion.

Stopping distance required for studded tires on bare pavement surfaces has been for some time a subject of controversy. It has been theorized in some quarters that the metal studs might offer less resistance to sliding than full rubber contact with a hard pavement surface. Should the studded tire be less safe on bare pavements than other tires, this would be an important disadvantage in such places as Illinois where their greatest travel would be on bare pavements. Until the study that is the subject of this report was completed, little information was available either to confirm or disprove the belief.

This study was undertaken to provide reliable information on stopping distances under bare-pavement conditions. It included a series of stopping-distance determinations from speeds of 20, 30, 40, and 50 mph with a standard passenger car equipped with four different tire arrangements which included conventional highway tires, snow tires, and studded snow tires. Tests were made on wet and dry portland cement concrete and bituminous concrete pavement surfaces with both new and used tires. The used tires had approximately 5000 miles of normal service before testing. In the interest of safety, the tests were conducted on the wide pavements of the Lawrenceville-Vincennes Municipal Airport through the cooperation of the Bi-State Authority, the

agency responsible for the Airport. Altogether, over 600 individual stopping-distance tests were made, representing 128 separate combinations of tire type and condition, vehicle speed, and pavement type and condition. All stops were made under a locked-wheel condition.

The study has shown that, overall, studded snow tires require somewhat greater stopping distances on bare pavement surfaces than do conventional highway tires, but that snow tires without studs require about the same stopping distances as do snow tires with studs. For all conditions of test, the increase in stopping distance over that required with conventional tires averaged 7 percent with studded snow tires on the rear wheels only, 8 percent with snow tires on the rear wheels only, and 11 percent with studded snow tires on all four wheels. The relative increases did not vary greatly for the various speeds at which tests were made, for the two types of pavement tested, for the wet or dry surface condition, and for new and used tires.

Normal highway driving causes the metal studs to become loosened. In the 5000 miles of normal highway driving to which 12 of the studded tires were subjected prior to testing as used tires, studs were loosened in all tires (up to 50 per tire) and a total of 14 studs were lost from 3 of the tires. During testing with the used tires, many additional studs were lost, with one tire losing 40 of its original 104 studs. Only 2 studs were lost from the 12 new tires when subjected to the same testing. The stud losses confirmed earlier findings by a number of agencies that stud ejections occur during use of studded tires, and did nothing to allay suspicion that the potential exists for personal injury or property damage by studs flung from tires.

SAFETY OF METAL-STUDDED TIRES ON BARE PAVEMENT SURFACES

INTRODUCTION

During the winter of 1964-1965, a short pilot study using vehicles equipped with studded snow tires was conducted by the Illinois Division of Highways on the grounds of the Physical Research Laboratory of the Bureau of Research and Development near Ottawa, Illinois.[1/] The purpose of this study was to develop some general information on the abrasive effects of studded tires on typical Illinois pavement surfaces and on the skid resistance effects of studded tires when operated on dry pavement surfaces. Studded snow tires mounted on passenger cars made 250 passes over dry portland cement concrete, asphaltic concrete, and bituminous surface treated roads. Normal starts and stops, as well as quick starts and emergency stops, were also made. Slight abrasion in normal driving and pronounced abrasion under emergency starts and stops were observed. Results of the tests were interpreted to suggest that special maintenance measures probably would be required at busier intersections where starts, stops, and sharp turning movements reach relatively high frequencies. Limited tests on dry pavements showed up to 23 percent increase in stopping distance to be required for a passenger car equipped with four studded snow tires as compared with one equipped with conventional highway tires. Nine percent more stopping distance was required for a passenger car equipped with conventional highway tires on the front and studded snow tires on the rear wheels. During the tests, which involved less than 200 vehicle miles of travel, four studs were lost from one tire and one stud from each of two others.

In view of the pilot nature of this study, because of a desire to obtain general information quickly, most of the results that were obtained were necessarily qualitative, with quantitative measurements being at a minimum. The results were believed to be of sufficient importance, however, to suggest that additional study was needed.

1/ "Some Tests of Studded Tires in Illinois," Highway Research Record No. 136, Highway Research Board

The apparent reduced traction on bare pavement surfaces was considered of particular importance because studded tires, unlike tire chains, are likely to be used continuously throughout the entire winter season, and would be used far more on bare pavements than on ice and snow. The average annual number of days on which ice glaze and sleet may occur at some time during the day ranges from six in the Cairo area to ten in the Springfield and Chicago areas. The average annual number of days on which snowfall of one inch or more is recorded ranges from four in the Cairo area to eleven in the Rockford area. Altogether then, icing, or snow in measurable quantity, can be expected to occur on an average of only 10 to 21 days annually. In most instances the ice or snow is removed within a few hours by maintenance forces to further reduce the time period during which drivers can expect to meet with these hazards.

