Technical Support Report for Regulatory Action

Variations in Tire Rolling Resistance

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Abstract

This paper analyzes the tire rolling resistance data obtained in a recent EPA road load project. Variations in the observed tire rolling resistances were analyzed versus tire type, tire manufacturer, and tire size. The differences between tire types have been previously investigated and are generally known. However, the variations by tire size and among manufacturers have not been previously reported.

Statistically significant variations were observed for all of the investigated parameters. The difference between the means of the rolling resistance coefficients for radial versus bias ply tires was approximately 24 percent. The observed variations among manufacturers were suprisingly large. The range of the variations among the manufacturers, within the class of radial or bias tires, was greater than the difference between the overall means of these tire types. In the case of radial tires, the range of the variations by tire size was somewhat smaller than the difference between the tire type means, while in the case of bias ply tires, the range of the variations by tire size was about the same as this difference between the tire types.

The fuel economy effect of a change in tire types; that is, from bias to radial tires, has been previously reported and is briefly discussed. From these results it is concluded that a 10 percent change in rolling resistance will yield approximately a 2 percent change in the vehicle fuel economy. It is estimated that the fuel economy effect of a low rolling resistance radial tire, versus an average radial tire, is as great as the fuel economy effect of a radial versus bias ply tire. Consequently, there is a very good potential for reduction in national fuel consumption if the use of low rolling resistance radial tires can be promoted. This is particularly attractive since the technology for these tires already exists. In addition, the implementation time for reduction in national fuel consumption by improvements in this area is much shorter than the time required for fuel economy improvements by changes in automotive technology. This would occur because the life expectancy of the tire is much less than the life expectancy of the vehicle, hence tire replacement occurs much more frequently.

At the present time, reduction of fuel consumption through optimization of tires cannot be expected to occur since there is no uniform method of rating and reporting tire energy dissipation. The development of a consistent, uniform method of rating and reporting tire energy dissipation over cyclic driving schedules, such as the EPA test schedules is recommended.

I. Purpose

This report presents the variations in tire rolling resistances which were observed during the recent EPA road load project (1)*. The variations are analyzed versus the type of tire construction, the tire manufacturers and the tire size. The fuel economy effects associated with these variations in tire rolling resistances are discussed.

II. Background

The vehicle tire has a very significant effect on the fuel consumption of the vehicle. The vehicle road load, that is the total force required to maintain the vehicle at a constant speed on a level road surface, is the sum of the mechanical rolling frictions of the vehicle chassis, the tire rolling resistance forces and the aerodynamic drag. Below 40 mph, the tire rolling resistances are typically predominate and are approximately constant with speed (2). Because of the large volume of driving conducted below 40 mph, the tire rolling resistance has a very significant effect on the fuel consumption of a vehicle.

The rolling resistances of 60 tires were measured during the recent EPA road load project. Because of the fuel economy significance of the tire rolling resistance it was decided to analyze these data and report the conclusions.

III. Discussion

The discussion is presented in three sections. The first section describes the EPA tire rolling resistance measurements. The results of a statistical analysis of these measurements are presented in the second section. Finally, the fuel economy effects of these results are discussed.

A. The Tire Measurements

In a recent project to determine vehicle road load, the rolling resistances of approximately 60 sets of tires were measured. These tires were tested, as received, installed on the test vehicles (1). The test vehicles were chosen to approximately represent the sales distribution of current light-duty vehicles. These vehicles are identified in Table 1 of Appendix A, while the tires are identified in Table 2 of Appendix A.

All tire rolling resistance measurements were conducted on one of the EPA light-duty vehicle electric dynamometers. This dynamometer is a G.E. motor-generator type with a 48" diameter single roll. During these experiments the normal 0-1000 lb. load cell of the dynamometer was replaced with a more sensitive 0-300 lb. load cell. Prior to all measurements, the cold tire pressures were adjusted to the inflation pressures recommended by the manufacturer and these pressures were recorded. These pressures are given in Table 5 of Appendix A.

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* Numbers in parentheses designate references at the end of the paper.

The vehicle was placed on the dynamometer, and then the vehicle and dynamometer were warmed up for 30 minutes at approximately 50 mph. After warm up, the torque necessary to motor the dynamometer and vehicle was measured at speeds from 60 to 10 mph in 5 mph decreasing speed intervals. For each measurement, steady state dynamometer speed and torque signals were recorded on a strip chart for a period of approximately 100 seconds. The stabilized values were then read from the strip chart by the dynamometer operator.

After the measurements were completed with the full vehicle weight resting on the dynamometer rolls, the vehicle was then lifted until the vehicle tires were just contacting the dynamometer roll. The vehicle tires were considered to be just touching the dynamometer roll if a person could, with difficulty, manually cause the tire to slip on the roll when the roll was locked. With this test configuration the torque versus speed measurements were repeated as before. These force measurements were conducted on both the front and rear axles of the vehicle. During the rear axle measurements the transmission was shifted into neutral.

The tire rolling resistances were computed by subtracting the torque measurements obtained when the tire was just contacting the dynamometer roll from the torque measurements obtained with the full axle load on the dynamometer. A scatter plot of the data from one vehicle, after conversion to units of force at the tire-roll interface, is given as an example in Figure 1.

The tire rolling resistance generally appeared nearly constant over the observed speed range, with a slight linear increase with increasing speed. Consequently, linear least squares regressions were conducted to yield equations for the tire rolling resistances as a function of the simulated vehicle speed. The coefficients of the regression analyses are given in Table 3 of Appendix A.

One purpose of this report is to estimate the fuel economy effect of various tires. This effect will be estimated over the EPA urban and highway driving cycles which are assumed to represent national driving characteristics. Consequently, the tire rolling resistance forces at the mean speeds of each of these driving cycles was considered to be the best single estimate of the performance of the tire over the cycle. These mean speeds are 19.6 and 48.2 mph for the urban and highway cycle respectively. The tire rolling resistance force for approximately each of these speeds, 20 and 50 mph, was computed from the speed dependent coefficients. These forces, representing the measurements obtained on the large single roll dynamometer for each vehicle axle, are presented in Table 4 of Appendix A.

The purpose for the original tire data collection was to characterize the vehicle experience. Therefore, all tire measurements were conducted on the test vehicle for which the tires were supplied, and at the inflation pressures recommended by the manufacturer of the vehicle.

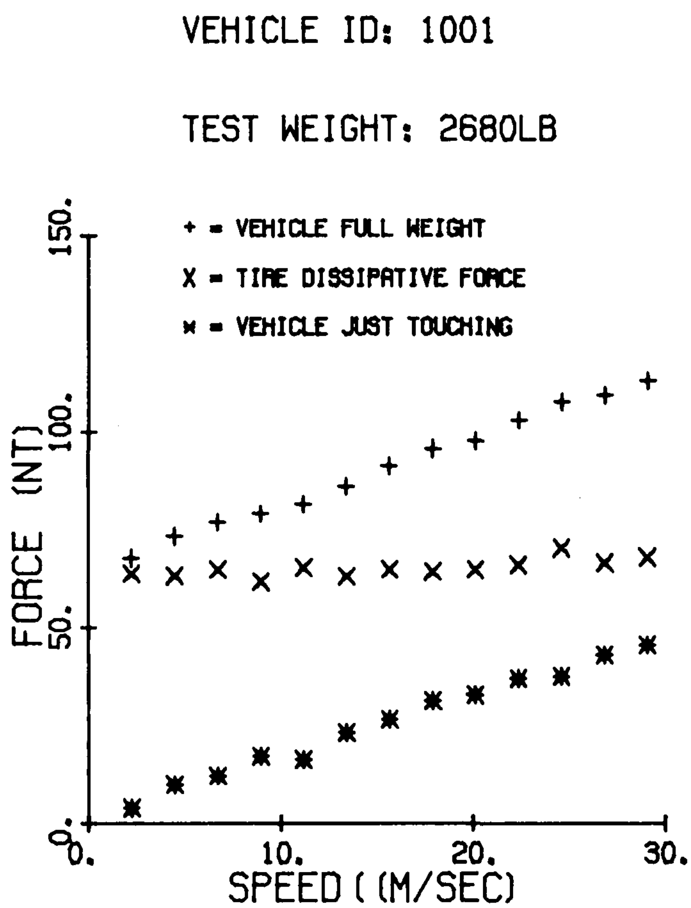

Fig. 1 - Example of Force Measurements at the Tire Roll Interface

The purpose of this report is to discuss the observed rolling resistances and to search for variations by tire type and tire manufacturer. Therefore, in this case it is necessary to remove any vehicle induced variations in the tire rolling resistances. Consequently tire inflation pressure corrections were applied to the measurements to correct to a standard average inflation pressure. Also, all data were converted to estimates of the flat road rolling resistances to minimize any effects of the dynamometer curvature. Finally, the tire rolling resistances were converted to coefficients of tire rolling resistance, in terms of pounds (or newtons) of rolling resistance force per thousand pounds (or newtons) of vehicle weight, to minimize the effects of variations in the weights of the test vehicles.

