TIRE WEAR INVESTIGATION

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A study of the wear of automobile tires has been made to determine as far as possible the destructive effect on the tread rubber caused by different types of road surfaces so that, insofar as possible and insofar as may be fair to the traffic using the road, surfaces may be so improved as to make the total cost of building and maintaining road surfaces and of operating the traffic over them a minimum

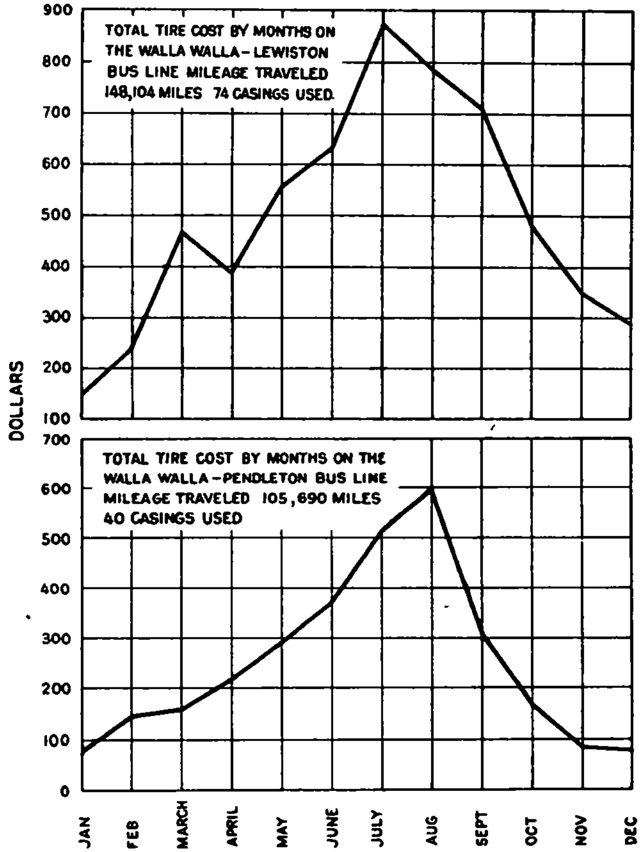

Figure 1

The cost of tires is one of the many elements entering into this cost

The State College of Washington has conducted a series of tests in an effort to determine the loss of tread rubber caused by the several types of road surfaces The surfaces tested have been concrete, brick, bitulithic, penetration macadam, and several types of gravel and broken stone The results of these types of road surfaces have been brought together and analyzed in this paper The factors influencing tire wear are discussed and an effort is made to evaluate some of the factors entering into the problem The following conclusions may be drawn from the data now available

1 Tire wear increases with the speed Sufficient data are not available to indicate the rate of increase
2 Road tests indicate an increased wear with higher temperatures but the results are not consistent and yield no information as to the rate of increase High temperatures are very destructive of tires Figure 1 shows the cost of tires, tubes and tire repairs for the entire 12 months on two bus lines, one operating over bitulithic and the other over broken stone macadam, and clearly shows the added cost during hot weather
3 The wear of rear tires is greater than that of front tires, the relative wear of rear tires being 200 per cent on smooth pavements and as little as 118 per cent on gravel surfaces, probably averaging 150 per cent of the wear on front tires
4 Tire wear per ton of car is probably consistent for any given road surface when the size of the tire, the load hauled and the inflation pressure on the tires are measured by the same standards

A billion dollars is probably expended each year in the United States in building and repairing roads, and likely more than ten times that much is used in operating motor vehicles over the roads Some way should be found to reduce these enormous operating charges Two and one-half billions are lost in depreciation, which is nearly one-third of the operating costs, and a billion is eaten up in interest If roads were made right, cars would last longer and the depreciation charges would be much less In the light of the enormous investment in motor vehicles and highways the problem of securing the most economical surface for highway transport becomes of the utmost importance In making economic comparisons between different road surfaces, consideration must be given to those costs which arise from the operation of the vehicle, and those which arise from the highway itself in order that the total costs of highway transportation may be a minimum The condition is rapidly being reached where the automobile owner not only pays the cost of operating his car, but the major part of the cost of building and maintaining the roads He is therefore interested in the effect upon motor vehicle operating costs of various road surfaces as well as in the cost of building and maintaining such surfaces