During the past spring and summer, an expanded study was undertaken to obtain a more positive body of knowledge of the stopping distances on bare pavements of vehicles equipped with studded tires as compared with vehicles equipped with tires not having studs. Experimental variables included in the study were tire system, tire condition, speed, pavement type, and pavement condition. Stopping-distance tests (wheels locked) were made from 20, 30, 40, and 50 mph on portland cement concrete and asphaltic concrete pavements under both wet and dry conditions. The tire systems that were tested included four conventional highway tires, snow tires in rear and conventional highway tires in front; studded snow tires in rear and conventional highway tires in front; and four studded snow tires. All tires used in the tests were first-line replacement tires purchased from one manufacturer. One half of the tests was made with new tires, while the other half was made with tires having 5000 miles normal wear.

Through the cooperation of the Bi-State Authority, the tests were conducted on the wide pavements of the Lawrenceville-Vincennes Municipal Airport located east of

Lawrenceville, Illinois, and north of Route US 50. An aerial view of the airport is shown in Figure 1. The tests on asphalt were made on the east-west runway while those on concrete were made on the ramp apron area in front of the hangars. The Authority supplied water for making tests on wet pavement, and furnished garage facilities to house vehicles and equipment.

Tests with the new tires were made in April and May, 1966. Tests with the used tires were conducted in July and August, 1966, following the accumulation of 5000 miles normal wear on passenger cars of the Division of Highways before testing.

EXPERIMENTAL PROCEDURE

The various combinations of tire system, tire condition, speed at brake application, pavement type, and pavement condition which were included in the stopping-distance tests are shown in Table 1. Altogether, 128 separate combinations were tested. Five repetitions of test were made for each test condition, making a total of 640 individual stopping-distance tests.

The airport pavements on which the tests were conducted were constructed during World War II. The field consists of a system of four one-mile long runways constructed of bituminous concrete. The runways are connected to a large portland cement concrete apron in front of the hangars by ramps also constructed of bituminous concrete. Air traffic at the field was sufficiently light that one runway could be closed during the testing. The east-west runway (top of Figure 1) was selected for the tests. It is 300 feet wide and crowned for drainage. The pavement consists of a 10-inch thick bituminous concrete surfacing on a granular base. The surface has been used by very little traffic and presents a relatively coarse texture for a dense-graded bituminous concrete. (Figure 2).

The portland cement concrete apron was constructed in 12-foot wide strips with contraction joints at 10-foot intervals. The surface was broomed transversely to

