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Technical Report

# Characterization of the Rolling Resistance of Aftermarket Passenger Car Tires

By

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Standards Development and Support Branch
Emission Control Technology Division
Office of Mobile Sources
Office of Air and Radiation
U. S. Environmental Protection Agency

## I. Background

In the early 1980s, EPA began to investigate the effects of tire rolling resistance. The benefits of improved (i.e., lower) rolling resistance include: reduced vehicle fuel consumption, lowered exhaust emissions and possibly reduced discrepanies between EPA and on-road vehicle fuel economy.

The amount of fuel consumed by a vehicle is a direct function of the tires that are used.[1] Improvements in the rolling resistance of tires would significantly reduce the amount of fuel consumed daily in the United States.

Vehicle exhaust emissions also depend upon rolling resistance. A strong correlation exists between rolling resistance and oxides of nitrogen (NOx) emissions; NOx emissions increase with the use of tires having higher rolling resistance. Carbon monoxide (CO) emissions are also affected by tire rolling resistance; CO emissions increase with increases in tire rolling resistance. In the case of hydrocarbons (HC), a weak relationship exists between HC emissions and rolling resistance.[2]

Variations in tire rolling resistance may contribute to the differences between EPA-measured fuel economies and those observed by consumers. Part of this discrepancy may result from aftermarket tires having significantly different rolling resistance from the tires on the corresponding production and EPA certification vehicles.

## II. Summary

The purpose of this program was to compare the rolling resistance of tire model lines within a sales-representative test matrix and to determine which tire characteristics influence rolling resistance.

The tires for this test program included all tires, as defined by manufacturer/brand name (i.e., Goodyear, Sears) and model (i.e., Arriva, Guardsman), that accounted for at least 1 percent of 1981 replacement market sales. Additional tires were selected to increase the representation of as many manufacturer/brand names as possible and to maximize the total fraction of the replacement market represented. The test matrix used consisted of 252 tires, from 20 different manufacturer/brand names and 54 different model lines. This matrix covered approximately 54 percent of the 1981 replacement market.

Significant correlations were found between a tire's rolling resistance and the tire model, construction type, and body cord. An inconclusive relationship was found between belt fiber and rolling resistance.

Comparisons were made between different tires based upon the mean rolling resistance coefficient (RRC) of the model. Table 1 lists the models tested and their construction type, in order of increasing mean RRC. The three models with the lowest rolling resistance were:

1. BF Goodrich Lifesaver XLM
2. Uniroyal Steeler
3. Delta Radial II

In the analysis of construction type, it was determined that average radial-ply tires have 20.2 percent lower rolling resistance than bias-belted tires and 26.0 percent lower than bias-ply.

The analysis of body cord showed, with a high level of statistical confidence ($p = 0.01$), that among steel-belted radial tires those having polyester body cords had 8.8 percent lower mean rolling resistance than those having rayon body cords.

The sample sizes available for analysis of the effect of belt fiber on rolling resistance were not, for all types of belt fiber, large enough to state definitely that the use of one type lowers tire rolling resistance. It was found that radial tires with steel + fiberglass belt fibers tended to have lower rolling resistance than those with fiberglass belt fibers and those with steel belt fibers; aramid belt fiber tended to have higher rolling resistance than the other types.

Little relationship was observed between a tire's price and its rolling resistance. That is, the price of a tire is not a good indication of its rolling resistance.

It was determined that rolling resistance results are consistent regardless of the date of manufacture (within a reasonable amount of time) or test date. However, it should be noted that: 1) all tires used in this program were purchased within a small amount of time, 2) all members of each model were purchased from the same supplier, and 3) only four or six tires of each model were tested. The above should be considered when interpreting the results of this analysis.

Finally, two tires were tested repeatedly throughout the program to check for any variations in the test results as a function of time. Only minute changes in the test results caused by time-dependent factors were observed, reflecting good test precision and repeatability.

## III. Test Program Design

The test matrix emphasized market coverage and represented as many tire models as feasible. To ensure that the test matrix was representative of tire sales, detailed knowledge of the breakdown of the 1981 replacement tire market was needed. Because of the fragmentation and size of the replacement tire market, Smithers Scientific Services, Inc. (SSS) of Akron, Ohio was contracted to develop the test matrix. SSS is a testing, research and consulting corporation with extensive experience in research and testing of automotive tires.