If all roads could be paved, a great saving in operating expenses would be made At present, however, only roads carrying heavy traffic can be paved Those carrying lighter traffic must be constructed with gravel and broken stone The other millions of miles of plain dirt roads ought to be graded and drained so that the traffic using these poorer roads would get its share of the road money It should not be required to help pay for the paved roads and then be compelled to use the poorer dirt roads The vehicle mile might well be made the measure of road expenditures This is a measure of the traffic service rendered by the road Attention might well be diverted toward grading and draining of dirt roads and some study might well be given to the cost of operating vehicles over such roads in an effort to determine the difference between the cost on one that is in good order and on one that is in poor condition

The cost of operating a motor vehicle is the sum of the cost of gasoline, oil, tires, maintenance, depreciation, interest, insurance, garage charges and license The first five items are influenced by the character of the road surface upon which the vehicle is generally operated It is believed that the maintenance and depreciation costs are influenced by the character of the road surface over which the motor vehicle is most frequently operated, but so far there appears to be no determination of the magnitude of this influence, and it would seem that it would be necessary to take similar cars of the same make and drive them to the end of their economic lives If this were done on different types of roads, the maintenance and depreciation costs could be fairly well eliminated The State College of Washington has made some tests and gathered some information relative to the wear of tires on some of the types of roads found in the State

In making tests to determine the wear on tread rubber, a considerable number of elements enter into the problem, some of which are as follows

FACTORS AFFECTING TIRE WEAR

I Those pertaining to the road surface

- a The kind of surface
- b Its condition

II Those pertaining to the car

- a Weight of car
  - 1 sprung
  - 2 unsprung

b Number of engine cylinders
c Character of springs
d Alignment of wheels

III Those pertaining to the driver
a The speed used and wind resistance
b The method of operating brakes
c The number of emergency stops
d Skids, acceleration and deceleration
e General care and skill displayed in driving

IV Climatic conditions
a Air temperature
b Amount and distribution of rainfall
c Amount of sunshine

V Those inherent in the tire
a Kind of tire
b Quality of the tire
c Character of the tread
d Inflation pressure
e Temperature of the tire
f ,Age of the tire.

To determine the effect of any one of these factors upon the wear of tires during a series of tests all others should be kept as nearly constant as possible This, in a measure, may be accomplished by using the same equipment and by making the tests over the same piece of road, in the same condition of maintenance, under corresponding temperature conditions, at the same speed, with tires of the same type, same manufacture, and the same curing, and of the same age with the same degree of inflation, with the same driver, and the chassis in the same state of maintenance In this way a considerable number of the unknown factors may be eliminated. There will still remain the type of road, condition of the surface, both as to roughness, sharpness of material of which constructed, compactness and the amount of uncompacted material floating over the surface The roads used in the State College tests were bitulithic and concrete pavements, water-worn gravel and western type of broken stone macadam The crushed stone roads used under the Washington tests are not water bound They are made from finer material than is common in a water bound macadam, both in the bottom and top courses After construction, they were left for the traffic to roll The crushed stone is basalt of good quality as to hardness, toughness and resistance to abrasion It is generally screened into two bins, one receiving the material from $\frac{7}{8}$ to $1\frac{1}{2}$ or 2 inches in size, and the other bin receiving the finer material. On such roads the stone is spread in two courses, each approximately one-half the total thickness. After the base course has been spread a layer of clay or sandy loam is spread over this for a binder. The traffic and trucks hauling stone over the roads do the rolling, and a blade grader is run over it to keep the ruts filled. Over this a finer top course is spread, but on this no binder is used. The surface of the road is left with a layer of sharp, fine, loose rock, which adds considerable resistance to the movement of a car and adds materially to the wear on the tires.

MAINTENANCE

These broken stone and gravel roads are in all stages of maintenance. The surfaces of new roads are loose, just as they are left by the contractor after the loose top course had been trued up with the blader. Under such conditions, automobile tires push the loose gravel or broken stone out to the sides and form ruts, a process destructive of tread rubber and one that forces the car to continually ascend a constant incline.

The same conditions, only in a lesser degree, obtain on roads that have been compacted through use and have been recently bladed to fill pot-holes and plane off corrugations. This kind of maintenance leaves a thinner layer of loose material for the traffic to work over and through. Where such maintenance is not frequently and regularly attended to, the roads soon develop pot-holes and corrugations, which materially reduce the comfort of passengers, shorten the useful life of the car, and increase the destruction of tread rubber.

There is generally little uniformity in these broken rock surfaces. Under wear they range all the way from hard smooth surfaces to loose gravel, corrugations and pot-holes, all of which conditions may be found on any stretch of sample road.