1. Tire Pressure Correction Effects

The rolling resistance measurements conducted in this study were performed at the inflation pressures recommended by the vehicle manufacturer. To minimize the tire effects of variations in inflation pressure, the rolling resistance forces were corrected to estimates of the rolling resistances at the inflation pressure of 25 psi for non-driving tires and 26 psi for the vehicle driving tires. These pressures were the approximate mean of the observed inflation pressures. The correction factor used, 3%/psi, was obtained from a Calspan Corporation report for DOT (3). Approximately similar results have been reported elsewhere in the literature (4). No recommended inflation pressures greater than 32 psi were observed and generally the pressure correction was for a much smaller variation. The cold tire inflation pressures prior to the test are given in Table 5 of Appendix A.

2. Dynamometer Roll Curvature Correction

The dynamometer roll curvature results in a higher measured rolling resistance on the dynamometer than would be observed on a flat road surface. This is particularly important since the roll curvature effect is dependent on the tire size. The total tire rolling resistance force coefficients for each axle were corrected to an estimate of the flat surface force by using the conversion factor (5):

$$F_f = F_d / \sqrt{1 + \frac{r}{R}}$$

where

F_f = the rolling resistance of the tire on a flat road surface

F_d = the rolling resistance of the tire on a cylindrical dynamometer surface

r = The radius of the tire

R = the radius of the dynamometer roll

The radii of the tires were determined by measuring the height of the loaded tire, from the contact patch to the top of the tread and dividing by two. Previous experiments at the EPA have shown this technique is a very good simple static measurement of the dynamic rolling radius. Five to ten tires of each tire size were measured and the average of the measured radii for all tires of that size was calculated. These average rolling radii are given in Table 1. The average rolling radius for each tire size was used in the dynamometer curvature corrections for all tires of that nominal size.

Table 1

Rolling Radii versus Tire Size

Nominal Tire Size	Average Rolling Radii
12 inches	0.27 m
13 inches	0.28 m
14 inches	0.31 m
15 inches	0.34 m

The rolling resistance forces for each axle, after all corrections, are presented in Table 6 of Appendix A.

The total corrected tire rolling resistance force for each vehicle was then computed by summing the forces of each axle. The dimensionless rolling resistance coefficient was then computed by dividing this force by the vehicle test weight. The concept of rolling resistance coefficient is useful since the tire dissipative losses are very nearly proportional to the vertical load on the tire (6). For this reason, the tire rolling resistance coefficient is frequently used in the literature for tire comparison. The computed tire-rolling resistance coefficients are presented in Table 7 of Appendix A, as are the total vehicle forces and the vehicle weight. While the rolling resistance coefficient is a dimensionless unit, these coefficients are presented in the more common form of the tire rolling resistance in pounds (newtons) per 1000 pounds (newtons) of vertical load.

B. Statistical Analysis of Tire Rolling Resistance Coefficients

1. Tire Type

It has been found in past studies, and is generally accepted, that radial tires have lower tire rolling resistance coefficients than bias tires (7). As shown in Table 2 the mean rolling resistance at 20 mph for the radial tires investigated in this study was 7.0 lb/klb, while the mean coefficient at 20 mph for the bias ply tires was 9.2 lb/klb. At 50 mph the means were 7.5 lb/klb and 9.9 lb/klb for radial and bias tires, respectively. A "t-test" of each difference indicated the rolling resistance coefficient for radial tires was lower than for bias tires at

Table 2

Tire Rolling Rsistance Coefficient
Means by Tire Type

Tire Type	Test Speed (mph)	Number of Vehicles in Sample	Mean Rolling Resistance Coefficient	Sample Variance
Radial	20	48	6.95	2.85
Radial	50	48	7.52	3.02
Bias	20	16	9.17	2.32
Bias	50	16	9.93	2.38

Conclusions

The rolling resistance coefficient for radial tires is significantly lower than the rolling resistance coefficient for bias ply tires at both test speeds. The t-test statistics for the difference of the means were 4.66 for the 20 mph data and 4.94 for the 50 mph data. Both were significant at the 99% confidence level.

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the 99% confidence level for both speeds. These results are graphically displayed in Figure 2. Since tire type strongly influences the rolling resistance coefficient, all subsequent analyses were conducted on radial and bias ply tires separately.

2. Tire Manufacturer

The comparison of rolling resistance coêfficients by tire manufacturer was considered an important part of this analysis since such comparisons are not generally available. For each tire type, the mean rolling resistance coefficient at 20 mph and at 50 mph for each tire manufacturer was compared to the grand mean of the corresponding tire type. The calculations are presented in Tables 3 through 6. The plots of each manufacturer's mean and standard deviation (in the cases of more than two observations) are shown in Figures 3 and 4.

The variations among tire manufacturers is quite noticeable. In the case of radial tires the range of the variations among manufacturers was greater than the difference between the grand means of radial versus bias types of construction.

3. Tire Size

It has been suggested that tire size may have a significant effect on the tire rolling resistance coefficient (8). Consequently, an investigation of the rolling resistance coefficients by tire size was

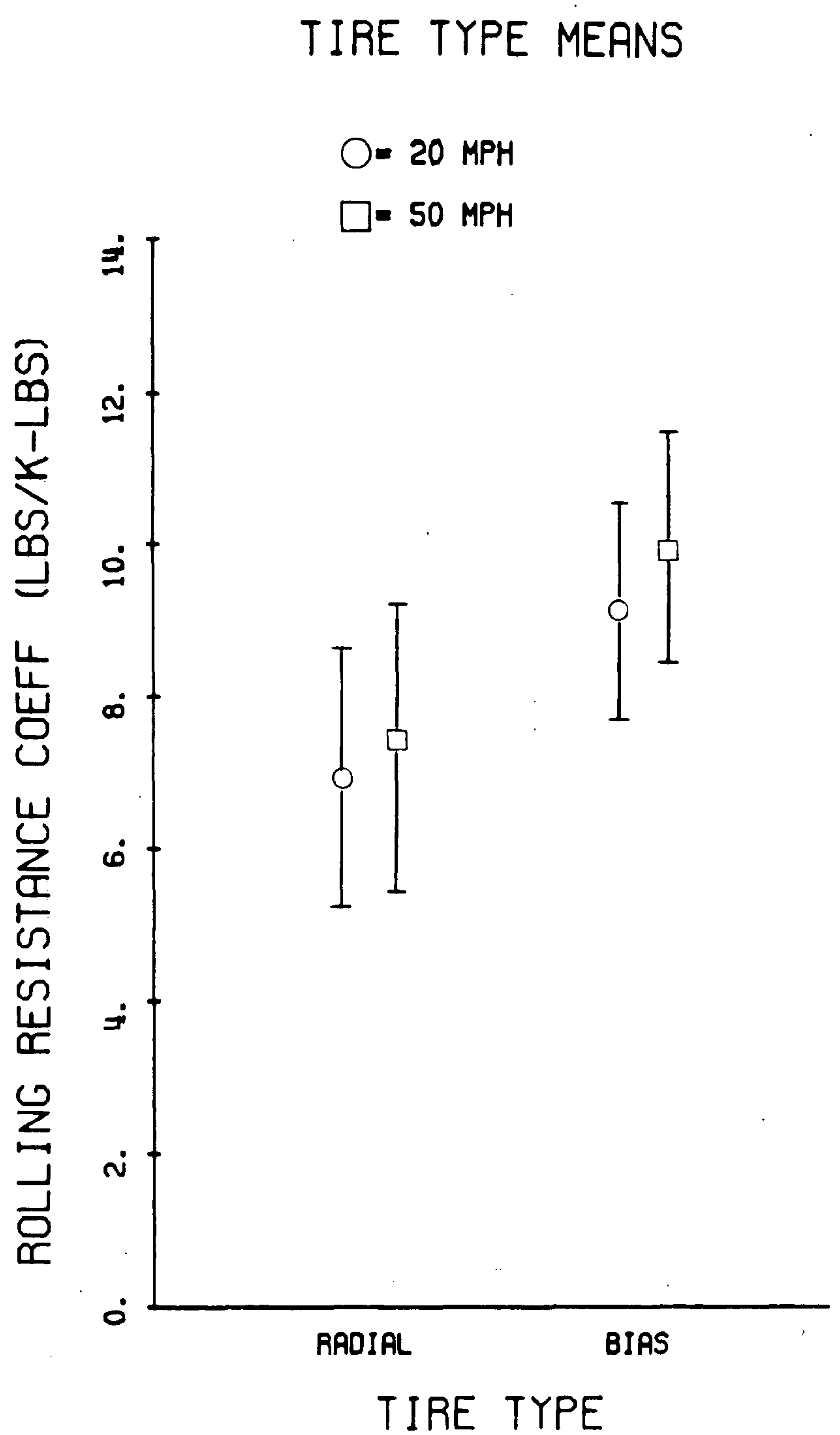

Fig. 2 - Means of the Tire Rolling Resistance Coefficients by Tire Type. The error bars designate one standard deviation of the data.