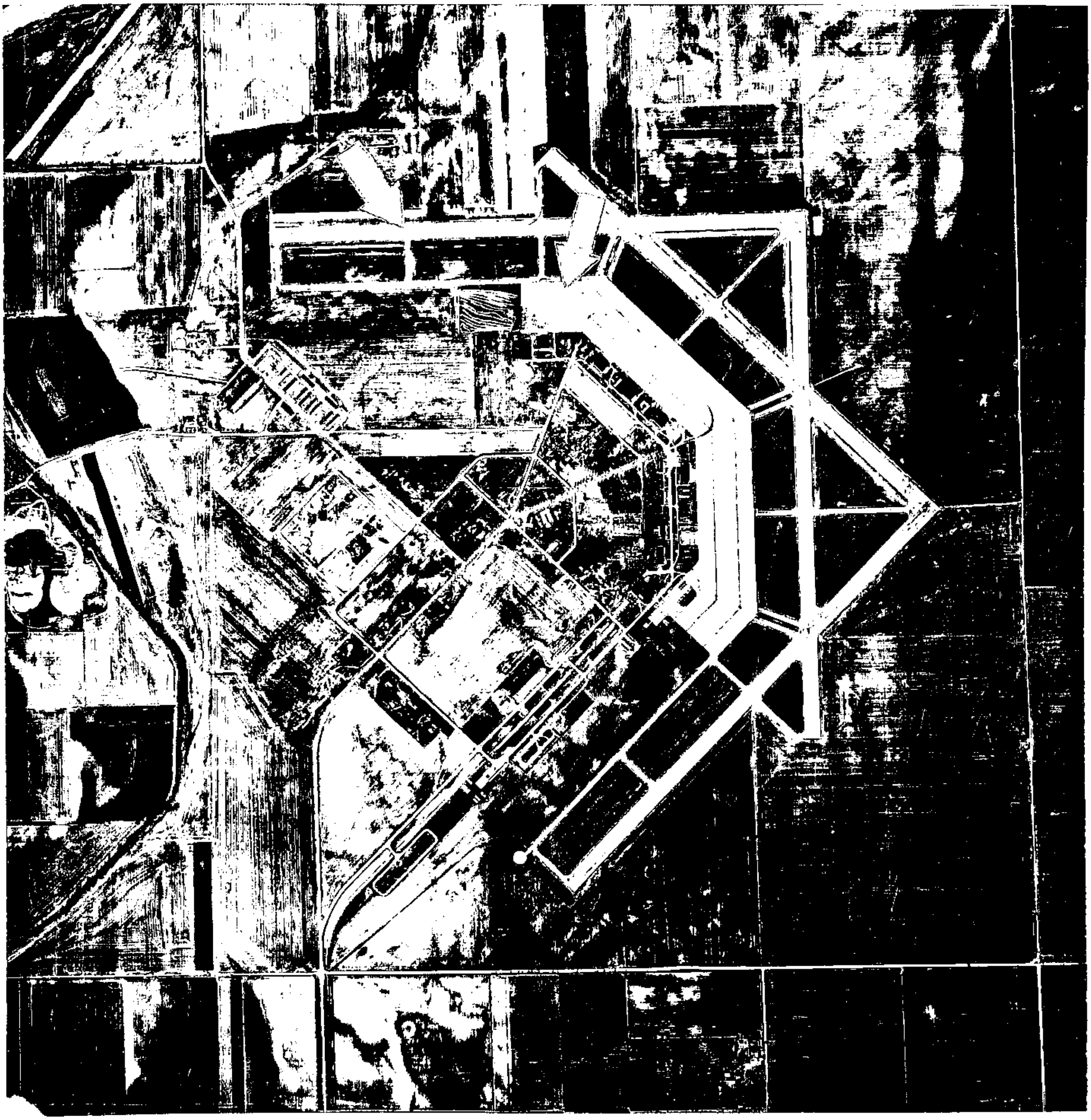


Figure 1: Aerial view of Lawrenceville-Vincennes Municipal Airport where studded tire tests were conducted.

TABLE 1

STOPPING DISTANCE TESTS

Variables Studied	Conditions Tested
Tire system	(1) Conventional tires on all wheels (2) Snow tires rear; conventional front (3) Studded snow rear; conventional front (4) Studded snow tires on all wheels
Tire condition	(1) New (2) Used (5000 miles)
Speed	(1) 20 mph (2) 30 " (3) 40 " (4) 50 "
Pavement surface	(1) Portland cement concrete (2) Bituminous concrete
Pavement condition	(1) Dry (2) Wet

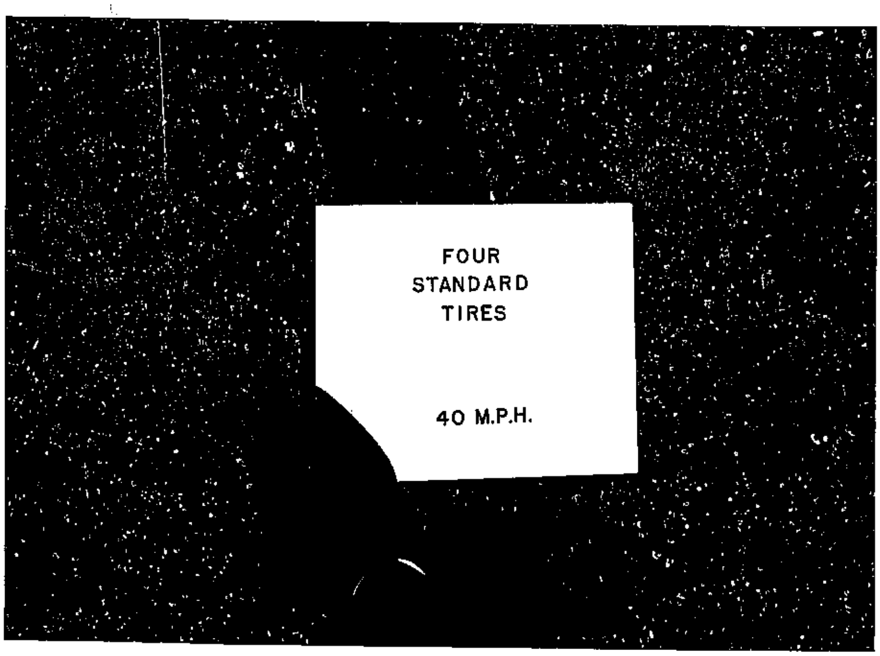


Figure 2. View of bituminous concrete pavement surface.

the placement (Figure 3), and to the direction in which the stopping-distance tests were made.

Natural sand and gravel aggregates were used in both the portland cement concrete and bituminous concrete mixes. All pavement surfaces were highly weathered, unpolished by traffic, and free from oil drippings when tests were made. Vegetation growing in many of the pavement joints was removed before tests were started.

Water for the wet-pavement tests was obtained from a nearby fire hydrant connected to the field water system.

All stopping-distance tests were made with a 1963, series 300, four-door, Ford sedan (Figure 4). Prior to testing, a thorough mechanical inspection was made of the test car and new brake linings were installed. Six extra wheel rims were purchased to reduce the time needed to change tires during the tests.

A toy pistol that fires a dart with a rubber suction cup was mounted low on the rear vehicle bumper (Figure 5) to make the point where the brakes were applied. The pistol was triggered by a solenoid connected into the vehicle's brake light system. When the brake pedal was depressed, the dart, daubed with white paint, was fired and marked the pavement. Stopping distances were measured from the paint mark on the pavement to the gun muzzle on the rear bumper of the stopped vehicle.