Corrugations on the broken rock roads examined were about 26 to 27 inches from crest to crest. Consequently, the automobile wheels jump from the crest of one corrugation to the trough of the next, roll up the incline to the succeeding crown and jump to the next trough. This continuous jumping and back kicking of the rear wheels, of necessity, wears down the tread rubber on the tires very much more rapidly than does a pavement, well bound broken rock or graveled road.

Under the conditions here enumerated, it becomes difficult to describe the condition of maintenance of the road under test. Even on the same road two runs might give a wide variation in gas consumed and rubber worn away, depending upon whether the car was driven over the well-beaten track or out of the hard track on loose, floating material

When an investigation is to be made relative to tire wear or destructive effect on a car, it is almost necessary to make up a score card calling attention to all of the variables found in the surfaces to be tested Some gravel and broken stone roads present well-compacted and hard surfaces, while in others the gravel is loose, either from having been recently placed, or having been recently bladed and left with a floating surface of loose material It might also be corrugated, or full of pot-holes There may be a large variation in the thickness of the loose floating material on the surface All of these should be taken into consideration as well as the size and sharpness of the material of which the road is built All of these items and any others that might in any way effect the life of the tire might be put down on such a score card They would be a great help in the effort to find a road surface that would be economical to construct, and which would supply the maximum of economy in operating the car over it

Some samples of a broken basalt road taken a year after the road was built showed the sharp edges practically gone and the fine material very much rounded It would seem that the crushing and grinding effect of the wheels soon grinds away sharp angles, rounds up the stone and makes an old broken rock surface when in good order less destructive to tires than a new one

GAS CONSUMPTION

The added power necessary to force a car through and over a loose broken rock surface, to overcome air resistance and to ascend grades is transmitted through the tires to the road surface and the work thus done requires a greater consumption of fuel, more power is transmitted through the tires to the road, thereby causing a more rapid destruction of the tires

SPRING ACTION

It has long been known that spring action is a leading factor in the upkeep of a car It has a leading part in the economic life of the car and is an important factor in the working life of the tires Efficient springs damp the blows, due to the corrugated roads and thereby minimize the work done by the carcass of the tires and by the rubber coming in contact with the road

ROAD MATERIAL

Theoretically, we would expect waterworn gravel to abrade a tire less than crushed rock, since crushed rock offers sharp edges to the tire This seems to have been proven in the Washington tests The studies made here and elsewhere would indicate that some study of the abrading effect on tires should be given to road materials to the end that flinty material with sharp cutting edges might be avoided

TIRE WEAR AND SPEED

It seems evident that tire wear should be influenced by the speed at which a car is operated Theoretically and actually, more power is required to drive a car at high speed than at low speeds The bounding and spinning of wheels due to ruts should be more destructive of tread rubber at the higher speeds

The few tests of tire wear so far made at different speeds reveal no consistent relationship between these factors The tests at different speeds made at the State College of Washington were made on broken stone covered with a mulch of finely divided broken stone and under constant patrol maintenance with blade graders The differences in wear on the several tires of a car were considerable, and the various runs with the same car did not show closely similar tire wear Plotting tire wear against speed for the cars operated on a single stretch of road produces a wide distribution of points approximately indicating tire wear increases with the speed

Some light upon this relation of tire wear and speed may be had from other investigations covering closely related factors The subject of power loss in automobile tires seems to have been first thoroughly investigated in this country by Professor Lockwood, and has been continued by W L Holt and P L Wormeley at the U S Bureau of Standards

In a report on "Research on Rubber Tires" at the Third Annual Meeting of the Highway Research Board, Mr W L Holt draws the conclusion that "the power loss (in automobile tires) is very nearly directly proportional to the speed—that is, at 40 m p h the loss is approximately twice that at 20 m p h This means that the resistance which a tire offers to rolling, or what will be referred to as the rolling resistance, is very nearly constant and is independent of the speed"

The same result was reached much earlier by Professor Lockwood who reported that "one surprising result of all measurements of rolling resistance at speeds from 20 to 40 m p h has been the slight increase of resistance at the higher speed With some cars the increase of resistance is less than the observation errors In other cases the increase amounts to from 5 to 10 per cent" Considering all tests, Professor Lockwood concluded that the internal rolling resistance of an automobile is practically constant at all speeds up to 50 m p h , and from other tests that the tires are responsible for nearly two-thirds of the power loss in the car itself However, Professor Lockwood says, "the relative resistance on rough, uneven and soft roads will doubtless increase materially with the speed."