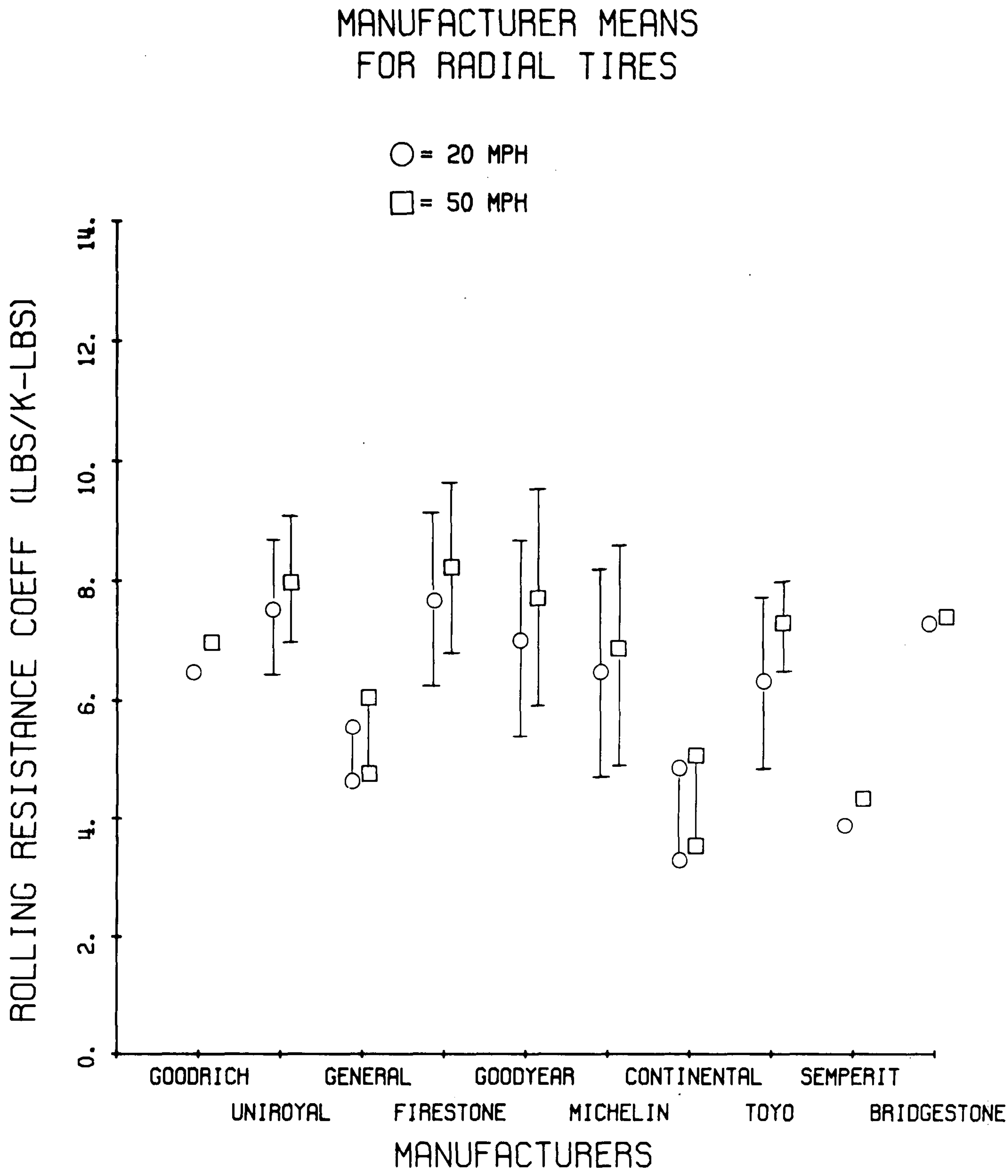

Fig 3. - Means of the Radial Tire Rolling Resistance Coefficients by Manufacturer. The error bars designate one standard deviation of the data for those manufacturers where at least three observations occurred. If only one or two observations occurred the plotted symbols designate the observed values.

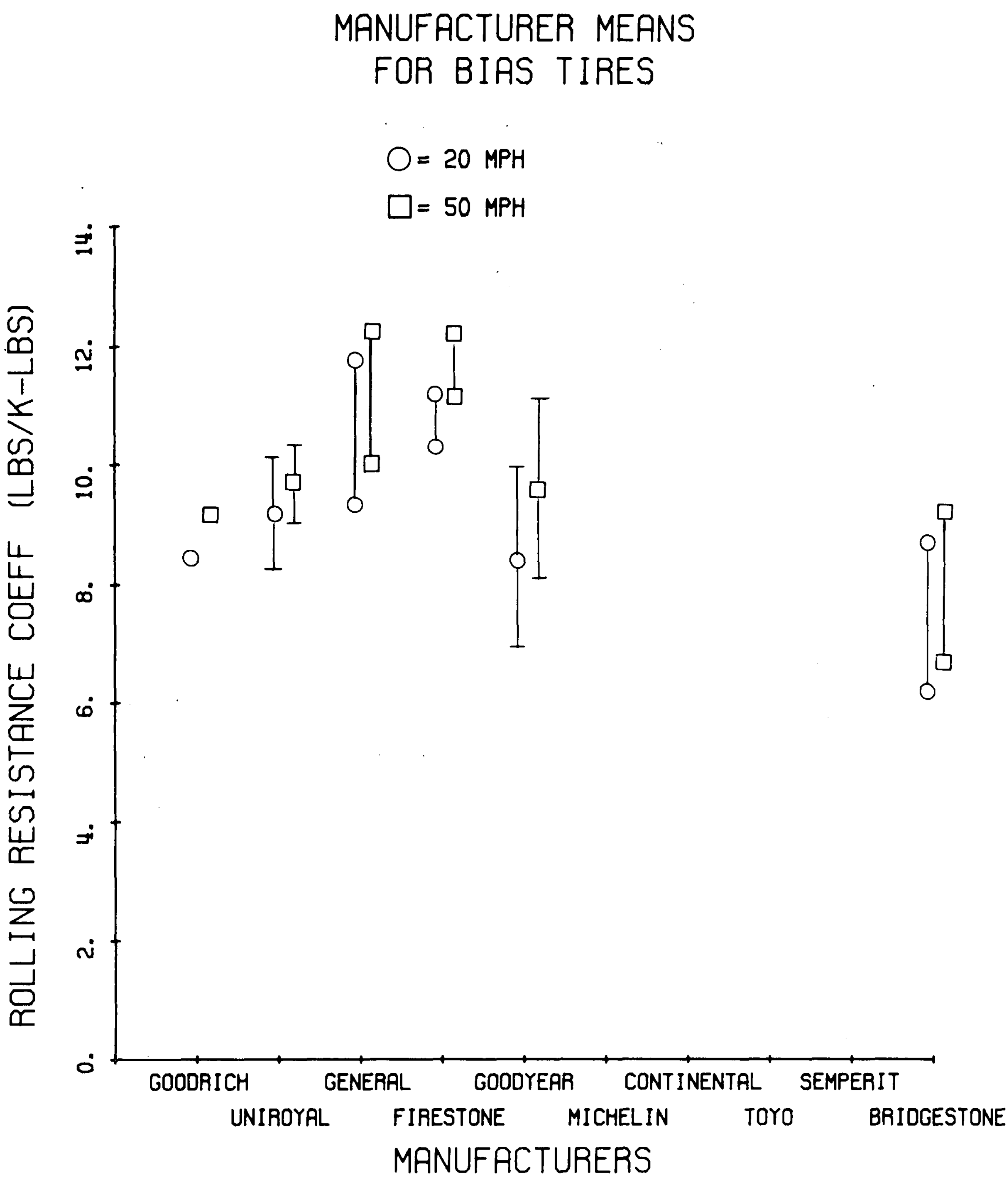

Fig. 4 - Means of the Bias Tire Rolling Resistance Coefficients by Manufacturer. The error bars designate one standard deviation of the data for those manufacturers where at least three observations occurred. If only one or two observations occurred, the plotted symbols designate the observed values.

Table 3

Radials - 20 MPH

Test of the Mean Tire Rolling Resistance Coefficient at 20 MPH for each Manufacturer vs. Grand Mean for all Radial Tires at 20 MPH

Manufacturer	Number of Vehicles in Sample	Mean Rolling Resistance Coefficient	Sample Variance	Z-Stat	Signif.
Goodrich	1	6.511	--	.260	.3974
Uniroyal	8	7.583	1.391	1.010	.1562
General	2	5.129	.448	-1.513	.0643
Firestone	15	7.733	2.250	1.601	.0548*
Goodyear	9	7.067	2.825	.185	.4267
Michelin	6	6.469	3.141	-.661	.2546
Continental	2	4.123	1.160	-2.341	.0096**
Toyo	3	6.213	2.234	-.741	.2296
Semperit	1	3.844	--	-1.825	.0336**
Bridgestone	1	7.214	--	.153	.4392
Grand	48	6.954	2.845		

Conclusions

* The rolling resistance coefficient at 20 mph for Firestone radial tires is significantly larger than the grand mean rolling resistance coefficient for all radial tires at 20 mph (confidence level is slightly less than 95%)

** The mean rolling resistance coefficients for Continental and Semperit are significantly smaller than the grand mean rolling resistance coefficient for all radial tires at 20 mph.