EPA requested that SSS supply market data and suggest a test matrix. The matrix which SSS prepared was based on market survey data where available, on requests for data sent to tire manufacturers, and, in a few cases where data were not publicly available and were not released by tire manufacturers, through estimates by Smithers staff.

The SSS matrix included every tire model known or estimated to represent 1 percent or more of the total 1981 tire replacement market. If a brand name represented more than 1 percent of the total market, but no individual model of that brand represented more than 1 percent, then the two most popular models sold under that brand name were included in the matrix. The tires included in the SSS matrix represented approximately 56 percent of the total 1981 replacement market; 58 models were included.

This program had maximum resources of approximately 300 tests. Therefore, some method was necessary to distribute the test capability over the SSS matrix. A previous test program[3] had indicated good homogeneity among tires of one model, therefore, to emphasize market coverage, tires were selected from all of the models of the SSS matrix.

For each of 19 models having 1 percent or more of the market, six test tires were selected. For each of the 39 models having less than 1 percent of the market, four test tires were included. Because of the small sample sizes, statistical confidence in the results was somewhat lower in this region of the test matrix. However, this was judged acceptable since these tires represent a smaller segment of the market. The sample sizes of four and six provided sufficient replicate testing to have good statistical confidence in the results from these tires. Statistical confidence in the sample sizes is discussed further in the section entitled "Results."

The tires chosen to represent each model were all of 14-inch nominal diameter. Tires marketed under the P-metric sizing were all P195/75R14, while alphanumerically sized tires were all E78-14 or ER78-14. These were projected to be the best selling sizes in the passenger car tire replacement market for 1982.[4]

The radial tires in the matrix represent about 70 percent of 1981 radial replacement sales, while non-radials represent only 37 percent of 1981 non-radial replacement sales. The lower number of non-radials tested was deemed acceptable because the percentage of radials sold in the replacement market was increasing when the matrix was designed and is still increasing.

The test matrix used in this program is shown in Table 2. Initially, 270 tires were to be tested, however, four models of the SSS matrix became unavailable during the course of the program. Therefore, the actual test matrix used contained 54 models rather than 58, and represented 252 tire tests, instead of 270.

As a means of checking for any variations in the test results as a function of time, two tires were chosen from the matrix to serve as "correlation" tires. These tires (Michelin XWW, P195/75R14) were the single best selling model included in the matrix, and alone represent 6 percent of 1981 replacement market sales. Each time that another group of tires (usually 30 to 40) was tested, these two Michelin tires were retested, and the results were compared to those obtained in earlier tests. These results, discussed in the section "Quality Control," characterize possible changes in the test results caused by calibration drift, lack of machine alignment maintenance, or other unknown time-dependent factors.

## IV. Test Contractor

The actual testing of the tires in this program was conducted by Standards Testing Laboratories, Inc., (STL) of Massillon, Ohio. STL has had extensive experience in tire testing, including rolling resistance testing. STL has tested tires for the Department of Transportation's (DOT) Uniform Tire Quality Grading program, has conducted testing for tire industry firms, and has participated in round-robin rolling

Table 1

Mean Rolling Resistance Coefficients ($\overline{RRC}$) by Models

| Brand & Model | Construction | $\overline{RRC}$ |
|---|---|---|
| BF Goodrich Lifesaver XLM | Radial | 0.00979 |
| Uniroyal Steeler | Radial | 0.00997 |
| Delta Radial II | Radial | 0.01009 |
| Laramie Glass Rider | Radial | 0.01018 |
| Atlas Silveraire | Radial | 0.01035 |
| Firestone Deluxe Champion Radial | Radial | 0.01041 |
| Michelin XWW | Radial | 0.01048 |
| Multi-Mile XL | Radial | 0.01052 |
| M. Ward Runabout | Radial | 0.01055 |
| General Steel Radial | Radial | 0.01059 |
| Uniroyal Tigerpaw | Radial | 0.01067 |
| Penney Mileagemaker Plus | Radial | 0.01078 |
| Goodyear Arriva | Radial | 0.01087 |
| Kelly-Springfield Navigator | Radial | 0.01087 |
| General Dual Steel III | Radial | 0.01091 |
| Multi-Mile Supreme | Radial | 0.01097 |
| Goodyear Custom Poly-Steel | Radial | 0.01101 |
| K-Mart KM-225 | Radial | 0.01104 |
| Dayton Quadra | Radial | 0.01109 |
| Delta Durasteel | Radial | 0.01110 |

Table 1 (cont'd.)

