FIELD METHODS FOR MEASURING TIRE WEAR

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SYNOPSIS

Since only a few well conducted field tests have been made to determine the relative tire wear on the various types of surfaces, this investigation was instigated primarily to obtain information on the methods of conducting such tests

In order that a reasonably wide divergence in results might be secured, the tests were run on two types of surfaces which it was felt would give such results Portland cement concrete and what is known as a non-skid type of asphaltic concrete were selected

Conclusions and recommendations are made on the type of vehicle, the relative value of measurements on front and rear tires, the design of tire best adapted to measurement, the length and other details of the test road necessary to secure accurate results, the effect of climatic conditions, the effect of temperature on inflation pressures, the relative value of measurements by depth of wear and by loss in weight, and the equipment and personnel

Field tire tests, published to date, have used weight losses entirely as a basis of determining wear These weight losses have been found to be affected by variations in atmospheric moisture as well as other moisture encountered during the tests It seems reasonable that weight losses would be similarly affected by pavements and road surfaces made up of materials and substances which may work into or be absorbed by the tire

The tests covered in this report were primarily instigated to obtain information on the best methods of determining tire wear on different road surfaces, and the influences of the many variables entering into such tests.

The material presented is based on data obtained from two test runs made in northern and southern California between June 3 and August 19, 1930 In order to have a reasonably wide divergence in pavement surface textures, test runs were made on representative sections of portland cement concrete and what is known as a " non-skid " type of asphaltic concrete pavement A total of 3088 62 and 3525 35 miles respectively, were driven on the two types of pavement

Wear determinations by actual tread depth measurements as well as loss in weight were included in the tests Detailed data were taken on air temperatures, relative humidity, temperatures of the tire casings and pavement surface, tire inflation pressures, area of tire in contact with the pavement, and driving speed as well as complete data on the length, curvature, gradient, and surface texture of the road test sections.

TEST METHODS AND EQUIPMENT

Prior to the test runs, a tire " break-in " run of 2,000 miles was made to remove mould filets and thus obtain a more uniform contact area. The tire inflation pressures required for the prevailing load to obtain a uniform wear and the maximum driving speed for safe and uniform operation as well as the methods of taking and observing the various data were determined and organized during these preliminary runs.

A Pontiac big six sedan, Model 1929, equipped with 5 x 19 six-ply balloon tires, manufactured by the General Tire Co., was used for the tests. The car was also equipped with a special Department of Agriculture odometer which was calibrated and found to be accurate for both speed and distance. Four tires were used in the test. Tires identified, as numbers 1 and 2, were used exclusively on the front wheels and numbers 3 and 4 were used exclusively on the rear wheels. Both the front and rear tires were alternated on the right and left wheels of the car on each test run increment. In mounting the tires, lugs and nuts for each wheel were placed in the same position and adjusted so that the plane of the tire sides was parallel to the plane of the wheel.

The total weight of the car was 3,490 pounds of which 1,935 pounds was on the rear axle and 1,555 pounds on the front axle. The Tire and Rim Association's recommended minimum inflation pressures for these loads are 36 for each rear and 29 pounds for each front tire. These pressures were used at the beginning of the break-in runs but were increased to 40 and 35 pounds because the bead each side of the center bead was found to be wearing more rapidly than the center one. The increased pressures eliminated the uneven wear and were used throughout the test runs. Pressures were maintained reasonably constant by frequent checking with a heavy duty, calibrated dial pressure gauge manufactured by the United States Gauge Company.

A standard driving speed of 40 miles per hour was adopted for the test runs. The actual average speed varied from 37.9 to 40.2 miles per hour. An average length of .17 mile was used on each end of the test sections for stopping and starting. Deceleration was largely accomplished with the motor and the car brought to a full stop with an easy application of the brakes after the speed of the car had been reduced to 15 or 20 miles per hour. All turns were made at the slowest speed possible, using intermediate gear.

On the tests in northern California, a run of 2,000 miles was made on each type of pavement. Each test run was divided into two increments of about 1,000 miles each and alternated between the pavement types so as to equalize the average area of tread rubber in contact with the pavement The increments on portland cement concrete pavement are identified by C3 and C6 and on the asphaltic concrete by NS4 and NS5 The first run was made on concrete, the second and third on asphalt, and the fourth on concrete

The test runs in southern California were discontinued after one increment on each type of pavement when it was found that the wear results obtained checked those in northern California These runs are similarly identified and were run in the following order NS7 and C8

Considerable difficulty was encountered with the wear observations on the front tires. These tires developed unusual and non-uniform wear which made it impossible to measure the wear by tread depth measurement An effort was made to eliminate this eratic wear by adjusting the front wheel and axle alignment but this did not overcome the difficulty so further tests and observations on front tires were discontinued

The depth of the non-skid tread at the end of each test run increment was measured with a Federal Dial Depth Gauge, graduated to one thousandth of an inch, at identical and opposite points on each side of the center bead at ten locations on the circumference of the tire The points in the tread at location 2 are shown in Figure 1 The average of eight readings, four on each side of the center bead, was taken as the depth of tread at each control point and the average of the ten locations as the depth of non-skid tread for the tire The difference between the depth of tread at the beginning and end of each increment gave the depth wear loss for the increment

The actual depth of the non-skid tread, as determined by the depth gauge requires a correction for the penetration of the blunted needle point of the gauge, however, where wear losses are determined by differences in successive readings, no correction for the penetration is necessary, provided that it remains constant Observations throughout the test runs did not show any change in the penetration so no correction was made

In making the depth measurements some difficulty was encountered in holding the gauge truly vertical and with equal pressure against the yielding tread faces This was overcome by the use of a guide template and by weighting the gauge to overcome the tension of the spring on the gauge stem The template with gauge in place for reading is shown in Figure 2 A close inspection of the picture will also show the lead weight around the circumference of the dial