Table 4

Bias - 20 MPH

Test of the Mean Tire Rolling Resistance Coefficient at 20 mph for each Manufacturer vs. Grand Mean for all Bias Tires at 20 MPH

Manufacturer	Number of Vehicles in Sample	Mean Rolling Resistance Coefficient	Sample Variance	Z-Stat	Signif.
Goodrich	1	8.555	--	-.410	.3409
Uniroyal	4	9.249	.827	.098	.4610
General	2	10.716	2.712	1.396	.0814
Firestone	2	10.809	.405	1.532	.0628*
Goodyear	5	8.587	2.260	-.779	.2180
Bridgestone	2	7.618	3.026	-1.401	.0808
Grand	16	9.173	2.136		

Conclusions

* The rolling resistance coefficient at 20 mph for Firestone is statistically larger than the grand mean rolling resistant coefficient for all bias tires at 20 mph but at a confidence level of at most 93.7%.

Table 5

Radials - 50 MPH

Test of the Mean Rolling Resistance Coefficient at 50 MPH for each Manufacturer vs. Grand Mean for all Radial Tires at 50 MPH

Manufacturer	Number of Vehicles in Sample	Mean Rolling Resistance Coefficient	Sample Variance	Z-Stat	Signif.
Goodrich	1	6.986	--	-.301	.3821
Uniroyal	8	8.095	1.397	.905	.1827
General	2	5.483	.902	-1.632	.0516**
Firestone	15	8.328	2.208	1.632	.0516*
Goodyear	9	7.756	3.438	.377	.3531
Michelin	6	6.821	3.325	-.918	.1793
Continental	2	4.402	1.092	-2.499	.0062**
Toyo	3	7.220	.541	-.290	.3859
Semperit	1	4.369	--	-1.792	.0367**
Bridgestone	1	7.536	--	.012	.4952
Grand	48	7.515	3.021		

Conclusions

* The rolling resistance coefficient at 50 mph for Firestone tires is significantly larger than the grand mean rolling resistance coefficient for all radial tires at 50 mph.

** The rolling resistance coefficients for General, Continental and Semperit tires at 50 mph are significantly smaller than the grand mean rolling resistance coefficient for all radial tires at 50 mph. (The confidence levels for Firestone and General are slightly less than 95%.)

Table 6

Bias - 50 MPH

Test of the Mean Rolling Resistance Coefficient at 50 MPH for each Manufacturer vs. Grand Mean for all Bias Tires at 50 MPH

Manufacturer	Number of Vehicles in Sample	Mean Rolling Resistance Coefficient	Sample Variance	Z-Stat	Signif.
Goodrich	1	9.257	--	-.422	.3365
Uniroyal	4	9.772	.455	-.195	.4227
General	2	11.174	2.677	1.072	.1419
Firestone	2	11.800	.427	1.660	.0485*
Goodyear	5	9.687	2.386	-.306	.3798
Bridgestone	2	8.066	3.814	-1.580	.0571**
Grand	16	9.929	2.381		

Conclusions

* The rolling resistance coefficient at 50 mph for Firestone bias tires is statistically larger than the grand mean rolling resistance coefficient for all bias tires at 50 mph.

** The rolling resistance coefficient at 50 mph for Bridgestone bias tires is significantly smaller than the grand mean rolling resistance coefficient at 50 mph for all bias tires (confidence level is slightly less than 95%).

conducted. The rolling resistance coefficients are plotted versus tire size for both radial and bias ply tires in Figures 5 and 6. This information is also presented in Table 7. For each tire type, the means of the rolling resistance coefficients decrease with an increase in the tire size. A paired comparison analysis of variance showed that for the 20 mph coefficients, the only significant decrease was that of the mean for 15 inch bias tires. For the 50 mph coefficients, both the 15 inch bias and radial tires means decreased significantly from the other tire size means.

Table 7

Tire Size Effects

Tire Type	Nominal Tire Size	Sample Size	Mean Rolling Resistance Coefficient		Sample Variance	
			20 MPH	50 MPH	20 MPH	50 MPH
Radial	13 inch	12	7.46	8.23	4.74	5.30
Bias	13 inch	2	10.36	10.89	4.60	4.16
Radial	14 inch	16	7.12	7.65	3.01	2.85
Bias	14 inch	10	9.60	10.47	1.24	.90
Radial	15 inch	20	6.52	6.97	1.53	1.50
Bias	15 inch	3	7.89	8.55	.83	1.20

Conclusions

For each speed and tire type, every pair of the above tire size means were compared to investigate what pairs were significantly different from each other at the 95% confidence level.

At 20 mph, the mean rolling resistance coefficient of 15 inch bias tires is significantly less than the rolling resistance coefficient for 13 inch bias tires.

At 50 mph, the coefficients for both 15 inch radial and 15 inch bias tires are significantly lower than the rolling resistance coefficients for other tire sizes.

Since tire size appears to have a significant effect on the rolling resistance coefficient it may be questioned if the previous analysis by manufacturer was influenced by tire size effects. That is, a manufacturer might have higher than average tire rolling resistances because no 15 inch tires of that manufacturer were tested. This does not appear to be the case, since only the Firestone rolling resistance coefficient mean was significantly higher than the rolling resistance coefficient mean and numerous 15 inch Firestone tires were included in the sample.

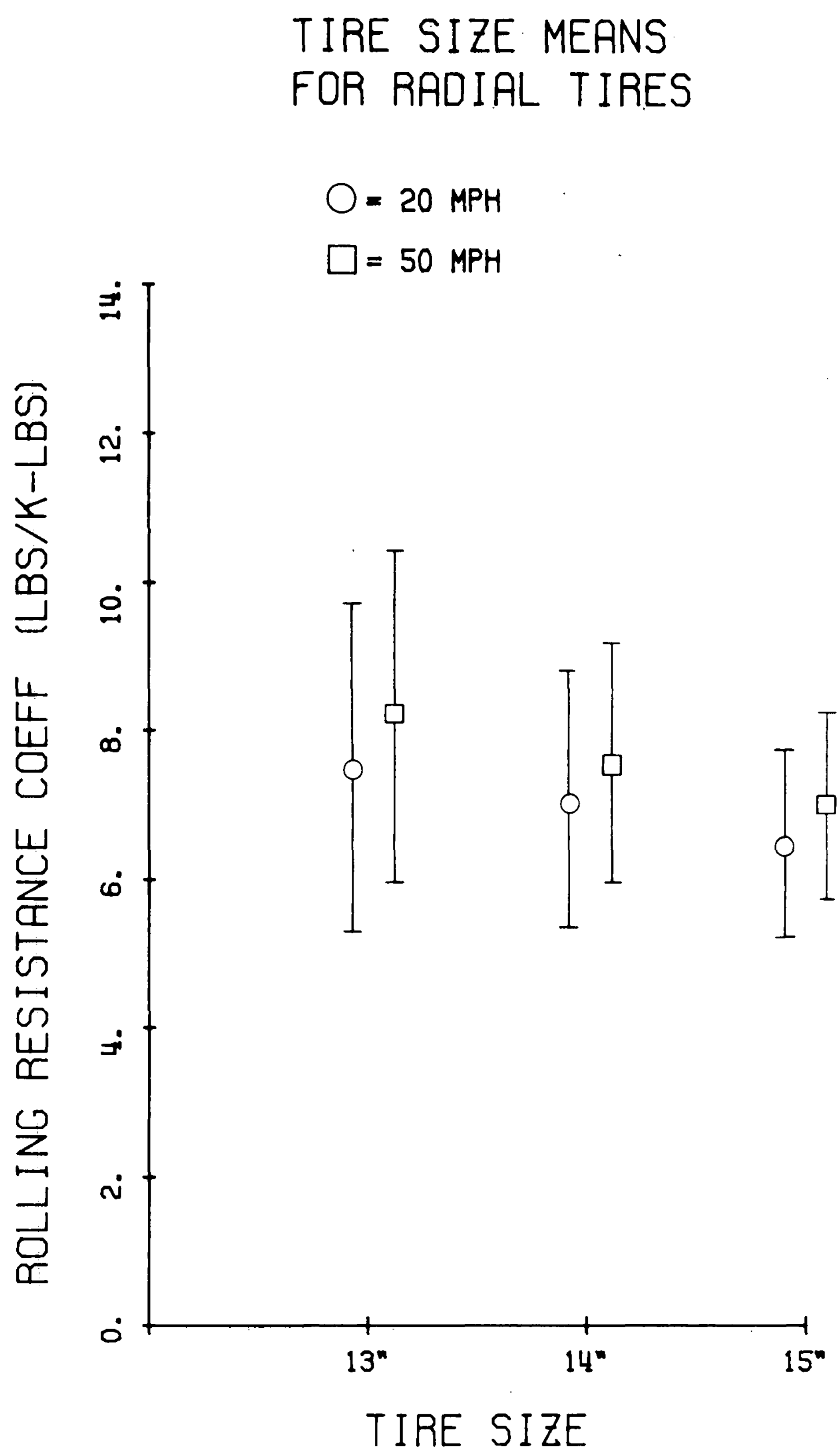

Fig. 5 - Means of the Radial Tire Rolling Resistance Coefficients by Tire Size. The error bars designate one standard deviation of the data.