The above tests were made upon absorption dynamometers which automatically eliminated the wind resistance This resistance must be overcome by the power of the engine transmitted to the surface of the road through the tires This wind resistance has been shown by Professor Conrad to be given by the formula $R = 0025 A V.^2$ where A is the projected area of the car and V is the relative velocity in miles per hour of air and car Since wind resistance causes an increased tractive force to be exerted and it seems logical to conclude that tire wear per thousand miles will likewise increase with the speed.

TIRE WEAR AND TEMPERATURE

Higher speeds produce increased tire temperatures that may result in increased tire wear through the softening of the rubber, and are undoubtedly the cause of a lessened mileage life of tires The generation of heat and the resultant rise of temperature of tires are the result of the work done by the tires in overcoming the rolling resistance This increase of temperature has been computed by Professor Lockwood, and checked almost exactly by a suitably conducted test

A few tests have been made to determine the effect upon tire wear of variations in air temperature, but have not as yet yielded consistent results The road tests made in 1924 apparently showed that tire wear increases with an increase of air temperature, the other variables of speed, road surface, car and driver being kept as nearly constant as conditions would permit.

The 1925 tire wear tests show no consistent relationship between tire wear and air temperature, probably because the tests on any one road extended over such a limited temperature range

Laboratory tests by Professor W C McNown at the University of Kansas[1] show that tire wear is increased at higher temperatures The increased wear at 130° F as compared to the wear at 70° F amounted to 13 per cent in one set of tests, and to 81 per cent in another, the results not being entirely conclusive

[1] Proceedings of Fifth Annual Meeting, Highway Research Board.

It is a popular impression that tires wear out more rapidly at high temperatures than at low ones A dealer furnishing tires for a Washington bus line that descends a vertical distance of 2,000 feet on an average 4 2 per cent grade ascribes the comparative low mileage (12,000) of the tires used on this run to the heat generated by the brakes upon this grade Tourists across the deserts of southern Nevada and California describe the landscape as littered with abandoned tires, and believe the heat causes a rapid deterioration of tires

Considerable trouble is being experienced by auto bus companies with tires being damaged through heat A heavy bus traveling on a fast schedule requires frequent application of the brakes, and the heat thereby generated produces destructive temperatures, particularly on the inside tire of a dual mounting Experience and tests have both demonstrated that brake drum temperatures of 550° to 600° F are common Ordinary operation over heated pavements will produce temperatures of 150° to 160° F Casings and tubes will withstand these temperatures without serious damage, but they will not withstand the much higher temperatures produced by a nearby brake drum Bus companies, through their large requirements for tires, are in a position to force the dealers to supply tires on a mileage guarantee, and the experience of many dealers has not been either pleasant or profitable Notwithstanding the short life of many tires damaged by heat, there is little information available showing the exact relationship between the wear of a tire and its temperature

Figure 1 shows the total cost of tire equipment used on two bus lines, and apparently it seems to show the effect of hot weather on the life of tires This chart includes the cost by the month of casings, tubes and maintenance, and was given to me by the manager, Mr Lewis A Corbett These data were taken directly from the company's books, and may be relied upon The busses make the same trip each day, the same number of trips each month, consequently, most of the unknowns are eliminated The plotted curve shows a very rapid increase in cost as the season advanced to midsummer, and a similar rapid decrease as the season shades off in the fall On one bus line the average cost for November, December, January and February was about one-third that for the average of July and August The distance traveled was 148,104 miles per year over a crushed rock road, each trip descending a long grade making a total drop of some 2,000 feet On this run 74 casings were used during the year On the other line, the July-August average was more than six times the November-December-January-February average Distance run was 105,600 miles per year over bitulithic surface with a small variation in grade. On this run 40 casings were used during the year.

The loads may have been heavier and the roads somewhat rougher in the dry summer months than in the winter. This may in part account for the wide variation in tire costs between the summer and winter months.

THE RELATIVE TIRE WEAR ON FRONT AND REAR WHEELS

It is generally believed that tires wear more rapidly on rear wheels than on front ones. The tests that have been made show very erratic results, but averages support the general belief. The State College of Washington tests show an average rear tire wear of 140 per cent on macadam, 158 per cent on gravel and 200 per cent on pavement, as compared to front tire wear. The Kansas tests show smaller differences, the averages being 118 per cent for gravel and 138 per cent for concrete. Professor McNown states that normal front tire wear is 50 per cent that of rear tire wear, but this likely would not apply to all road surfaces.