The wear losses by weight were determined by differences in weight of individual tires mounted on the rims but with the tire deflated and

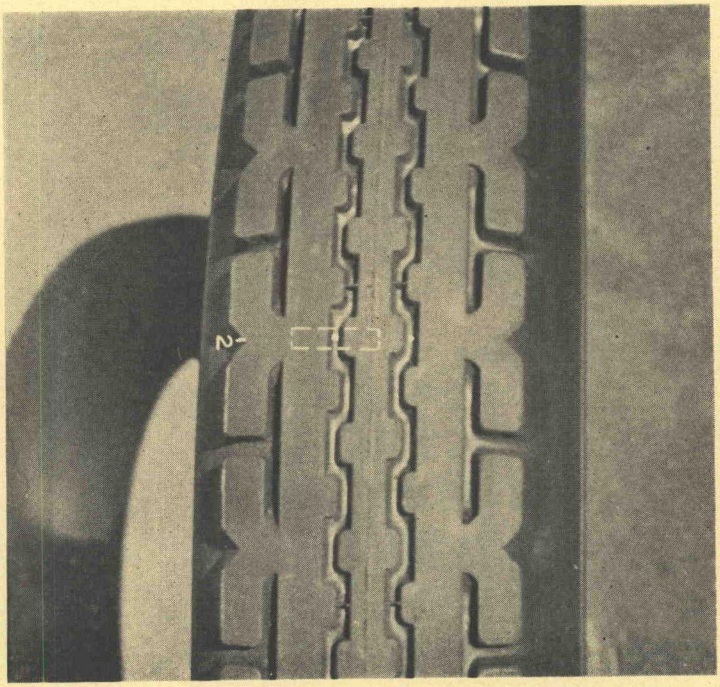

Figure 1. Tread of Test Tires Before Being Used. White Dots Show Depth Measuring Points. Dotted Line Marks Outline of Depth Gauge Foot when in Place for Reading Depth of Tread

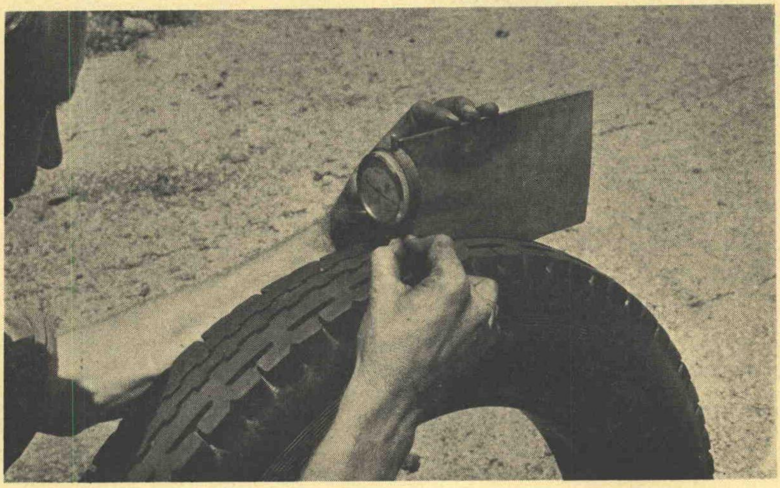

Figure 2. Dial Depth Gauge in Place Against Guide Template as Used in Measuring the Depth of Tread

the valve core removed. The weight was determined from an average of two readings after thoroughly cleaning the tire with fiber brushes, cloths and air blast. A multiple lever scale, having a capacity of 20 kilograms and sensitive to one gram, was used to weigh the tires. At each set up, and prior to each weighing, the scale was calibrated with standard weights.

All data relative to temperatures were taken with short bulbed thin walled thermometers graduated from 0 to 150 degrees Fahrenheit. Air temperatures were taken in the shade at a convenient location on the test section. Tire temperatures were taken by inserting the bulb of the thermometer into the tire tread, the thermometer being held in place, shielded and insulated from air currents by a 6 x 9 x $\frac{3}{4}$ inch felt pad strapped on the tire. Thermometers were left in place until a decrease in temperature was noted and the highest temperature attained was recorded. Pavement surface temperatures were taken with the thermometer mounted in a white, double walled rubber bulb, which was made by cutting a flush tank ball into two parts, the conical half forming the inner wall and spherical half the outer wall. This assembly, shown in Figure 3, provided an insulating air space between the walls of the bulb, insulated and shielded the thermometer against the sun and air currents and also served as a support for the thermometer.

Figure 3. Bulb and Thermometer Used in Observing Pavement Surface Temperatures

The relative humidity of the air during the tests was taken with a sling psychrometer

Preliminary information, secured from various tire manufacturers, indicated that tire wear losses decrease as the area of tire in contact with the pavement increases Variations in wear losses from this cause were reduced to a minimum by alternating test runs on the two types of pavement In addition, as a check on the control of this factor, impressions were taken of the test tires at the beginning of each run. Comparison of the areas of these impressions show, that the contact areas on the runs for each type of pavement were substantially equal

DESCRIPTION OF TEST SECTIONS

Test sections were selected to give, as near as practicable, comparable lengths, curvature, and grades and representative surface textures Sections complying with these conditions were necessarily relatively short, ranging from 7 1 miles to 7 5 miles in length The curvature and gradient of the sections were low, there being no curves on which the standard speed could not be maintained The maximum grade on any test section was 2 5 per cent and more than 60 0 per cent of the length of all sections had a gradient of less than 1 0 per cent

The pavement surface on the "Non-skid" asphaltic concrete had the characteristic open texture of this type of pavement. Figures 4 and 5 illustrate this texture Figure 5, is a close-up view of the pavement shown in Figure 4