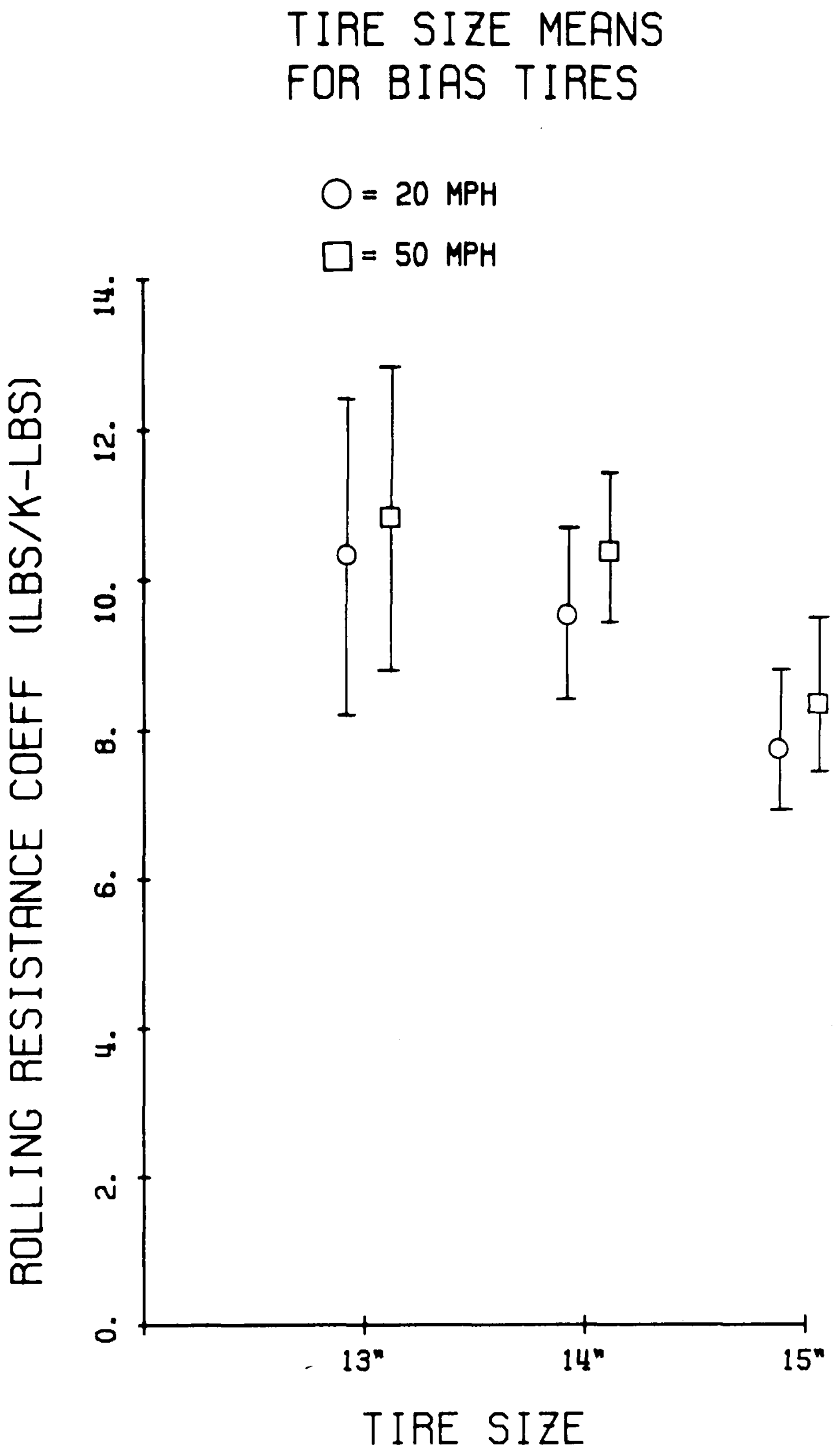

Fig. 6 - Means of the Bias Tire Rolling Resistance Coefficients by Tire Size. The error bars designate one standard deviation of the data.

Likewise, those manufacturers which had lower than average rolling resistance coefficients in one or more categories; General, Continental, Semperit and Bridgestone might have appeared to have lower than average rolling resistance because of a predominance of 15 inch tires by these manufacturers. However, with the exception of Semperit, the tires by these manufacturers included sizes smaller than 15 inches. Therefore, only the Semperit results may be significantly influenced by tire size effects.

The tire literature indicates that the rolling resistance of tires decrease as the percentage of remaining tread decreases (9). Since the vehicles were tested as received, tire wear could influence the results. The percent of remaining tread depth could not be recorded since there was no method to determine the original tread depth. The influence of this effect is believed to be minimal since many of the test vehicles were EPA certification vehicles, volunteered by the manufacturers. These vehicles would have nearly identical accumulated mileage, approximately 5000 miles. Most of the remaining vehicles were late model rental vehicles. These vehicles typically had low accumulated mileage, however this parameter was uncontrolled.

C. Fuel Economy Effects

The previous section demonstrated that variations in rolling resistances are observed between different tires. This section will investigate the effect these variations in rolling resistances have on vehicle fuel economy.

The fuel economy advantages of radial tires have previously been reported in the literature (10). However, these measurements have often been conducted at steady state conditions or over arbitrary transient road routes. While results may have given good indications of the fuel economy effects of tire variations, the cycles used have not been standardized with respect to national driving patterns.

Recently EPA completed a project measuring the effect of radial versus bias ply tires on vehicle fuel economy over the EPA urban and highway driving cycles (11). In this program the fuel economies of six vehicles were measured when these vehicles were equipped with radial and with bias ply tires. Each vehicle was equipped with OEM tires of the type, radial or bias-belted, which were sold as standard equipment for that model. A matched set of tires of the alternate construction type, bias-belted or radial, was acquired to provide a controlled comparison. The alternate sets were furnished for the program by the vehicle manufacturers. These tires were also OEM tires, made by the same tire manufacturer, with the same load rating, and with the nearest available rolling radius as the standard equipment set. The vehicles and the tires used are identified in Table 1 of Appendix B.

These vehicles were operated over the EPA driving cycles on the test track of the Transporation Research Center of Ohio. Fuel consumption over these cycles was measured by integrating the fuel flow rate determined by an in-line fuel flow meter. The results of these measurements are given in Table 2 of Appendix B.

The estimated changes in the tire rolling resistance experienced by the vehicles are given in Table 3 of Appendix B. In this table the tire on the vehicle was assumed to have the mean rolling resistance coefficient of tires of that type and manufacturer, as given in Tables 3 through 6.

Theoretically, the changes in fuel economy should be related to the changes in energy required to drive the vehicle over the cycle and the engine efficiency of the vehicle. The energy required over the cycle is a function of the vehicle weight and aerodynamic characteristics, in addition to the tire rolling resistance coefficient. Also, the engine efficiency characteristics vary. Consequently a uniform change in fuel economy can not be expected based on a change in the tire rolling resistance coefficient alone. However, the average percent change in fuel economy, divided by the average percent change in the tire rolling resistance coefficient, gives a sensitivity coefficient which may be considered a "rule of thumb" number for predicting the fuel economy effect expected from a change in the tire rolling resistance coefficient. These computed sensitivity coefficients are given in Table 4 of Appendix B and repeated in Table 8 of the text. As anticipated, the magnitude of the sensitivity coefficient for the low speed urban cycle is greater than the corresponding magnitude of the coefficient for the higher speed highway cycle, however, the difference between the coefficients is very small. Most important from a national average standpoint, is that both cycle coefficients and the composite coefficients are approximately -0.2. This indicates a 10 percent decrease in the tire rolling resistance coefficient and can be expected to yield a 2 percent increase in the national average fuel economy.

Table 8

Average
Sensitivity Coefficients

Cycle	% Change in Fuel Economy / % Change in Tire Rolling Resistance Coefficient
Urban	-0.20
Highway	-0.19
Composite	-0.19

IV. Conclusion

It is concluded that there are significant effects on tire rolling resistance coefficients from:

a) tire construction type
b) tire manufacturer
c) tire size.

The average decrease in tire rolling resistance from bias ply tires to radial tires was about 24 percent. This was a difference of about 2.3 pounds(newtons)/kilopound(kilonewtons). The variations among tire rolling resistance coefficients by tire manufacturer, within each tire type were greater than this difference between the means of the tire types. For example, within the radial tire classification the variations among manufacturers were almost 4.0 lb (nt)/klb (knt).

In the case of bias tires the observed decrease in the rolling resistance coefficients from 13 inch to 15 inch tire sizes was as great as the difference between the means of the rolling resistance coefficients for radial and bias tires. For radial tires, the decrease in rolling resistance coefficients from 13 inch to 15 inch tire was somewhat less, about 0.9 lb(nt)/klb(knt).

The fuel economy effects of these observed variations in rolling resistance are very significant. Based on the EPA cycles, the use of average radial ply tires versus average bias tires improves fuel economy about four percent. Improvements of a similar size would be expected in transitions from average to low rolling resistance radial tires. Somewhat smaller improvements may also be expected if a general transition were made to larger diameter tires. These improvements of about four and two percent in the fuel economy of a typical vehicle represent respective reductions in national average fuel consumption of about four and two billion gallons of gasoline annually (12).

V. Recommendations

The basic recommendation is to continue investigative efforts in this area. It must be remembered that the data reported here were collected for the purpose of describing the vehicle road experience. Consequently, the tires were tested in the operating condition recommended by the vehicle manufacturer. While the data analysis attempts to remove the vehicle dependent effects, it is possible that some vehicle dependence remains. Also, the reported effects of the tire manufacturer and tire size have not been reported elsewhere in the literature. Therefore, these effects should be confirmed.