Professor McNown states that "it is to be expected that rear tire indices would be higher for the rough surfaces due to the bounding and spinning of rear wheels. There is abundant evidence in the above data, however, to indicate that for rough surfaces, under the condition of this test, the front and rear tire wear is more nearly the same than for well conditioned surfaces." The tests at the State College of Washington abundantly bear out the above statement.

These tests were made upon western type broken stone macadam, the surface of which when well maintained is covered by a thin mulch of finely broken rock, and when newly constructed or in poor condition by a considerably thicker layer of three-fourth-inch rock. On such surfaces the front wheels are being pushed through a layer of loose material, spreading it out and preparing a path for the rear wheels, with the result that operating over such surfaces, tire wear is more nearly equal upon front and rear wheels. The extremely erratic nature of the results secured indicate that many additional data must be secured before dependable conclusions may be reached.

EFFECT OF WEIGHT OF CAR

Due to a lack of sufficient data, an analysis of tire wear as influenced by the weight of the car is not entirely conclusive. The results seem to show that tire wear per ton of vehicle is either independent of the weight of the vehicle, or else increases slightly with an increase in the weight of the vehicle. Averaging all results on concrete pavements, the tire wear per 1,000 miles per ton of car was

9 8 per cent greater on the heaviest car than on the lightest, the increase of weight of car being 153 per cent While all four cars were not tested on the same pavement, tire wear increased with increased weight of car for each of the two pavements tested, and for all four cars tested

On broken stone macadam the results are not consistent Of the two cars tested on the same road between Pullman and Palouse, the light car has a higher wear per ton of car than the heavier one The average of all tests on macadam are erratic, inasmuch as the medium weight car shows the greatest tire wear per ton of car The average tire wear upon the two heavier vehicles is 18 per cent greater per ton of car than upon the lighter one, the increase of weight being 81 per cent

It is probable, therefore, that tire wear per ton of car is independent of the weight of car, at least for those cars supplied with the correct size of tires and designed by the same engineering standards, and yet there is the question whether the size of tire is not a factor in tire wear There is some evidence to show that the wear on an overloaded tire is greater than on one carrying a more reasonable load

EFFECT OF ROAD SURFACE ON LIFE OF TIRES

While such tests as have been reported yield valuable information, showing the effect of various road surfaces upon the wear of tires, the real factor desired is the effect of road surfaces upon the mileage life of tires This can be determined only by a long-time test, starting with new tires and operating the car continuously over the same road surface until the tires are destroyed Many such tests would be necessary in order to secure dependable averages, and the cost of such testing would be considerable It is well known that the mileage life of tires is sometimes greatly reduced by such factors as tread cuts, blisters, stone and rail bruises, shimmying, under-inflation, punctures, corrugation, ice, ruts, pot-holes and other conditions

Probably the most reliable method of determining the mileage life of tires upon various road surfaces would be to secure the life history of tires from the owners of cars operated exclusively upon certain road surfaces This is difficult to do, as few owners keep accurate record of their tire mileage and fewer still operate their cars exclusively upon one kind of surface Cars operating exclusively upon surfaces with similar wear characteristics are probably mostly owned by taxicab companies and automobile bus lines A few records secured from western bus lines and other sources are brought together in Table IV

These scattered records seem to be in agreement with the tire wear tests, inasmuch as tires operated over pavements seems to have a mileage life about twice as great as those driven over gravel or macadam

In addition to a greater tire mileage on pavement, bus companies report other items of expense materially greater when operating on gravel or macadam surfaces One company reports that there is a great deal more tire trouble when using earth, gravel or macadam surfaces Tacks and nails are more easily picked up and are more frequently the cause of punctures Cuts in casings fill quickly with dirt, which soon causes blisters and tread separation

The life of a tire is generally not determined by external, but by internal wear An interesting confirmation of this was obtained from J C Corbett, of Walla Walla, who stated that on the bus line to Pendleton tires were seldom discarded from excessive wear of tread rubber, but generally as a result of internal defects Mr Holt has stated that "contrary to what seems to be the popular idea, the problem in tire building is not to make a tread which will wear, but to make a tire in which the component parts—the plies, the breaker, the tread, etc ,—will stay together, and at the same time distribute the various strains so that the strain will not be excessive at any point As soon as any of thep arts separate, chafing immediately sets in, blisters begin to appear at various places, and the life of the tire is about gone "