Forty-eight tires were used in the tests. Of these, 16 were conventional highway tires, 8 were snow tires, and 24 were studded snow tires each with 104 tungsten carbide studs arranged in six concentric rows. The depths of tread of all tires were measured and recorded prior to use. Also, the protrusion of studs in the studded tires was measured and the studs counted. Wheel location, and direction of rotation were recorded for each of the tires that was used before testing. Where possible, used tires were mounted on wheels of the test vehicle in the same position that wear was originally obtained. All used studded tires were placed so that the direction of tire rotation during tests was the same as during conditioning. A view

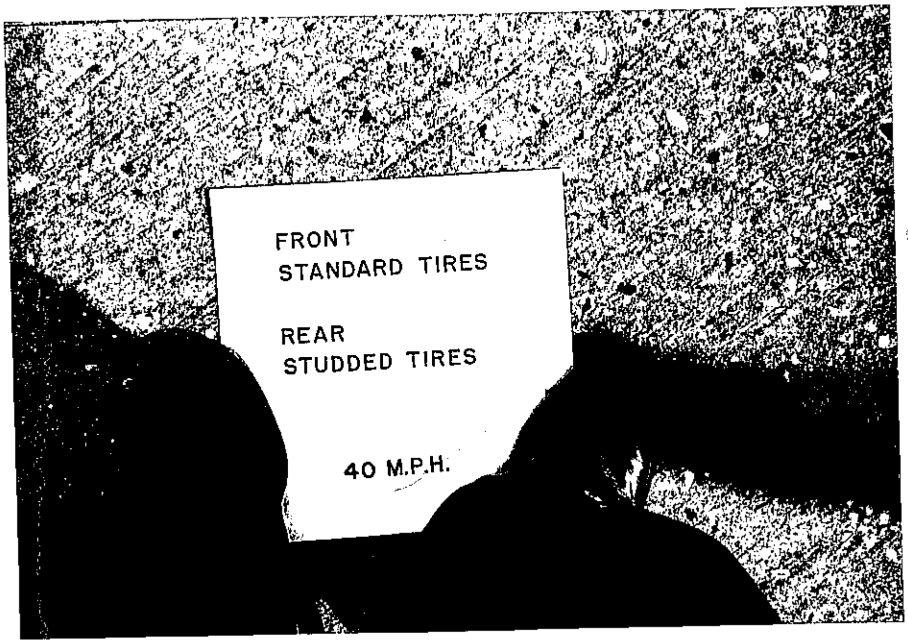


Figure 3. View of portland cement concrete pavement surface.

Figure 4. View of the 1963 Ford sedan used in the tests.

Figure 5. View of device used to mark point where brakes were applied.