Should these results be confirmed, it would indicate that transitions to more fuel conserving tires offers a potential for a significant reduction in national fuel consumption in a relatively short time. The transition time could be short because the technology apparently exists since such tires are already available in the market. The replacement rate for tires is much more frequent than the replacement rate of the vehicle population, thus, the effect of tire improvements on national fuel economy would be seen more quickly than would the the effect of changes in production vehicles.

For the most part the transition to radial tires has already occurred, particularly in the OEM market. In 1976 approximately two-thirds of the OEM tires were radial construction. Also, beginning in 1978 the vehicle manufacturer already has the incentive of national fuel economy regulations to choose low rolling resistance tires for this market. Therefore, the greatest potential area for fuel conservation is in the region of replacement tires. This is a very significant area since approximately 73 percent of all tires are sold in this market. Of these tires only about 37 percent are currently radials (13).

Transitions to fuel efficient tires in the replacement market, particularly within the category of radial tires, is limited by the amount of information available to the consumer. The average tire purchaser simply does not have the essential rolling resistance information or the associated fuel economy information available to select a tire on this basis. If fuel economy improvements are to be obtained by consumer selection of low rolling resistance tires, then this essential information must be made available.

The evaluation of the rolling resistances of tires should be based on measurements of the energy dissipation of the tire over typical operating conditions. The current EPA driving cycles are the logical beginning for a cyclic tire energy dissipation procedure, therefore, the feasibility of a program based on these cycles should be investigated.

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APPENDIX A

TABLE 1
TEST FLEET

VEHICLE IDENTIFICATION NUMBER	MODEL YEAR	MANUFACTURER	MODEL NAME	BODY STYLE	TEST WEIGHT (LBS)
101	1974	Chevrolet	Impala	Sedan	4560
201	1975	Chevrolet	Chevelle	Sedan	4100
301	1975	Pontiac	Firebird	Sedan	3640
401	1975	Pontiac	Ventura	Sedan	3520
502	1975	Ford	Pinto	Sedan	2800
601	1975	Oldsmobile	Cutlass	Sedan	4250
804	1974	American Motors	Gremlin	Sedan	2970
901	1975	Chevrolet	Impala	Stationwagon	5250
1001	1975	Chevrolet	Vega	Sedan	2680
1102	1975	Ford	Granada	Sedan	3510
1201	1975	Buick	Century	Sedan	4140
1301	1975	Buick	Special	Sedan	4020
1401	1975	Buick	Skylark	Sedan	3720
1501	1975	Buick	Apollo	Sedan	3910
1601	1975	Chevrolet	Monza	Sedan	3490
1702	1975	Ford	Mustang Mach 1	Sedan	3000
1802	1975	Ford	Mustang	Sedan	3020
1901	1975	Buick	Skyhawk	Sedan	3200
2102	1975	Mercury	Capri II	Sedan	2570
2203	1975	Plymouth	Valiant	Sedan	3600
2301	1975	Buick	LeSabre	Sedan	4870
2401	1975	Buick	Estate	Stationwagon	5590
2502	1975	Lincoln	Continental	Sedan	5450
2602	1973	Mercury	Capri	Sedan	2350
2706	1975	Toyota	Corolla	Sedan	2470
2802	1975	Mercury	Comet	Sedan	3320
2906	1975	Toyota	Celica	Sedan	2760
3011	1975	Saab	99	Sedan	2710
3102	1975	Ford	Mustang Mach 1	Sedan	3320
3212	1975	Triumph	TR6	Convertible	2650
3304	1975	American Motors	Pacer	Sedan	3330
3402	1975	Ford	Maverick	Sedan	3320
3505	1975	Volkswagen	Rabbit	Sedan	2170
3613	1975	Honda	CVCC	Sedan	1900
3908	1975	Mazda	RX-3	Stationwagon	2680
4014	1975	Fiat	128	Sedan	2180
4102	1975	Mercury	Montego	Sedan	4560
4202	1975	Ford	Gran Torino	Sedan	4570
4302	1975	Mercury	Marquis	Sedan	4990
4402	1975	Ford	LTD	Sedan	4860
4507	1975	Datsun	280Z	Sedan	3110
4607	1975	Datsun	B210	Sedan	2310
4701	1975	Pontiac	Lemans	Sedan	4230
4801	1975	Oldsmobile	Cutlass Supreme	Sedan	4330
4903	1975	Dodge	Dart	Sedan	3610
5103	1975	Plymouth	Valient Custon	Sedan	4260
5203	1975	Plymouth	Gran Fury	Sedan	4840
5303	1975	Plymouth	Scamp	Sedan	3680
5403	1975	Plymouth	Valiant	Sedan	3620
5503	1975	Chrysler	New Yorker	Sedan	5120
5601	1975	Pontiac	Lemans	Sedan	4320
5603	1975	Chrysler	Newport	Sedan	4840
5701	1975	Oldsmobile	Delta 88	Sedan	4770
5802	1975	Ford	Granada	Sedan	3760
6002	1975	Mercury	Montego	Sedan	4500
6102	1975	Ford	LTD	Sedan	5020
6202	1975	Ford	Torino	Sedan	4420
6402	1975	Ford	LTD	Sedan	5060
6502	1975	Ford	Torino	Stationwagon	5210
6702	1975	Ford	Gran Torino	Stationwagon	5000
6802	1975	Ford	Gran Torino	Sedan	4600
6909	1976	Volvo	264DL	Sedan	3290
8101	1975	Chevrolet	Corvette	Sedan	3850
8401	1975	Oldsmobile	Toronado	Sedan	5170

TABLE 2
TIRE DESCRIPTION

ID	MANUFACTURER	TYPE	DESCRIPTION
0101	GOODRICH	BIAS	G 78-15
0201	UNIROYAL	BIAS	G 78-14
0301	UNIROYAL	BIAS	F 78-14
0401	GENERAL	BIAS	F 78-14
0502	FIRESTONE	RADIAL	BR78-13
0601	FIRESTONE	RADIAL	GR78-15
0804	FIRESTONE	BIAS	6.45-14
0901	GOODYEAR	BIAS	L 78-15
1001	GENERAL	BIAS	A 78-13
1102	FIRESTONE	RADIAL	DR78-14
1201	UNIROYAL	RADIAL	GR78-15
1301	FIRESTONE	RADIAL	FR78-15
1401	UNIROYAL	RADIAL	FR78-14
1501	UNIROYAL	BIAS	E 78-14
1601	GOODYEAR	RADIAL	BR78-13
1702	FIRESTONE	RADIAL	195/70R13
1802	FIRESTONE	RADIAL	190/70R13
1901	UNIROYAL	RADIAL	BR78-13
2102	GOODYEAR	RADIAL	165SR13
2203	GOODYEAR	RADIAL	DR78-14
2301	UNIROYAL	RADIAL	HR78-15
2401	FIRESTONE	RADIAL	LR78-15
2502	MICHELIN	RADIAL	230SR15
2602	CONTINENTAL	RADIAL	165SR13
2706	TOYO	RADIAL	185/70HR13
2802	FIRESTONE	RADIAL	DR78-14
2906	TOYO	RADIAL	185/70HR14
3011	SEMPERIT	RADIAL	165SR15
3102	MICHELIN	RADIAL	DR70-13
3212	MICHELIN	RADIAL	185SR15
3304	FIRESTONE	BIAS	6.95-14
3402	FIRESTONE	RADIAL	DR78-14
3505	CONTINENTAL	RADIAL	155SR13
3613	BRIDGESTONE	BIAS	6.00S12
3908	BRIDGESTONE	RADIAL	155SR13
4014	MICHELIN	RADIAL	145SR13
4102	UNIROYAL	RADIAL	HR78-14
4202	UNIROYAL	RADIAL	HR78-14
4302	MICHELIN	RADIAL	JR78-15
4402	FIRESTONE	RADIAL	HR78-15
4507	TOYO	RADIAL	195/70HR14
4607	BRIDGESTONE	BIAS	155/6.1513
4701	UNIROYAL	RADIAL	GR78-15
4801	GOODRICH	RADIAL	GR78-15
4903	GOODYEAR	BIAS	D 78-14
5103	GOODYEAR	BIAS	D 78-14
5203	GOODYEAR	RADIAL	LR78-15
5303	GOODYEAR	BIAS	E 78-14
5403	GOODYEAR	BIAS	E 78-14
5503	GOODYEAR	RADIAL	JR78-15
5601	UNIROYAL	RADIAL	GR78-15
5603	GOODYEAR	RADIAL	HR78-15
5701	UNIROYAL	BIAS	H 78-15
5802	FIRESTONE	RADIAL	FR78-14
6002	GOODYEAR	RADIAL	HR78-14
6102	FIRESTONE	RADIAL	HR78-15
6202	FIRESTONE	RADIAL	HR78-14
6402	FIRESTONE	RADIAL	LR78-15
6502	GOODYEAR	RADIAL	HR78-14
6702	GENERAL	RADIAL	HR78-14
6802	GENERAL	RADIAL	JR78-14
6909	MICHELIN	RADIAL	185SR14
8101	GOODYEAR	RADIAL	GR78-15 F
8401	FIRESTONE	RADIAL	JR78-15