Professor McNown has, however, more recently stated that "tire manufacturers are of the opinion that at present the carcass is developed ahead of the tread and that the normal failure of a tire is by tread wear and not by carcass failure " Probably this is true for present day tires running over improved surfaces, but it may not be the case when running over unimproved surfaces

TIRE OPERATING COSTS

Tests of tire wear upon various road surfaces will be of value both to the owner of automobiles and to the public officials who build and maintain the highways The automobile owner is chiefly interested in his tire cost per mile and for the year, while the highway engineer is interested in determining the amount he can afford to spend in providing road surfaces that reduce tire wear

With the impossibility of considering and accounting for all the elements that enter into tire wear, it does not seem probable that any definite law can be laid down covering the amount of tread rubber lost due to any particular type of road surface

If all cars used in making the tests were equipped with an autographic meter to record the gasoline consumption, an instrument to record graphically the roughness of the road surface, an instrument to autographically record grades and one to autographically record distances, all were to be synchronized, it would seem that much additional information might be secured that, in the end, would be valuable in road studies I take it that the aim of all the work that is being done on road surfaces is to furnish information on how best to build a road so as to secure greatest economy both in construction and in operating costs It would seem that some system of measuring operating losses ought to be worked out so that it would be understood by the great mass of people using the highways If a general rule based upon gasoline consumption could be worked out and promulgated, one that the public would understand, it might help to improve road conditions We must somehow get before the users of the roads the relationship of the cost of the road and the cost of operating a vehicle over it in terms of some unit of measure that is common It would seem to me that since the tires are only a part of the transmission, transmitting the work of the engine to the road surface, that the amount of gasoline required to drive the engine should be a fair measure of the cost of operating a vehicle If the public could understand about what travel there is on a certain piece of road and what it costs per mile to the user of the road to have it ready to use and what it cost per mile for him to operate a car over such a road and the cost of gasoline per mile driven and the relationship of the gasoline to the total operating charge, he would soon begin to understand that more good roads would reduce his total expenditure for transportation over the highways

Particularly here in the west, we must use a large mileage of roads, surfaced with gravel and broken stone and we need to know how to maintain such roads so as to make the cost of operating over them as low as possible Studies that would provide such information would be timely We have thousands of miles of earth roads that American farmers must use to haul their produce to market Thousand of miles of these are yet ungraded and undrained, making the expense of hauling over them very great The study on how to construct and maintain earth roads so that they may be passable for light winter traffic as well as heavy summer hauling is timely

TABLE I

RESULTS OF TESTS

No of test	Average loss, grams per 500 miles	Loss, lbs per 1,000 miles	Kind of road surface	Remarks
R-1	47 25	0 2083	Concrete	Aggregate 4/5 soft limestone, 1/5 Joplin flint, surface rough
R-3	20 50	0904	Concrete	Aggregate medium limestone, surface very good
R-8	37 25	1642	Concrete	Aggregate medium limestone, surface very good
R-13	48 50	2128	Concrete	Aggregate medium limestone, surface very good
R-16	83 25	3571	Concrete	Surface fair, balloon tires
R-5	61 00	2690	Brick-monolithic	Surface good
R-9	48 25	2117	Brick-monolithic	Bituminous filled, air 92°
R-10	29 00	1279	Brick-monolithic	Bituminous filled, air 92°
R-14	53 50	2359	Brick-monolithic	Bituminous filled, balloon tires, air 64°
R-15	11 00	0485	Brick-monolithic	Bituminous filled, air 90°
R-4	68 00	2998	Bituminous macadam	Left-hand wheels
R-4	282 00	1 2334	Bituminous macadam	Right-hand wheels
R-11	283 25	1 2389	Bituminous macadam	
R-12	301 50	1 3294	Bituminous macadam	
R-2	148 00	6526	Gravel	Gravel from uncrushed chert
R-7	60 5	2668	Gravel	Typical of good gravel, loose surface, unplaned
36		0325	Concrete	Surface good, but not excellent, car 1
38		0629	Concrete	Surface good, but not excellent, car 1
37		0760	Concrete	Surface good, but not excellent, car 2
39		0360	Concrete	Surface good, but not excellent (1 tire only), car 2
42		1136	Concrete	Surface generally good, car 3
48		0960	Concrete	Surface generally good, car 3
43		2080	Concrete	Surface generally good, car 4
49		0570	Concrete	Surface generally good, car 4
44		1020	Bitulithic	Car 3
46		1890	Bitulithic	Car 3
45		1170	Bitulithic	Car 4
47		0910	Bitulithic	Car 4