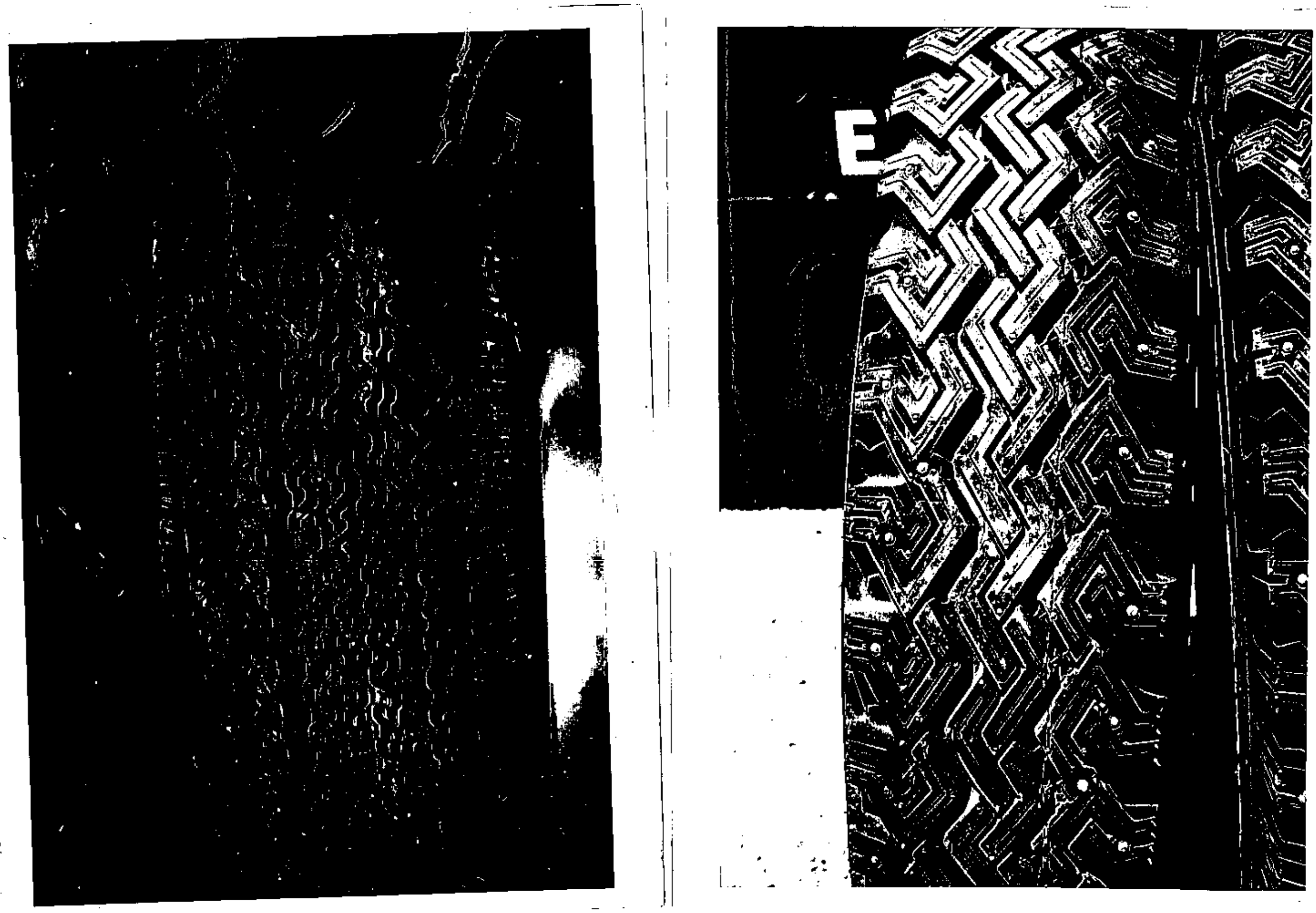


Figure 6. Conventional highway tire on left and studded snow tire on right.

of the conventional highway tires and studded snow tires showing tread design is shown in Figure 6. The tread design of the snow tires without studs was the same as was that of the studded tires.

All stopping-distance tests were conducted with the same car, by the same driver, and in the same manner. Each test was made on a surface area which previously had not been used in testing. Traffic cones were used in each case to outline for the driver the area where the test was to take place.

A radar speed measuring unit was used for calibration of the speedometer prior to testing. The runway and apron where tests were conducted were of sufficient length to allow adequate time for the test driver to reach and maintain the intended test speed. The radar speed meter was used to check the speed of each test, and whenever a speed reading in excess of plus or minus one mph of the desired speed was recorded the data was discarded.

All stops were made by locking the wheels. Observers were on hand to make certain that the locked-wheel condition occurred.

A 1 1/2-ton dump truck equipped with a large water tank and a pressure pump was used to apply water to the pavement for the wet-surface tests. The pavement surface was wetted to runoff immediately prior to each test in the wet-surface series. No attempt was made to continue sprinkling the surface during actual testing.

No special order of testing was established prior to conducting the tests except for the limitation that all tests involving stops from speeds below 50 mph were to be completed for a tire system before conducting the 50 mph series for that system. This limitation was set up because of a belief that excessive tire wear might take place in the series of stops from 50 mph. The limitation was observed in the new-tire tests conducted in April and May, but experience proved it not to be necessary and it was not observed in the July-August tests of used tires. All tests for each tire system were completed before going on to another system. The five repetitions of test for each individual set of conditions were conducted consecutively. In the April-May tests, the stops from 20 mph were made first for each tire system, pavement type, and pavement condition, and were followed successively by the stops from 30 mph and 40 mph. In the July-August tests, test stops from the various speeds were randomized.

The stopping distance in each test was measured by tape from the paint spot to the gun muzzle previously described and recorded to the tenth of a foot. Side slip of the vehicle from the initial wheelpath at braking also was measured by tape and recorded.

Tire pressure and tire condition were checked after each test. Tread wear and stud protrusion were measured, and stud losses counted and recorded at frequent intervals. Climatic conditions including air temperature, cloud cover, and precipitation were observed and recorded during each day of testing.

Measurements of the sliding resistance under wet and dry conditions made with a hand-operated skid resistance tester showed no major differences between the airport pavements and typical highway pavements. The device was not capable of furnishing absolute values of the frictional coefficient.

TEST RESULTS

As previously stated, a total of 640 individual stopping distance tests were made, representing 128 separate combinations of tires, speed, pavement type, and pavement condition. The results of the tests are summarized in Table 2 for each combination tested. With few exceptions, each value in the table is the average of the results of five individual tests. The few exceptions concern individual tests where the radar-measured vehicle speed varied from the intended test speed

TABLE 2. SUMMARY OF TEST RESULTS

Tire System	Speed	Stopping Distance							
		Portland Cement Concrete				Bituminous Concrete			
		Dry		Wet		Dry		Wet	
		New Tires	Used Tires	New Tires	Used Tires	New Tires	Used Tires	New Tires	Used Tires
	(mph)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
Conventional tires on all wheels	20	18	16	15	16	19	14	16	15
	30	40	38	39	43	41	37	39	40
	40	72	68	70	80	70	65	76	73
	50	110	106	156	146	109	106	127	131
Snow tires in rear; conventional tires in front	20	19	15	20	16	19	14	18	13
	30	42	39	46	42	42	38	41	37
	40	77	69	88	90	77	72	85	78
	50	129	113	150	150	119	117	150	144
Studded snow tires in rear; conventional tires in front	20	19	18	17	18	20	16	16	15
	30	41	43	44	46	43	41	41	40
	40	76	77	82	88	75	75	80	76
	50	122	122	148	155	117	115	131	140
Studded snow tires on all wheels	20	19	18	19	19	17	18	15	17
	30	43	44	47	47	42	42	44	40
	40	74	80	86	89	82	74	84	79
	50	128	128	150	155	118	116	130	135

Note: "Used tires" received approximately 5000 miles of normal use before testing.

by more than one mile per hour. In these few instances the test results were not used. While it will be noted in the table that some variability exists in the test data, some reasonably firm relationships that will be discussed later were developed.