The pavement surface on the portland cement concrete sections was characteristic of this type of pavement Figures 6 and 7 illustrate this texture Figure 7 is a close-up of the pavement shown in Figure 6

TEST DATA

The complete and detailed results for each test run increment are shown in Tables I to VI inclusive Table VII is a summary of Tables I to VI with a segregation and comparison of the test data on the two types of pavement The temperatures of the air, tires and pavement surface as well as the relative humidity are weighted averages for the run computed from daily averages

The observed temperatures and relative humidity on each day's run for each test run as well as the tire inflation pressures and corrections necessary to maintain the standard pressure for each tire are shown on the graphs of Figures 8 to 13 inclusive These curves show the relation between the atmospheric temperature, pavement and tire temperature, relative humidity and the tire inflation pressures

Figure 4. Pavement Surface Texture on Asphaltic Concrete Test Section (NS7 Run)

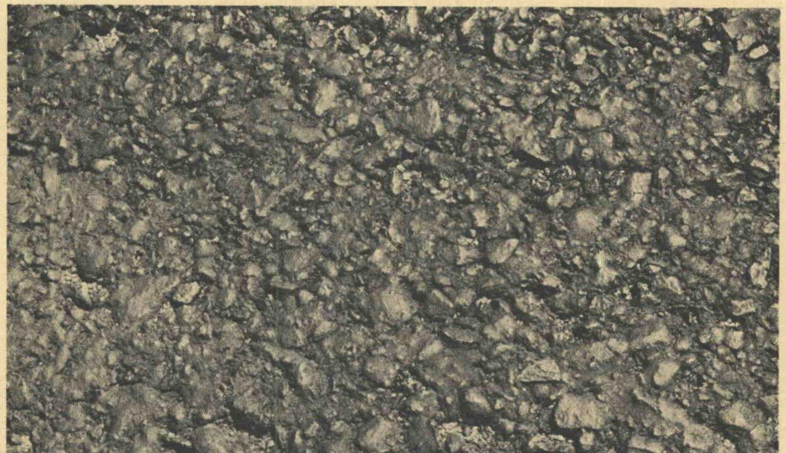

Figure 5. Close-Up of Pavement Surface Shown in Figure 4

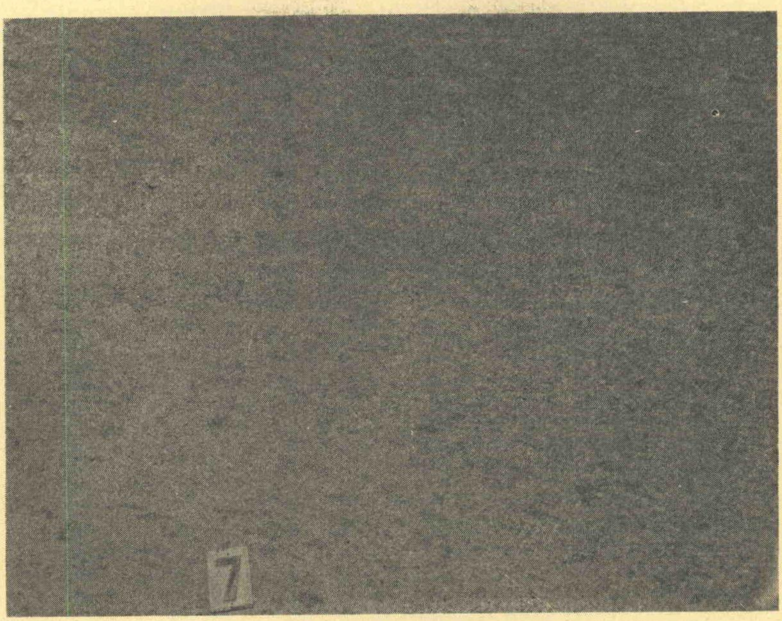

Figure 6. Typical Pavement Surface Texture on Portland Cement, Concrete Test Section (C8 Run)

Figure 7. Close-Up of Pavement Surface Shown in Figure 6

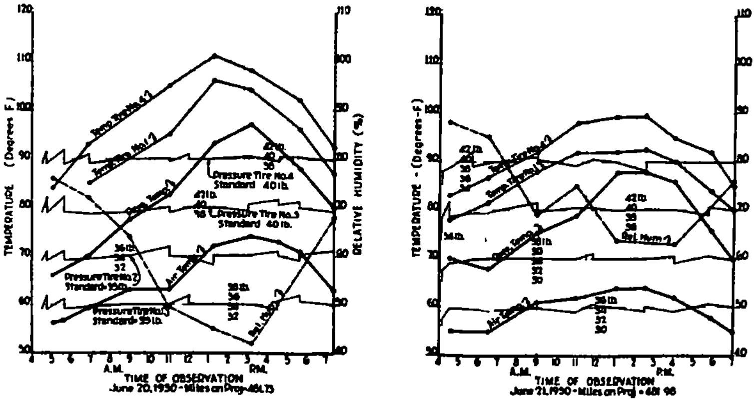

Figure 8. Data Taken on C3 Run, Portland Cement Concrete, Contract M 168, Rt. 5B. Alameda Co, Calif