TABLE I—Continued

RESULTS OF TESTS

No of test	Average loss, grams per 500 miles	Loss, lbs per 1,000 miles	Kind of road surface	Remarks
50		723	Gravel	Water worn, car 3
52		527	Gravel	Water worn, car 3
1		542	Macadam	Pullman to Palouse, car 1
5		271	Macadam	Pullman to Palouse, car 1
7		360	Macadam	Pullman to Palouse, car 1
19		418	Macadam	Pullman to Palouse, car 1
21		433	Macadam	Pullman to Palouse, car 1
23		275	Macadam	Pullman to Palouse, car 1
25		343	Macadam	Pullman to Palouse, car 1
34		290	Macadam	Dishman south, car 1
40		244	Macadam	Dishman south, car 1
8		590	Macadam	Pullman to Spokane, car 2
35		618		Dishman south, car 2
41		777		Dishman south, car 2
11		1 122		Pullman south, car 2
17		1 045		Pullman south, car 2
27		1 456		Pullman south, car 2
33		435		Pullman south, car 2
1		911		Pullman to Palouse, car 3
4		271		Pullman to Palouse, car 3
6		573		Pullman to Palouse, car 3
18		965		Pullman to Palouse, car 3
20		528		Pullamn to Palouse, car 3
22		697		Pullman to Palouse, car 3
24		453		Pullman to Palouse, car 3
9		308		Pullman to Spokane, car 3

TABLE II A
RELATIVE WEAR, FRONT AND REAR WHEELS

State College of Washington Tests

Test No	Average wear, grams		Miles per test	Average wear, gms per 100 mi		Wear on rear tire in per cent of front tire wear	Surface
	Front	Rear		Front	Rear		
2	11 3	17 3	61 1	18 5	28 4	154	Macadam
5	7 9	6 8	60 0	13 2	11 3	86	Macadam
7	7 1	12 4	60 0	11 8	20 7	175	Macadam
19	9 1	12 9	59 6	15 3	21 7	142	Macadam
21	8 6	13 6	60 0	14 3	22 7	159	Macadam
23	6 7	9 8	61 3	10 9	16 0	147	Macadam
25	7 9	10 1	60 4	13 1	16 7	128	Macadam
34	6 3	14 9	80 4	7 8	18 6	238	Macadam
40	5 2	12 7	80 9	6 4	15 7	246	Macadam
8	53 0	70 3	169 0	31 4	41 6	133	Macadam
11	9 6	8 5	23 3	41 2	36 5	89	Macadam
17	11 3	9 9	23 6	48 0	41 9	87	Macadam
27	14 9	15 6	23 5	63 4	66 4	105	Macadam
33	6 1	2 8	24 9	24 5	11 3	46	Macadam
35	23 4	21 7	80 4	29 2	27 0	92	Macadam
1	21 1	27 1	61 1	34 6	44 4	128	Macadam
4	21 6	14 7	60 0	36 0	24 6	68	Macadam
6	18 9	11 7	61 1	31 0	19 2	62	Macadam
18	25 4	25 5	59 6	42 6	42 8	101	Macadam
20	12 0	15 8	60 0	20 0	26 3	132	Macadam
24	4 5	19 3	59 6	7 6	32 4	427	Macadam
					Average 140 for		Macadam
36	0 7	3 9	157 0	0 4	2 5	625	Concrete
37	13 8	4 4	170 3	8 1	2 6	32	Concrete
42	4 4	7 9	120 0	3 7	6 7	181	Concrete
48	5 2	5 1	117 8	4 4	4 3	98	Concrete
43	15 2	7 8	122 0	12 5	6 4	51	Concrete
49	2 1	5 0	119 0	1 8	4 2	233	Concrete
					Average 203 for		Concrete
44	3 4	7 4	117 0	2 9	6 3	217	Bitulithic
46	5 6	9 2	114 1	4 9	8 0	163	Bitulithic
	6 3	6 5	120 4	5 2	5 4	104	Bitulithic
..	2 3	7 1	114 9	2 0	6 2	310	Bitulithic
					Average 198 for		Bitulithic
52	9 2	14 5	58 7			158	Gravel