Although tangential to the main analysis of the experimental data, some seeming departures of the data from what might be expected under previously held beliefs, that will be apparent from an inspection on Table 2, require discussion before proceeding with a discussion of the main analysis.

First it will be noted that the stopping distances recorded for new and used tires under what were supposedly similar conditions otherwise, show the used tires to be performing about as good as the new tires. When it is taken into consideration that the used tires lost, at the most, little more than 2 mm. (.08 in.) of wear in the 5000 miles to which they were subjected, and that the few months of use allowed little weathering to take place, the results seem more consistent.

Second, it will be noted that the stopping distances for the wet-pavement conditions are in most instances not as much greater than those for the corresponding dry-pavement conditions as would be anticipated. The dry-pavement results are reasonably consistent with those reported by most other agencies testing in this field, while the wet-pavement results are not. Although water was applied until runoff immediately prior to each test run, and a sheen was visible at the time of testing, it is believed that the highly absorptive nature of the pavement surface, together with a coarser-than-average texture, created a condition in which the water film on the surface particles in immediate contact with the tires at the time of testing was not sufficient to produce the added slipperiness usually expected of wet pavements. It will be recalled that the surfaces of the test pavements had experienced over 20 years of weathering without receiving traffic wear and oil drippings, all of which could be expected to increase the absorption characteristics.

Insofar as the main line of testing is concerned, the tests produced what are considered to be reasonably conclusive results regarding the relationship between stopping distances of studded snow tires and other tires operated on bare pavements.

A comparison of the stopping distances for studded snow tires with those for conventional highway tires, as recorded in Table 2, shows that in the great majority of instances the stopping distances for the studded snow tires exceeded the stopping distances for the conventional highway tires under comparable conditions. A further inspection of the table will show that this was also true for the snow tires without studs when compared with conventional highway tires.

A comparison of the stopping distances for studded snow tires with those for snow tires without studs, as recorded in Table 2, shows no distinct trend, with a fairly even division of the numbers of times the stopping distances for the studded snow tires were greater than or less than the stopping distances for snow tires without studs. It can be presumed that significant differences did not occur.

The results of all stopping tests on dry pavements have been summarized for each of the test speeds for each tire system, and are shown graphically in Figure 7 to illustrate the differences in stopping distances for conventional highway tires, snow tires, and studded snow tires on dry pavement surfaces. A similar summarization has been prepared to illustrate these differences on wet pavement surfaces, and the results shown in Figure 8. With very few exceptions, each value in the two figures represents the average of 20 individual tests. It will be noted in the figures that for each given set of conditions the stopping distances for the conventional highway tire are consistently lower than for the other combinations. It will be noted further that little difference exists between the stopping distances for combinations involving two studded snow tires as compared with two snow tires without studs. In most instances, the stopping distances for the combinations