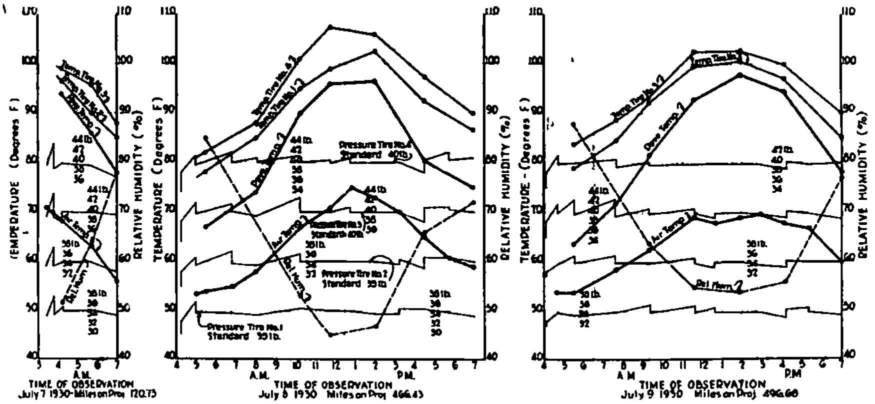

Figure 9 Data Taken on C6 Run, Portland Cement Concrete, Contract M 168, Rt 5B, Alameda Co, Calif

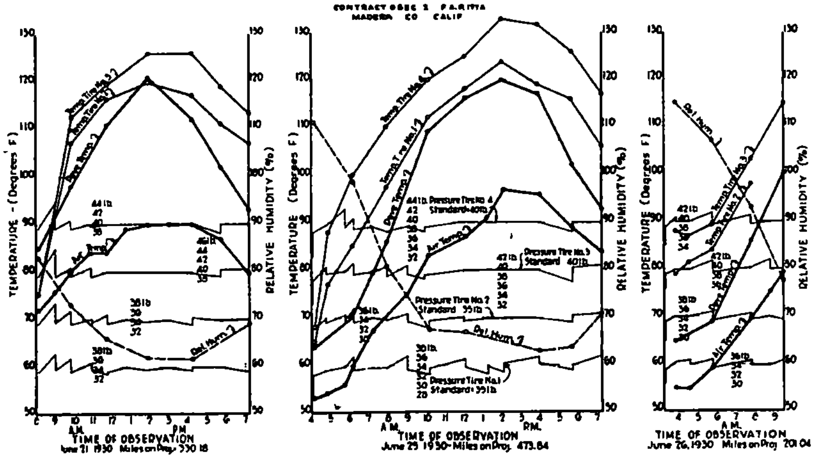

Figure 10 Data Taken on NS4 Run, Asphaltic Concrete, Contract 06EC2, F. A P. 177A, Madera Co, Calif.

DISCUSSION OF TESTS

A study of the test data shows that a low wear per unit length was obtained on both types of pavement The physical conditions imposed during the tests should be considered in connection with this fact, since the tests represent wear losses obtained from continuous running, under controlled and constant tire inflation pressure and without any appreciable braking action. These conditions were imposed as a means of controlling variables other than differences in abrasion and temperatures and should give wear losses proportional to those prevailing under normal car operation .

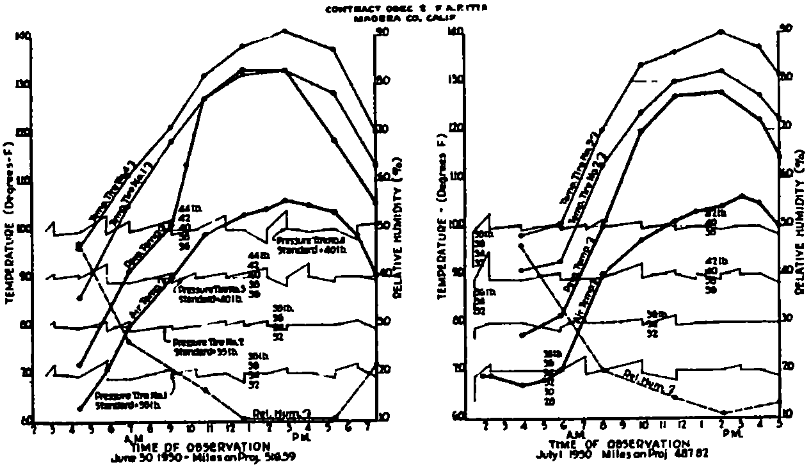

Figure 11. Data Taken on NS5 Run, Asphaltic Concrete, Contract 06EC2, F. A. P. 177A, Madera Co., Calif.

Wear Losses Determined by Depth Measurements

The average depth loss obtained on portland cement concrete in northern California was 0039 inch per 1,000 miles (see Table VII) on runs having average air and pavement surface temperatures of 63 1 and 81 8 degrees F. respectively This loss is an average of 0030 and 0048 obtained on the C3 and C6 test runs having practically equal temperatures and individual tire losses practically equal on each increment (See Tables I and II.)

The average depth loss obtained on portland cement concrete in southern California was .0033 inch per 1,000 miles (see Tables V and VII) on a run having average air and pavement surface temperatures of 83 1 and 101 5 degrees F. respectively. This loss is 15.5 per cent less than, and was obtained on a run having average air and pavement surface temperatures 20 degrees F greater than, on the test runs in northern California