TABLE 3
REGRESSION COEFFICIENTS

ID	DRIVING A (NT)	DRIVING B (KG/SEC)	NON-DRIVING A (NT)	NON-DRIVING B (KG/SEC)
0101	76.182	0.635	114.778	0.597
0201	69.682	0.810	123.098	0.525
0301	76.373	0.305	123.098	0.525
0401	71.451	0.289	115.314	0.412
0502	55.387	0.145	81.985	0.452
0601	68.166	0.617	72.462	0.188
0804	79.993	0.730	100.238	0.538
0901	74.341	1.049	104.881	-0.011
1001	76.744	0.276	92.313	0.216
1102	30.407	0.708	50.929	0.923
1201	98.372	-0.789	91.932	0.326
1301	46.631	0.676	93.828	0.235
1401	50.241	1.000	86.315	0.307
1501	86.593	-0.608	123.098	0.525
1601	39.212	0.637	86.202	0.715
1702	56.213	0.564	69.056	0.560
1802	73.240	0.297	74.448	0.416
1901	53.471	0.856	82.243	0.583
2102	46.485	0.580	67.495	0.601
2203	44.149	-0.633	21.178	1.949
2301	89.550	0.364	108.010	0.097
2401	88.606	0.995	86.186	1.013
2502	41.021	0.639	76.672	-0.123
2602	37.919	0.138	16.797	0.083
2706	-6.761	1.540	57.807	0.550
2802	27.733	0.418	100.708	0.367
2906	47.383	0.436	35.769	0.520
3011	31.906	0.328	18.202	0.234
3102	69.702	0.139	92.667	0.377
3212	49.000	0.119	46.007	0.273
3304	79.946	0.798	100.238	0.538
3402	64.990	0.687	108.100	0.305
3505	18.437	0.167	16.797	0.083
3613	47.619	0.175	20.527	0.069
3908	46.001	0.064	53.398	0.280
4014	26.975	0.324	39.645	0.062
4102	132.244	0.505	95.874	-0.696
4202	85.202	0.868	135.400	0.815
4302	61.592	0.694	124.442	0.230
4402	68.730	0.506	145.133	0.059
4507	62.980	0.269	59.390	-0.063
4607	47.277	0.437	62.766	0.139
4701	67.365	0.672	62.457	0.692
4801	69.927	0.541	86.218	0.348
4903	66.040	0.570	109.712	0.603
5103	58.705	0.575	59.503	2.035
5203	47.075	0.160	122.697	-0.073
5303	40.020	1.540	92.273	0.402
5403	79.322	0.533	92.582	0.666
5503	56.476	0.768	119.843	0.985
5601	60.255	0.815	80.086	0.415
5603	66.405	0.658	103.466	0.883
5701	76.031	0.858	129.581	0.808
5802	64.147	0.342	101.203	0.597
6002	70.702	0.482	109.818	-0.190
6102	87.241	0.589	117.844	0.305
6202	75.627	0.692	153.439	0.196
6402	97.069	0.420	124.460	0.548
6502	69.242	0.583	124.729	0.275
6702	33.696	0.119	77.671	0.170
6802	53.527	0.768	84.692	0.308
6909	47.097	-0.018	62.098	0.386
8101	59.739	0.907	79.239	0.363
8401	70.915	-0.035	81.411	0.560

TABLE 4
UNCORRECTED FORCES

ID	20 MPH DRIVING (LBS)	20 MPH NON-DRIVING (LBS)	50 MPH DRIVING (LBS)	50 MPH NON-DRIVING (LBS)
0101	18.403	27.003	20.317	28.803
0201	17.293	28.729	19.735	30.312
0301	17.782	28.729	18.702	30.312
0401	16.644	26.752	17.515	27.994
0502	12.743	19.339	13.180	20.702
0601	16.564	16.668	18.425	17.235
0804	19.450	23.616	21.651	25.238
0901	18.821	23.556	21.984	23.523
1001	17.807	21.187	18.640	21.838
1102	8.259	13.305	10.393	16.087
1201	20.529	21.322	18.150	22.305
1301	11.842	21.566	13.880	22.274
1401	13.305	20.021	16.320	20.947
1501	18.245	28.729	16.412	30.312
1601	10.096	20.816	12.016	22.972
1702	13.771	16.650	15.471	18.338
1802	17.062	17.573	17.957	18.827
1901	13.741	19.661	16.322	21.419
2102	11.616	16.381	13.365	18.193
2203	8.653	8.678	6.744	14.555
2301	20.863	24.477	21.961	24.769
2401	21.919	21.411	24.919	24.466
2502	10.506	16.989	12.433	16.618
2602	8.802	3.943	9.218	4.193
2706	1.575	14.101	6.218	15.759
2802	7.075	23.378	8.335	24.484
2906	11.528	9.086	12.843	10.654
3011	7.832	4.562	8.821	5.268
3102	15.949	21.590	16.368	22.727
3212	11.255	10.892	11.614	11.715
3304	19.577	23.616	21.982	25.238
3402	15.991	24.915	18.062	25.834
3505	4.480	3.943	4.984	4.193
3613	11.057	4.753	11.585	4.961
3908	10.470	12.567	10.663	13.411
4014	6.715	9.037	7.692	9.224
4102	30.745	20.154	32.267	18.056
4202	20.899	32.077	23.516	34.534
4302	15.241	28.438	17.334	29.131
4402	16.468	32.746	17.994	32.924
4507	14.699	13.225	15.510	13.035
4607	11.507	14.390	12.824	14.809
4701	16.495	15.432	18.521	17.518
4801	16.808	20.082	18.439	21.131
4903	15.992	25.876	17.711	27.694
5103	14.353	17.467	16.087	23.603
5203	10.904	27.437	11.387	27.217
5303	12.092	21.552	16.735	22.764
5403	18.904	22.152	20.511	24.160
5503	14.240	28.922	16.555	31.891
5601	15.184	18.838	17.641	20.089
5603	16.251	25.035	18.235	27.697
5701	18.817	30.755	21.404	33.191
5802	15.108	23.951	16.139	25.751
6002	16.863	24.306	18.316	23.733
6102	20.796	27.105	22.572	28.025
6202	18.393	34.888	20.479	35.479
6402	22.666	29.081	23.932	30.733
6502	16.738	28.593	18.496	29.422
6702	7.814	17.803	8.173	18.315
6802	13.577	19.659	15.892	20.587
6909	10.552	14.736	10.497	15.900
8101	15.253	18.543	17.987	19.638
8401	15.872	19.428	15.766	21.116

TABLE 5
PRESSURES

ID	NON-DRIVING (PSI)	DRIVING (PSI)
0101	28.0	28.0
0201	24.0	24.0
0301	26.0	24.0
0401	24.0	24.0
0502	22.0	22.0
0601	26.0	26.0
0804	24.0	24.0
0901	22.0	32.0
1001	24.0	26.0
1102	24.0	26.0
1201	26.0	26.0
1301	32.0	32.0
1401	24.0	24.0
1501	26.0	26.0
1601	30.0	32.0
1702	26.0	26.0
1802	26.0	26.0
1901	24.0	26.0
2102	27.0	31.0
2203	28.0	28.0
2301	24.0	24.0
2401	24.0	28.0
2502	26.0	26.0
2602	27.0	31.0
2706	24.0	24.0
2802	24.0	26.0
2906	24.0	24.0
3011	27.0	27.0
3102	26.0	26.0
3212	20.0	24.0
3304	26.0	24.0
3402	24.0	26.0
3505	27.0	27.0
3613	22.7	22.7
3908	26.0	26.0
4014	24.0	26.0
4102	24.0	24.0
4202	24.0	24.0
4302	26.0	26.0
4402	26.0	26.0
4507	28.0	28.0
4607	24.0	24.0
4701	26.0	24.0
4801	24.0	24.0
4903	28.0	28.0
5103	28.0	28.0
5203	26.0	26.0
5303	28.0	28.0
5403	28.0	30.0
5503	24.0	24.0
5601	26.0	24.0
5603	26.0	26.0
5701	26.0	25.0
5802	24.0	24.0
6002	24.0	24.0
6102	24.0	26.0
6202	24.0	24.0
6402	26.0	26.0
6502	24.0	34.0
6702	24.0	32.0
6802	24.0	24.0
6909	25.0	26.0
8101	20.0	20.0
8401	20.0	26.0