FIGURE 7: STOPPING DISTANCE TESTS— AVERAGES FOR DRY PAVEMENT CONDITIONS

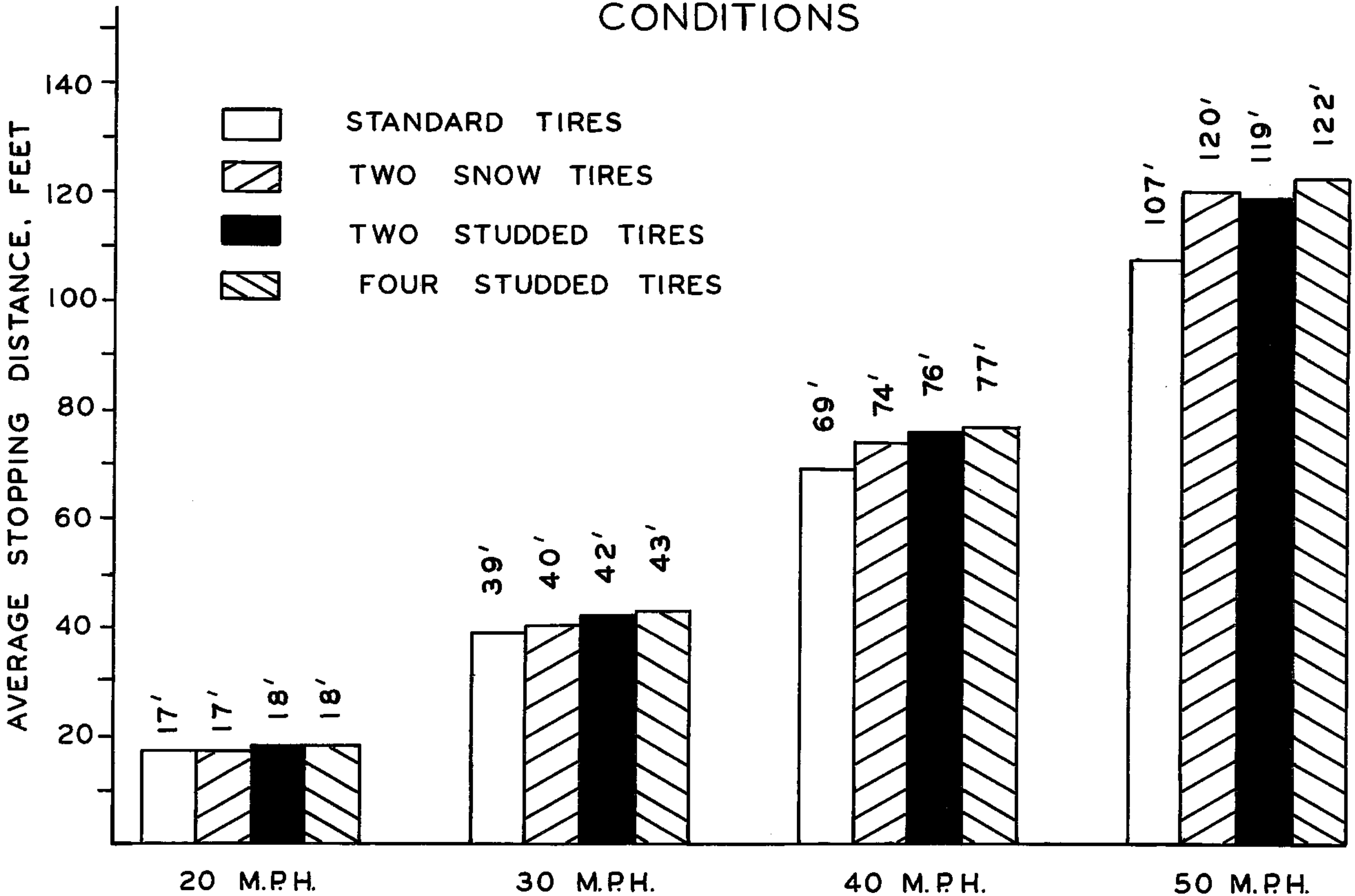
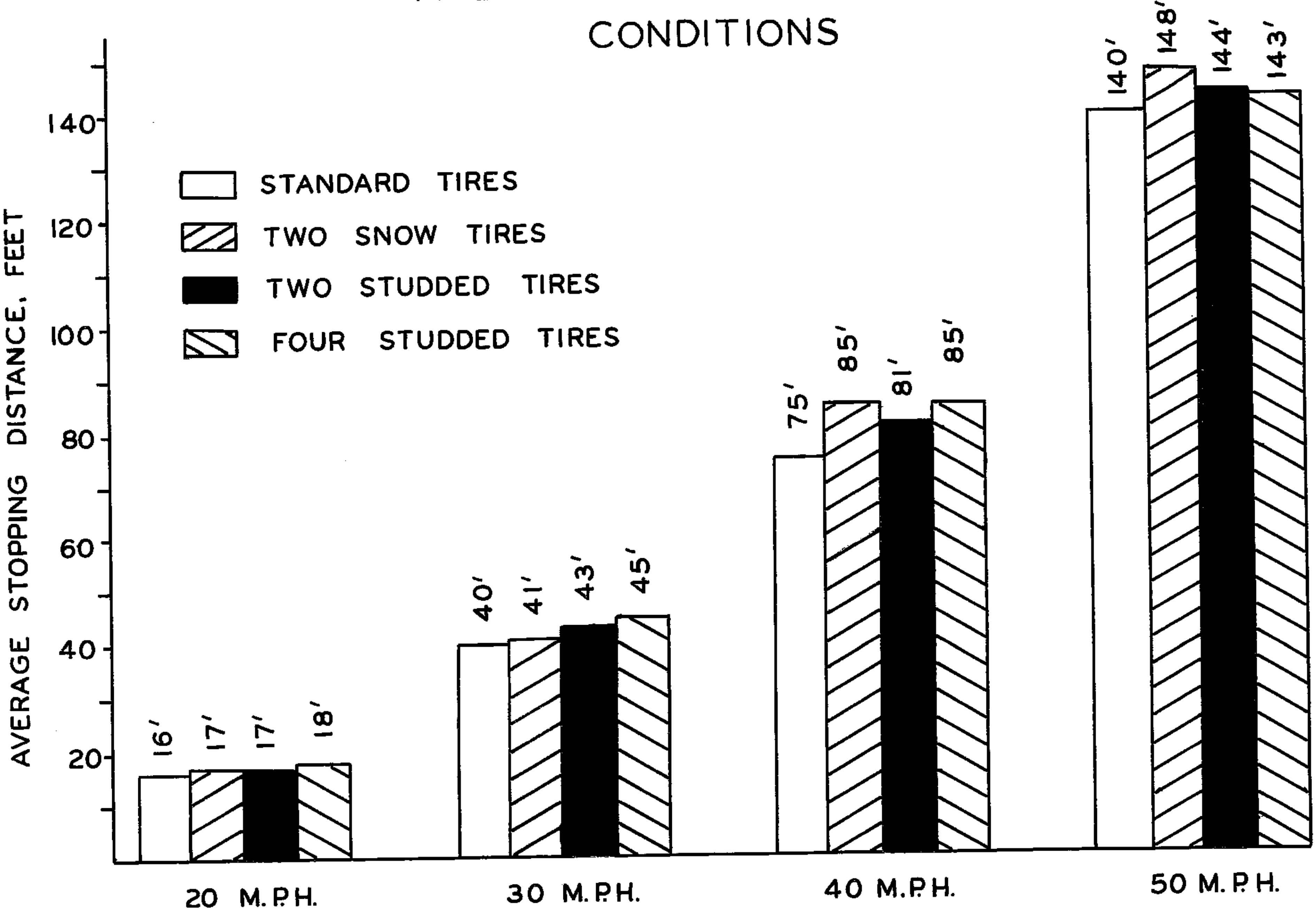