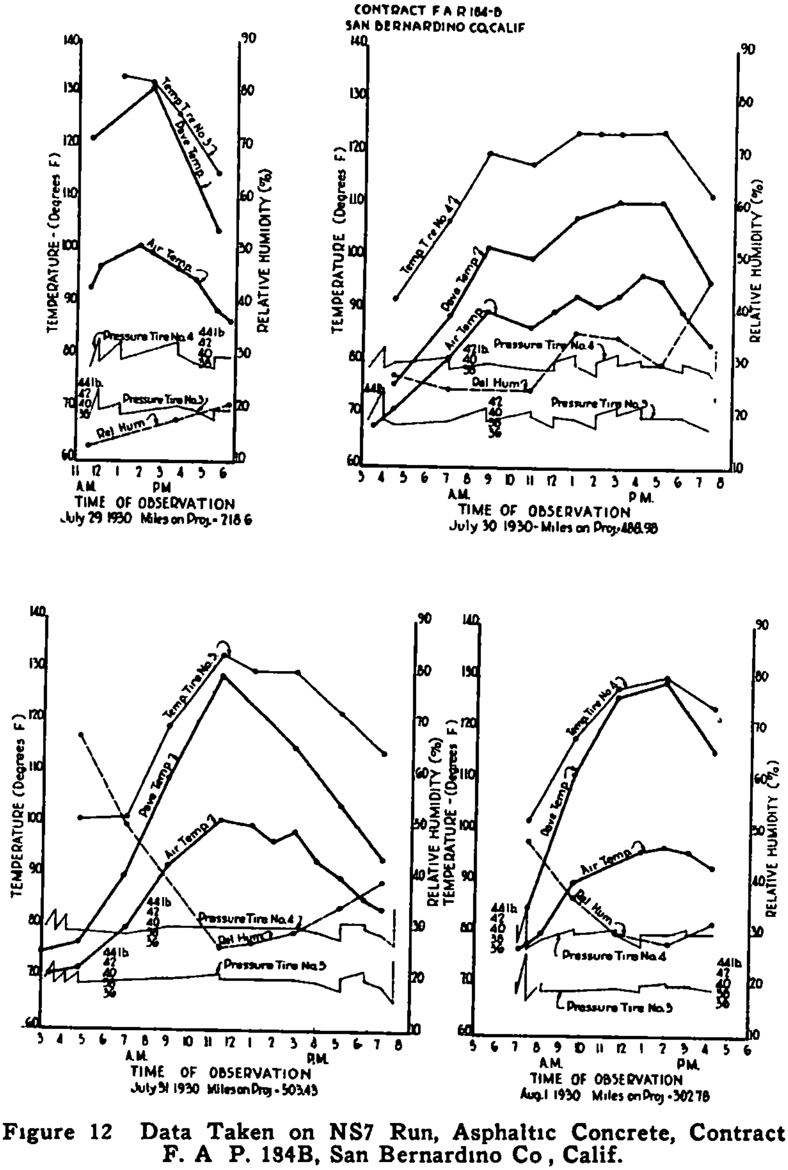

Figure 12 Data Taken on NS7 Run, Asphaltic Concrete, Contract F. A P. 184B, San Bernardino Co, Calif.

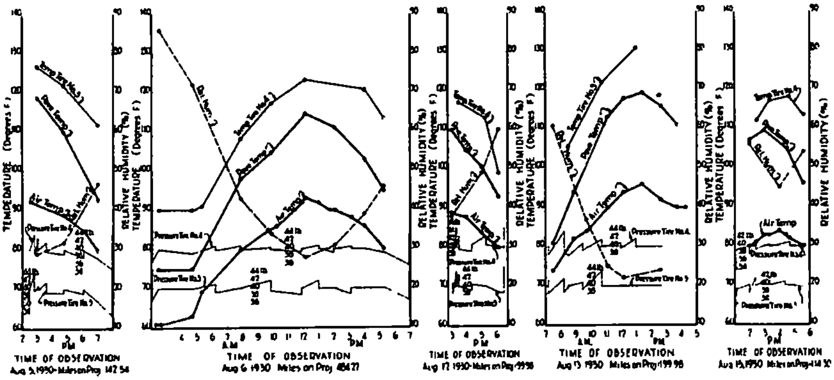

Figure 13 Data Taken on C8 Run, Portland Cement Concrete, Maintenance Contract 84F. A P 163A, San Bernardino Co., Calif

TABLE I

Run C3—Portland Cement Concrete, Dublin-Livermore, June 20–21, 1930

Average Temperatures, Deg F, Air 62 7, Pavement Surface 80 2
Average Relative Humidity, 65 3 per cent
Standard Tire Pressures, Front 35 lbs, Rear 40 lbs
Net Miles on Project, 963 71
Average Driving Speed, 39 5 miles per hour

Tire No	Position on Car	Average Temperature—Deg F			Wear per 1000 miles	
		Tire	Difference, Tire & Air	Difference, Tire & Pave	Weight—Gms	Depth—Ins
3	Right Rear				9 3	0 0031
4	Left Rear	96 3	33 6	16 1	9 3	0 0029
Ave	Rear	96 3	33 6	16 1	9 3	0 0030

TABLE II

Run C6—Portland Cement Concrete, Dublin-Livermore, July 7–8–9, 1930

Average Temperatures, Deg F, Air 63 4, Pavement Surface 83 3
Average Relative Humidity, 64 4 per cent
Standard Tire Pressures, Front 35 lbs, Rear 40 lbs
Net Miles on Project, 1083 84
Average Driving Speed, 39 4 miles per hour

Tire No	Position on Car	Average Temperature—Deg F			Wear per 1000 miles	
		Tire	Difference, Tire & Air	Difference, Tire & Pave	Weight—Gms	Depth—Ins
3	Left Rear	95 0*	31 6	11 0	10 1	0 0047
4	Right Rear	95 6*	33 1	13 3	10 1	0 0048
Ave	Rear	95 2†	31 8	11 9	10 85	0 00475

* Based on different days averages
† Based on weighted averages on total run

The average depth loss obtained on the " Non-skid " asphaltic concrete pavement in northern California was 00675 inch per 1,000 miles on runs having an average air and pavement temperature of 84.2 and 103.4 degrees F respectively. This loss is the average for the NS4 and NS5 runs (see Tables III and IV), which show individual average losses of 0067 and 0068 inch respectively The air and pavement surface temperatures averaged about 12 degrees higher on the second run than on the first