TABLE II B

RELATIVE WEAR, FRONT AND REAR WHEELS

Kansas Results

Test No	Average tire wear, grams per 500 miles		Wear on rear tires in terms of wear on front tires, percent	Kind of surface
	Front	Rear		
R-1	32½	62	191	Concrete
-3	11½	29½	256	Concrete
-8	53½	21	39	Concrete Same as R-3
-13	59	38	64	Concrete Same as R-3
-16	81½	85	104	Concrete Surface fair
Average			131	Concrete
R-5	94	28	30	Brick—Monolithic
-9	64½	32	50	Brick—Bituminous filled
-10	40	19	47	Brick—Bituminous filled
-14	59	48	81	Brick—Bituminous filled
-15	15	9	60	Brick—Bituminous filled
Average			54	Brick
R-11	289	278	93	Bituminous macadam
R-12	290	314	108	Bituminous macadam
Average			100	Bituminous macadam
R-7	60	61	102	Gravel, typical Iowa
R-2	136	160	118	Gravel, uncrushed chert

TABLE III

SUMMARY OF TIRE WEAR TESTS

Effect of Weight of Car

Car No	Weight	Average wear, lbs per 1,000 miles	Average wear, lbs per 1,000 miles per ton of car	Kind of road surface
1	1740	0 0477	0 0549	Concrete, Spokane to Cœur d'Alene
2	2750	0760	0552	Concrete, Spokane to Cœur d'Alene
3	3560	1048	0589	Concrete, Olympia to Vancouver
4	4400	1325	0603	Concrete, Olympia to Vancouver
1	1740	349	401	Macadam, Pullman to Palouse
3	3560	628	335	Macadam, Pullman to Palouse
1	1740	353	407	Macadam, av of all runs
2	2750	863	628	Macadam, av of all runs
3	3560	588	330	Macadam, av of all runs
1			407	Macadam, av of all runs
2 and 3			479	Macadam, av of all runs

TABLE IV

TIRE OPERATING DATA FROM BUS COMPANIES

Owner or authority	State	From	To	Kind of bus	Size of tire	Length run, miles	Reported mileage	Surface
Red Ball Transportation Company	Iowa	Mason City	Algona	Fageols, Macks			28,000–30,000	Concrete
Red Ball Transportation Company	Iowa	Mason City	Various	Fageols, Macks			20,000	Earth and gravel
Hawley	Washington	Spokane	Cœur d'Alene		36x6	33	30,000	Concrete
Hawley	Washington	Spokane	Almira		36x6		16,000	24 m concrete 58 m macadam
—(?)—	Washington	Spokane	Almira				Summer 12,000	24 m concrete 58 m macadam
Spokane-Lewiston Stage Line	Washington	Spokane	Lewiston, Idaho		34x7	115	12,000	102 m macadam 13 m concrete
S C Hadden	Indiana	Indianapolis	Richmond	2½ ton G M C			28,000	Concrete
Mrs W I Coldiron		Indianapolis	Bloomington	Studebaker			12,000	Gravel
J C Corbett	Washington	Walla Walla	Lewiston	White 2-ton trucks		100	8,005	Macadam
J C Corbett	Oregon	Walla Walla	Pendleton	White 2-ton trucks		42	10,570	Bitulithic

TABLE V

PASSENGER AUTOMOBILE COSTS

From Bulletin 69, Iowa State College

Composite car	Cents per mile
Gasoline	1 61
Oil	0 31
Tires	0 98
Maintenance	1 24
Depreciation	3 16
Interest	1 24
Insurance	0 31
Garage	0 83
License	0 59
Total	10 27

PROGRESS REPORT ON TIRE WEAR INVESTIGATION

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The following is a summarized report upon part of the work done during the past season on the cooperative tire wear project between the U S Bureau of Public Roads and the University of Kansas This part deals with the wear of balloon tires only Further data upon the wear of high pressure tires will be available later

The same general method has been used as in previous years A Dodge Bros Special Touring Car of 1925 model was substituted for the older model used in other years The speed was increased from 25 to 35 miles per hour A set of 30 x 5 77 All Weather Tread balloon tires were used throughout and the same two tires were kept in front and in rear These tires were made for this work by the Goodyear Tire & Rubber Company and were all from the same batch in order to insure uniformity.

The effect of temperature upon the tread wear of balloon tires seemed to be so marked that an attempt has been made to reduce all tire wear indices to the same temperature basis Table I summarizes the results