FIGURE 8: STOPPING DISTANCE TESTS — AVERAGES FOR WET PAVEMENT CONDITIONS



involving four studded snow tires were somewhat higher than for any of the other combinations.

The overall average increase in stopping distance over that required for conventional highway tires for all conditions of test was found to be 8 percent for the combination involving two snow tires, 7 percent for that involving two studded snow tires, and 11 percent for that involving four studded snow tires. These percentages indicate about the same performance for snow tires either with or without studs.

Measurements of tread depth made before and after 5000 miles of normal driving for those tires tested as used tires indicated the conventional highway tires to provide the best wear. The maximum tread wear recorded for the conventional highway tires after 5000 miles was about 0.04 in. The tread wear recorded for both the snow tires without studs and the snow tires with studs was of the order of 0.10 in.

The tread of the studded snow tires wore at a faster rate than did the tungsten carbide studs. Stud protrusion which ranged between 0.04 and 0.06 in. for new tires increased to a range of 0.06 to 0.08 in. after 5000 miles of normal driving.

Three of the twelve studded snow tires lost studs (1, 4, and 9) during 5000 miles of normal driving; all contained numerous loose studs. From 5 to 50 of 104 studs per tire became loosened during the 5000 miles of travel, averaging 19 per tire for those mounted on the front of the vehicles and 12 per tire for those mounted on the rear. A view of a typical studded snow tire following 5000 miles of travel is shown in Figure 9.

The effect of the studs becoming loose during normal driving was evident during testing. As many as 40 studs were lost from individual used tires during the 80 stopping-distance tests to which each tire was subjected, while a total of only 2 studs were lost from the 12 new tires after the same number of tests.

Figure 9. Studded winter tire after 5000 miles of normal driving - note loosened studs.

As mentioned previously, the tests that are the subject of this report were made with one manufacture and quality of tire, one design of stud and stud arrangement, one type of vehicle, a single bituminous concrete pavement, and a single portland cement concrete pavement. Variations in any of these factors could be expected to be reflected in stopping distances. Therefore, the numerical values of the stopping distances obtained apply only to the particular conditions of the tests and cannot be considered as absolute values for all test conditions. However, it is believed that the relationships between the various tire systems that were recorded have general application.

CONCLUSIONS

(1) Studded snow tires require somewhat greater stopping distances on bare pavement surfaces than do conventional highway tires.

The tests showed an average increase in stopping distance of 7 percent when studded snow tires were mounted on the rear wheels only, and of 10 percent when the vehicle was equipped with four studded snow tires.

(2) Studded snow tires require about the same stopping distances on bare pavement surfaces as do snow tires without studs.

Under all conditions of testing, the average increase in stopping distance over that required for conventional tires was 8 percent when two snow tires were used on the rear wheels of the vehicle, and 7 percent when two studded snow tires were used. Slightly longer stopping distances were required when four studded snow tires were used.

(3) Normal highway driving causes tungsten carbide studs to work loose and be removed from the tread.

After traveling 5000 miles under normal driving conditions, 3 of 12 studded snow tires lost a total of 14 studs. All of the 12 tires had loose studs, with some of them having up to 50 of 104 studs loosened. After 80 stopping-distance tests with the used tires, all lost studs and as many as 40 were lost from a single tire. Only two studs were lost from the 12 new tires during the same number of tests.

(4) The 5000 miles of normal driving did not change the ability of any of the tire types, including the studded snow tire, to stop on bare pavement surfaces.

(5) For the tire rubber and the particular tungsten carbide studs tested, the tread wore faster than the studs.

Measurements of stud protrusion from the tire tread ranged between 0.04 and 0.06 in. for the new tires, and increased to a range of 0.06 to 0.08 in after 5000 miles of normal driving.

(6) For the particular manufacture of tire tested, tread wear progressed at a faster rate for the snow and studded snow tires than for the conventional highway tires.

Measurements of tread depth before and after 5000 miles of driving showed no more than 0.04 in. of tread wear for the conventional highway tires, and an average tread wear of about 0.10 in. for both the snow tires and studded snow tires.