TABLE III

Run NS4— "Non Skid" Asphaltic Concrete, Madera-North, June 24–25–26, 1930

Average Temperatures, Deg F , Air 78 4, Pavement Surface 96 8
Average Relative Humidity, 28.0 per cent
Standard Tire Pressures, Front 35 lbs , Rear 40 lbs
Net Miles on Project, 1005 06
Average Driving Speed, 40 1 miles per hour

Tire No	Position on Car	Average Temperature—Deg F			Wear per 1000 miles	
		Tire	Difference, Tire & Air	Difference, Tire & Pave	Weight—Gms	Depth—Ins
3	Left Rear	108 3†	30 9	12 8	35 9	0 0074
4	Right Rear	115 3†	35 7	17 1	30 9	0 0061
Ave	Rear	111 5*	33 1	14 7	33 3	0 0067

TABLE IV

Run NS5—"Non-Skid" Asphaltic Concrete, Madera-North, June 30 and July 1, 1930

Average Temperatures, Deg F , Air 90 0, Pavement Surface 110 0
Average Relative Humidity, 20 0 per cent
Standard Tire Pressures, Front 35 lbs , Rear 40 lbs
Net Miles on Project, 1004 41
Average Driving Speed, 40 2 miles per hour

Tire No	Position on Car	Average Temperature—Deg F			Wear per 1000 miles	
		Tire	Difference, Tire & Air	Difference, Tire & Pave	Weight—Gms	Depth—Ins
3	Right Rear	124 7†	35 9	15 7	20 9	0 0052
4	Left Rear	125 0†	34 2	14 0	31 4	0 0084
Ave	Rear	124 9*	34 9	14 9	26 1	0 0068

* Based on weighted averages on total run
† Based on different days averages

The average depth loss obtained on the " Non-skid " asphaltic conciete in southern California (NS7 run), was 0066 inch per 1,000 miles (see Tables VI and VII), on a run having averaged air and pavement temperatures of 89 9 and 106 9 degrees respectively. This loss is practically equal to but is less than the average or the individual increment runs in northern California at temperatures which are comparable but somewhat less

The inflation pressures were found to increase with rising temperature Higher inflation pressures reduce the area in contact with the pavement and produce more bounce in the tire both of which would tend to increase wear losses, however, the effect of their influence was practically eliminated in these tests by maintaining reasonably constant tire inflation pressures.

TABLE V

RUN C8—PORTLAND CEMENT CONCRETE, SAN BERNARDINO-REDLANDS, AUGUST 5, 6, 12, 13 AND 15, 1930

Average Temperatures, Deg F, Air 83 1, Pavement Surface 101 5
Average Relative Humidity, 42 8 per cent
Standard Tire Pressures, Front 35 lbs, Rear 40 lbs
Net Miles on Project, 1041 07
Average Driving Speed, 37 9 miles per hour

Tire No	Position on Car	Average Temperature—Deg F			Wear per 1000 miles	
		Tire	Difference, Tire & Air	Difference, Tire & Pave	Weight—Gms	Depth—Ins
3	Left Rear	107 9	24 8	6 4	6 7	0 0038
4	Right Rear				1 9	0 0027
Ave	Rear	107 9	24 8	6 4	4 3	0 0033

TABLE VI

RUN NS7—NON-SKID ASPHALTIC CONCRETE, CUCAMONGA-FONTANA JULY 29, 30 AND 31 AUGUST 1, 1930

Average Temperatures, Deg F, Air 89 9, Pavement Surface 106 9
Average Relative Humidity, 31 8 per cent
Standard Tire Pressures, Front 35 lbs, Rear 40 lbs
Net Miles on Project, 1513 78
Average Driving Speed, 39 5 miles per hour

Tire No	Position on Car	Average Temperature—Deg F			Wear per 1000 miles	
		Tire	Difference, Tire & Air	Difference, Tire & Pave	Weight—Gms	Depth—Ins
3	Right Rear	116 5	26 6	9 6	24 5	0 0060
4	Left Rear				28 5	0 0072
Ave	Rear	116 5	26 6	9 6	26 5	0 0066

In summary of the preceding discussion and from further study of wear loss on individual increments, it may be concluded that the air and pavement temperatures did not materially influence the depth wear losses On this basis the data may be combined to show the relative wear losses on each type of pavement as in Table VIII

This summary shows that wear, as obtained by tread depth measurements, was 81 0 per cent greater on the " Non-skid " asphaltic concrete than on the portland cement concrete pavement.

TABLE VII

SUMMARY OF TEST RUNS

Run No	Net Length of Run, Miles	Ave Driving Speed, Miles Per Hour	Ave Rel Humidity Per Cent	Average Temperature—Deg F			Ave Temp Diff Deg F		Wear per 1000 miles Ave of two rear tires		Unit Weight Loss, Grams per 001 inch of Depth Loss
				Air	Pavement Surface	Ave Rear Tire	Air and Pavement	Air and Rear Tire	Weight Gms	Depth Ins	
PORTLAND CEMENT CONCRETE											
C3	963 71	39 5	65 3	62 7	80 2	96 3	17 5	33 6	9 3	0 0030	3 10
C6	1083 84	39 4	64 4	63 4	83 3	95 2	19 9	31 8	10 1	0 0048	2 11
Av C3 and C6	2047 55	39 4	64 8	63 1	81 8	95 8	18 7	32 7	9 7	0 0039	2 60
C8	1041 07	37 9	42 8	83 1	101 5	107 9	18 4	24 8	4 3	0 0033	1 30
"NON-SKID" ASPHALTIC CONCRETE											
NS4	1005 06	40 1	28 0	78 4	96 8	111 5	18 4	33 1	33 3	0 0067	4 97
NS5	1004 41	40 2	20 0	90 0	110 0	124 9	20 0	34 9	25 9	0 0068	3 81
Av NS4 and NS5	2009 47	40 1	24 0	84 2	103 4	118 2	19 2	34 0	29 6	0 00675	4 39
NS7	1513 78	39 5	31 8	89 9	106 9	116 5	17 0	26 6	26 5	0 0066	4 02

Wear Losses Determined by Weight

The weight losses obtained on the several increments for each type of pavement (see Table VII) are consistent except on the C8 test run. The low weight loss obtained on this run is believed due to conditions which inadvertently developed during the test.