TABLE 6
CORRECTED FORCES

ID	20 MPH DRIVING (LBS)	20 MPH NON-DRIVING (LBS)	50 MPH DRIVING (LBS)	50 MPH NON-DRIVING (LBS)
0101	16.074	22.936	17.746	24.465
0201	13.659	21.990	15.588	23.201
0301	14.914	21.990	15.685	23.201
0401	13.146	20.476	13.834	21.427
0502	9.600	14.090	9.930	15.082
0601	13.672	13.356	15.207	13.810
0804	15.363	18.076	17.101	19.317
0901	13.724	22.273	16.030	22.242
1001	14.300	17.540	14.969	18.079
1102	6.523	10.834	8.209	13.099
1201	16.944	17.086	14.980	17.874
1301	11.482	20.391	13.458	21.061
1401	10.509	15.325	12.890	16.033
1501	15.302	23.393	13.765	24.682
1601	9.612	20.335	11.440	22.441
1702	11.743	13.784	13.193	15.182
1802	14.549	14.548	15.313	15.587
1901	11.035	16.277	13.107	17.732
2102	10.194	15.596	11.728	17.321
2203	7.680	7.491	5.986	12.563
2301	16.216	18.437	17.070	18.657
2401	17.037	18.187	19.369	20.781
2502	8.671	13.614	10.261	13.317
2602	7.724	3.754	8.089	3.992
2706	1.265	10.974	4.994	12.264
2802	5.588	19.036	6.583	19.937
2906	9.106	6.955	10.144	8.155
3011	6.652	3.766	7.492	4.348
3102	13.600	17.874	13.957	18.815
3212	7.666	8.204	7.910	8.824
3304	16.419	18.076	18.437	19.317
3402	12.631	20.288	14.267	21.036
3505	3.932	3.362	4.374	3.576
3613	8.571	3.566	8.980	3.722
3908	8.928	10.404	9.093	11.103
4014	5.393	7.482	6.177	7.636
4102	24.284	15.427	25.486	13.820
4202	16.507	24.553	18.574	26.433
4302	12.580	22.788	14.306	23.343
4402	13.592	26.240	14.851	26.382
4507	13.046	11.415	13.766	11.251
4607	9.240	11.198	10.298	11.524
4701	13.614	11.624	15.286	13.195
4801	13.064	15.127	14.332	15.917
4903	14.194	22.335	15.719	23.904
5103	12.739	15.076	14.278	20.372
5203	9.000	21.985	9.398	21.809
5303	10.733	18.602	14.854	19.648
5403	16.778	20.202	18.204	22.033
5503	11.068	21.785	12.868	24.022
5601	12.532	14.190	14.560	15.132
5603	13.413	20.061	15.050	22.194
5701	15.531	23.905	17.666	25.799
5802	11.933	18.333	12.748	19.710
6002	13.319	18.604	14.467	18.166
6102	16.165	21.720	17.545	22.457
6202	14.527	26.704	16.175	27.157
6402	18.708	23.303	19.753	24.627
6502	13.220	28.870	14.609	29.707
6702	6.172	17.106	6.456	17.598
6802	10.724	15.047	12.553	15.758
6909	8.592	11.999	8.548	12.947
8101	10.389	12.184	12.252	12.903
8401	10.811	15.568	10.739	16.920

TABLE 7
ROLLING RESISTANCE COEFFICIENTS
AND
TOTAL ROLLING RESISTANCE FORCES

ID	TEST WEIGHT (LBS)	TOTAL FORCES 20MPH (LBS)	50MPH (LBS)	ROLLING RESISTANCE COEFF 20MPH (LBS)	50MPH (LBS)
0101	4560	39.010	42.211	8.555	9.257
0201	4100	35.649	38.789	8.695	9.461
0301	3640	36.904	38.886	10.138	10.683
0401	3520	33.622	35.261	9.552	10.017
0502	2800	23.690	25.012	8.461	8.933
0601	4250	27.028	29.017	6.359	6.828
0804	2970	33.439	36.418	11.259	12.262
0901	5250	35.997	38.272	6.857	7.290
1001	2680	31.840	33.048	11.881	12.331
1102	3510	17.357	21.308	4.945	6.071
1201	4140	34.030	32.854	8.220	7.936
1301	4020	31.873	34.519	7.929	8.587
1401	3720	25.834	28.923	6.944	7.775
1501	3910	38.695	38.447	9.896	9.833
1601	3490	29.947	33.881	8.581	9.708
1702	3000	25.527	28.375	8.509	9.458
1802	3020	29.097	30.900	9.635	10.232
1901	3200	27.312	30.839	8.535	9.637
2102	2570	25.790	29.049	10.035	11.303
2203	3600	15.171	18.549	4.214	5.152
2301	4870	34.653	35.727	7.116	7.336
2401	5590	35.224	40.150	6.301	7.182
2502	5450	22.285	23.578	4.089	4.326
2602	2350	11.478	12.081	4.884	5.141
2706	2470	12.239	17.258	4.955	6.987
2802	3320	24.624	26.520	7.417	7.988
2906	2760	16.061	18.299	5.819	6.630
3011	2710	10.418	11.840	3.844	4.369
3102	3320	31.474	32.772	9.480	9.871
3212	2650	15.870	16.734	5.989	6.315
3304	3330	34.495	37.754	10.359	11.338
3402	3320	32.919	35.303	9.915	10.633
3505	2170	7.294	7.950	3.361	3.663
3613	1900	12.137	12.702	6.388	6.685
3908	2680	19.332	20.196	7.214	7.536
4014	2180	12.875	13.813	5.906	6.337
4102	4560	39.711	39.306	8.708	8.620
4202	4570	41.060	45.007	8.985	9.848
4302	4990	35.368	37.649	7.088	7.545
4402	4860	39.832	41.233	8.196	8.484
4507	3110	24.461	25.017	7.865	8.044
4607	2310	20.438	21.822	8.848	9.447
4701	4230	25.238	28.481	5.966	6.733
4801	4330	28.191	30.249	6.511	6.986
4903	3610	36.529	39.623	10.119	10.976
5103	3580	27.815	34.650	7.770	9.679
5203	4840	30.985	31.207	6.402	6.448
5303	3680	29.335	34.502	7.971	9.375
5403	3620	36.980	40.237	10.216	11.115
5503	5120	32.853	36.890	6.417	7.205
5601	4320	26.722	29.692	6.186	6.873
5603	4840	33.474	37.244	6.916	7.695
5701	4770	39.436	43.465	8.267	9.112
5802	3760	30.266	32.458	8.049	8.632
6002	4500	31.923	32.633	7.094	7.252
6102	5020	37.885	40.002	7.547	7.968
6202	4420	41.231	43.332	9.328	9.804
6402	5060	42.011	44.380	8.303	8.771
6502	5210	42.090	44.316	8.079	8.506
6702	5000	23.278	24.054	4.656	4.811
6802	4600	25.771	28.311	5.602	6.154
6909	3290	20.591	21.495	6.259	6.533
8101	3850	22.573	25.155	5.863	6.534
8401	5170	26.379	27.659	5.102	5.350

APPENDIX B

Table 1

Fuel Economy Test Vehicles

Vehicle and Tire Identification

	Vehicle	Bias Ply Tire	Radial Ply Tire
1.	AMC Pacer	Goodyear 6.95 - 14	Goodyear DR70 - 14
2.	Chevrolet Impala	Goodrich H78 - 15	Goodrich HR78 - 15
3.	Datsun B-210	Bridgestone 155 - 13	Toyo 155SR - 13
4.	Dodge Aspen Station Wagon	Goodyear E78 - 14	Goodyear FR78 - 14
5.	Ford Granada	Goodyear C78 - 14	Goodyear DR78 - 14
6.	Ford Pinto	Goodyear A78 - 13	Goodyear BR78 - 13

Table 2

Measured Fuel Economies

	Urban Fuel Economy			Highway Fuel Economy			Composite Fuel Economy		
Vehicle	Bias Tire	Radial Tire	Percent Improvement	Bias Tire	Radial Tire	Percent Improvement	Bias Tire	Radial Tire	Percent Improvement
AMC Pacer	14.4	14.5	0.7	18.3	18.3	0.0	15.9	16.0	0.6
Chevrolet Impala	10.9	12.0	10.1	17.2	18.3	6.4	13.0	14.2	9.2
Datsun B-210	24.3	25.1	3.3	35.6	36.8	3.4	28.4	29.3	3.2
Dodge Aspen SW	14.2	15.3	7.8	19.9	20.8	4.5	16.3	17.3	6.1
Ford Granada	14.0	13.5	-3.6	17.8	18.3	2.8	15.5	15.3	-1.3
Ford Pinto	18.2	19.0	4.4	24.9	26.0	4.4	20.7	21.6	-4.4
AVERAGE			3.8			3.6			3.7

Table 3

Estimated Changes in Tire Rolling Resistance
During Fuel Economy Measurements

	Estimated Tire Rolling Resistance Coefficient at 20 mph			Estimated Tire Rolling Resistance Coefficient at 50 mph			Weighted Average 55/45 Weighting		
Vehicle	Bias Tire	Radial Tire	Percent Change	Bias Tire	Radial Tire	Percent Change	Bias Tire	Radial Tire	Percent Change
AMC Pacer	8.59	7.07	-17.7	9.69	7.76	-19.9	9.05	7.36	-18.7
Chevrolet Impala	8.56	6.51	-24.0	9.26	6.99	-24.5	8.86	6.72	-24.2
Datsun B-210	7.62	6.21	-18.5	8.07	7.22	-10.5	7.82	6.63	-15.2
Dodge Aspen SW	8.59	7.07	-17.7	9.69	7.76	-19.9	9.05	7.36	-18.7
Ford Granada	8.59	7.07	-17.7	9.69	7.76	-19.9	9.05	7.36	-18.7
Ford Pinto	8.59	7.07	-17.7	9.69	7.76	-19.9	9.05	7.36	-18.7
AVERAGE			-18.9			-19.1			-19.0

Table 4

Average
Sensitivity Coefficients

Cycle	% Change in Fuel Economy / % Change in Tire Rolling Resistance Coefficient
Urban	-0.20
Highway	-0.19
Composite	-0.19