The metaled shoulders were oiled during the test run and the oil was tracked onto the outside quarters of the pavement. The foggy weather and lower temperatures encountered also necessitated intermittent running and a longer storage interval between weighings than on the other test runs (see Figure 13).

That the oil had an influence on the weight determinations on the C8 run is evident by comparison of the weight losses on the right and left tire (see Table V). The left tire shows 3.5 times more loss in weight than the right tire which traveled on the outside quarters of the pavement. That the oil, which was not much more than a stain on the pavement surfaces, did not effect the abrasiveness of the pavement is shown by comparison of the relative depth losses of the left and right tires on this run with those of the other runs. (See Tables I to VI inclusive.) Since the weight losses on the C8 run were affected by unusual conditions they will be given no further consideration.

TABLE VIII

Test Run Nos	Type of Pavement	Total Miles	Total Depth Wear Loss Inches	Depth Wear Loss Inches per 1000 Miles	Wear Index*
C3, C6, C8	Portland Cement Concrete	3088.6	0.01145	0.0037	1.00
NS4, NS5, NS7	Non-skid Asphaltic Concrete	3523.3	0.0235	0.0067	1.81

*Average wear on portland cement concrete given wear index of 1.00

The effect of atmospheric moisture and pavement temperature on weight losses is shown by comparison of the weight losses per unit length on successive increment runs. A high loss was generally obtained when changing from an atmospheric condition having low temperature and high moisture to high temperatures and low moisture and vice versa.

Assuming that the weight loss per unit depth loss should be equal irrespective of pavement type, the influence of atmospheric moisture and temperature on weight losses is apparent in the tests in northern California as a group. The average weight loss per 0.001 inch of depth loss obtained on the C3 and C6 runs is 2.6 grams and on the NS4 and NS5 runs is 4.39 grams. (See Table VII.) The latter loss was obtained on runs having an average air temperature of 21 6 degrees F higher and a relative humidity 40 8 per cent less than the former The gram loss per 0 001 inch obtained on the NS7 run which was made at comparable temperature and humidity, is also consistent with the average of the NS4 and 5 runs (See Table VII)

Obviously weight losses are affected by conditions of tests which are difficult to evaluate but which must be considered in making comparisons of the abrasiveness of pavement types

Data on tire wear, determined by weight (omitting the C8 run for reasons previously discussed), are summarized in Table IX.

This summary shows that wear as determined by weight is 191 0 per cent greater on the " Non-skid " asphaltic concrete than on the portland cement concrete pavement, if the effect of differences in atmospheric moisture and temperature are disregarded This differential is 2 35 times greater than the wear determined by depth measurement

TABLE IX

Run Nos	Type of Pavement	Average Rel Hum %	Pavement Surface Temp Deg F	Ave Wear Grams per 1000 miles	Wear Index*	Unit Wt Loss Grams per 001 inch of Depth Loss
C3, C6	Portland Cement Concrete	63 1	81 8	9 7	1 0	2 60
NS4,5 and 7	Non-skid Asphaltic Concrete	28 0	105 5	28 2	2 91	4 20

*Average wear (by weight) on concrete given a wear index of 1 0

The indicated correction of the weight losses for the existing differences in pavement temperature and relative humidity may be determined, in accordance with the previous assumption, from the ratio of the gram losses per 0 001 inch of depth loss This ratio, as shown in Table IX, is 4 2 to 2 6 or an indicated correction of about 62 0 per cent Applying this correction to the weight losses, will show the same 81.0 per cent greater wear on asphaltic concrete than on portland cement concrete.

TEMPERATURES AND INFLATION PRESSURES

A study of the temperature charts (See Figures 8 to 13 inclusive) shows that the difference between the air and pavement surface temperature is greater at higher altitudes of the sun and decreases rapidly at lower altitudes, tire temperatures are generally higher and follow the pavement temperature, their difference becoming less at higher pavement temperatures, and inflation pressures increase with increasing tire temperatures The interrelation of these factors and their influence on tire inflation pressures is shown by these data

The required changes of the inflation pressures to maintain the standard pressure adopted for the tests are also shown in detail on the temperature charts (See Figures 6 to 13 inclusive) It was found that the deflation and inflation required for the daily increasing and decreasing temperatures ranged from 5 to 15 pounds but was more generally 8 to 10 pounds.

Indirectly these data show the possible variations in contact area as well as bounce of the tire that might have occurred if the tire inflation pressures had not been maintained constant A control of this factor is considered important in connection with tire wear tests.

CONCLUSIONS AND RECOMMENDATIONS

The following principal conclusions and recommendations for further tests appear justified from the data obtained under the conditions of tests covered in this report

CONCLUSIONS

(1) The most satisfactory method of determining tread wear is by depth measurements

(2) The wear obtained by weight determinations is affected by variables hard to control in field tire wear tests.

(3) Wear losses determined by measuring the depth of tire tread were not affected by differences in the average temperatures and humidity encountered in these test runs

(4) When measured by depth, the tire wear on " Non-skid " asphaltic concrete is 81 0 per cent greater than on portland cement concrete pavement

(5) Wear losses determined by weight are affected by differences in temperature, relative humidity and any substances which may work into or be absorbed by the tire and a correction must be made to obtain the actual wear due to abrasiveness

(6) Comparison of the summary of wear obtained by weight and the weight loss per unit depth loss indicates that a correction of 62 0 per cent is required to reduce the observed wear by weight to actual wear, for a difference in pavement temperature of 24 degrees F and a difference in relative humidity of 35 0 per cent encountered in the tests.

(7) Making a correction of the observed wear by weight, in the manner indicated in conclusion 6, the wear on " Non-skid " asphaltic concrete is 81 0 per cent greater than on portland cement concrete pavement.

(8) Tire inflation pressures of balloon tires vary directly with the temperatures of the tire casing These variations are of sufficient magnitude, unless controlled, to produce appreciable variations in the contact area as well as the bounce of the tire

(9) The minimum tire inflation pressure recommended by the Tire and Rim Association for the tire, the size and load was four pounds lower than the pressure required to give uniform wear on the full width of the tread on the tires used in this test

(10) Uniform, consistent and measurable depth wear could not be obtained on the front tires

(11) Depth measurements could be made with greater accuracy and ease on tires having straight bead treads Straight bead tread tires would also greatly facilitate cleaning and eliminate the unusual wear which develops on tread designs having transverse projections or openings

(12) Data on air, pavement surface and tire temperatures are desirable in connection with interpretation of wear determined by depth of tread measurements but not necessary to properly interpret and evaluate wear losses by weight

(13) Test run increments should be of sufficient length to produce appreciable wear losses so that the results will not be materially affected by the limits of accuracy in the method of observation

RECOMMENDATIONS FOR FURTHER TESTS

(1) A practically new, heavier and better constructed car should be used This would eliminate the mechanical difficulties encountered on front wheel alignment and unequal braking action as well as ensuring more uniform car operation with a minimum of maintenance

(2) The rim and wheel should be of sturdy construction and such that the tires may be readily mounted with the vertical plane of the tire sides parallel to the vertical plane of the wheel

(3) Tire inflation pressures should be such as will give uniform tread wear for the full width of tread in contact with the pavement

(4) Tire inflation pressures should be maintained constant during the test runs.

(5) A dependable and practical device mounted on the valve stem which will automatically control inflation pressures would be desirable for accuracy and would at the same time reduce the number of stops required during the test runs

(6) Self-recording thermometers should be used for the air and pavement surface temperatures

(7) Electrical thermometers for obtaining pavement surface and tire temperatures would be desirable

(8) The use of an accurate and calibrated odometer is justified to obtain accurate speeds and lengths

(9) The stem on the dial depth gauge should be fitted with a spring having a minimum amount of tension

(10) Identification marks and reference points should be permanently branded on the tire

(11) The test runs should be made on dry pavement surfaces.

(12) Test sections of various pavement types should be as long as possible, of equal length and of comparable curvature and gradient

(13) A constant and uniform driving speed should be maintained at all times to insure uniform contact pressures on the rear wheels. Consideration to ease of driving should be given in the selection of test sections

(14) A break-in run of 2,000 miles should be made on test tires to remove mould fillets and secure uniform and proportional wear losses on subsequent test run increments.

(15) The test runs should be divided into increments on each type of pavement and arranged in sequence in a test cycle so as to give, as near as practicable, equal average areas of the tire in contact with the pavement

(16) The length of runs in a comparative test cycle should be between 2,000 and 4,000 miles. The actual length depends on the abrasiveness of the pavement surface and should be such as will produce wear losses commensurate with accuracy in the method of observation and also a total wear loss approximately equal for each type of pavement

(17) In determining wear on different pavement types the tests may well be confined to rear tires

(18) Pictures make very satisfactory records of the texture of the pavement surfaces, equipment and any unusual wear on the tires which may develop in the tests, and should be included as part of the test records.

(19) For best results four men are required to carry out the tests This includes two drivers and two observers to supervise the tests, equipment and supplies.

DISCUSSION ON TIRE WEAR

ABSTRACTED

Mr B. E Gray, *Highway Engineer, Asphalt Institute.* The method of measuring tire wear described is better than the old weight method. The inference should not be drawn from these tests however, that asphalt surfaces are more damaging to tires than concrete surfaces The particular asphaltic concrete surface used in the tests was designed for a non-skid surface. If the rate of wear were the only thing to be considered, there is no pavement surface that would show a smaller amount than orthodox sheet asphalt According to Mr Gray, the facts as to amount of wear on both concrete and asphalt surfaces of ordinary smoothness, are that before a tire would fail because of tread abrasion, a useful life of over 50,000 miles would have been obtained in either case

Prof H B Shaw, *North Carolina State College* The voluminous data on temperature and weather conditions in the report throw little light on the reasons for the inaccuracy of measuring tire wear by weighing The inaccuracy is probably due to varying conditions of the tire having a larger effect than the loss in weight determined by the difference between relatively large weights before and after the wear.

Prof R L Morrison, *University of Michigan* Generally speaking, the same people pay for the roads and for the operation of vehicles over them and, as a rule, the only justification for highway improvements is to reduce the cost, or add to the safety, of vehicle operation The cost of a road is simply one element in the cost of conducting highway transportation, perhaps not more than one fifth, or one tenth of the total and, from a broad economic standpoint, a surface is cheap, or expensive only as it affects the sum of its own annual cost and the annual cost of operating vehicles upon it

Unfortunately we know much less about the larger item of vehicle operating costs than we do about the smaller item of road surface costs, and the public is much less conscious of the former than of the latter

Whenever the asphaltic concrete is mentioned in this paper the authors have been careful to refer to it as " Non-skid " asphaltic concrete and the study is evidently offered as a comparison of tire wear upon a smooth surface and a non-skid surface rather than a comparison of tire wear upon typical portland cement concrete and typical asphaltic concrete It seems to me very probable that tire wear is a function of the roughness of the surface and that it is affected very little by the particular materials of which a smooth surface is composed