Mean Rolling Resistance
Coefficients (RRC) by Models

| Brand & Model | Construction | $\overline{RRC}$ |
|---|---|---|
| Firestone 721 | Radial | 0.01122 |
| Dayton Blue Ribbon | Radial | 0.01149 |
| Penney Mileagemaker XP | Radial | 0.01152 |
| Firestone Trax 12 | Radial | 0.01167 |
| Sears Road Handler 78 | Radial | 0.01177 |
| Summit Steel | Radial | 0.01176 |
| Dunlop Goldseal | Radial | 0.01186 |
| M. Ward Grappler | Radial | 0.01208 |
| Sears Weather Handler | Radial | 0.01212 |
| Goodyear Tiempo | Radial | 0.01227 |
| Cooper Lifeliner (glass belt) | Radial | 0.01228 |
| Armstrong SXA | Radial | 0.01232 |
| Dunlop Generation IV | Radial | 0.01249 |
| Cooper Lifeliner (steel belt) | Radial | 0.01261 |
| Michelin XVS | Radial | 0.01363 |
| Goodyear Cushion Belt Polyglas | Bias-Belt | 0.01371 |
| Armstrong Coronet All-Season | Radial | 0.01381 |
| Kelly-Springfield Roadmark | Bias-Ply | 0.01393 |
| Sears SuperGuard | Bias-Belt | 0.01409 |

Table 2

Tire Test Matrix

| Tire Description[1,2] | Number of Tires Sampled |
|---|---|
| Michelin XWW Radial[3] | 6 |
| Firestone 721 Radial | 6 |
| Goodyear Custom Polysteel Radial | 6 |
| Goodyear Power Streak Bias | 6 |
| Sears Road Handler 78 Radial | 6 |
| Sears Weather Handler Radial | 6 |
| Goodyear Tiempo Radial | 6 |
| Goodyear Arriva Radial | 6 |
| BF Goodrich Lifesaver XLM Radial | 6 |
| Michelin XVS Radial | 6 |
| Sears Guardsman Bias | 6 |
| Goodyear Cushion Belt Polyglas Bias-Belted | 6 |
| BF Goodrich CLM Bias-Belted | 6 |
| Firestone Deluxe Champion Radial | 6 |
| General Dual Steel III Radial | 6 |
| Uniroyal Steeler Radial | 6 |
| General Steel Radial | 6 |
| Sears Super Guard Bias-Belted | 6 |
| Dunlop Generation IV Radial | 4 |
| Firestone Trax 12 Radial | 4 |
| Firestone Deluxe Champion Bias | 4 |
| K-Mart KM78 Bias | 4 |
| Multi-Mile Supreme Radial | 4 |
| Uniroyal Tiger Paw Radial | 4 |
| Cooper Trendsetter Bias | 4 |
| Multi-Mile XL Radial | 4 |
| Kelly-Springfield Navigator Radial | 4 |
| K-Mart Economizer Bias | 4 |
| Atlas Cushionaire Bias | 4 |
| Kelly-Springfield Benchmark Bias | 4 |
| Armstrong Coronet All-Season Radial | 4 |
| Dayton Blue Ribbon Radial | 4 |
| Dayton Quadra Radial | 4 |
| Dayton Deluxe 78 Bias | 4 |
| Multi-Mile Poly IV Bias | 4 |
| Atlas Silveraire Radial | 4 |
| Kelly-Springfield Roadmark Bias | 4 |
| Armstrong SXA Radial | 4 |
| Cooper Lifeliner Radial (steel belted) | 4 |
| Dunlop Gold Seal Radial | 4 |
| Laramie Easy Rider Bias | 4 |
| K-Mart KM-225 Radial | 4 |
| Uniroyal Fastrak Poly Bias | 4 |

Table 2 (cont'd.)

Tire Test Matrix

| Tire Description[1,2] | Number of Tires Sampled |
|---|---|
| Montgomery Ward Runabout All Season Radial | 4 |
| Cooper Lifeliner Radial (glass belted) | 4 |
| JC Penny Mileagemaker XP Radial | 4 |
| JC Penny Mileagemaker Plus Radial | 4 |
| Delta Radial II | 4 |
| Laramie Glass Rider Radials | 4 |
| Summit Supreme 120 Bias | 4 |
| Delta Durasteel Radial | 4 |
| Montgomery Ward Grappler All Season Radial | 4 |
| Montgomery Ward Road Guard Bias-Belted | 4 |
| Summit Steel Radial | 4 |

Total: 252 individual tests, not including repeat correlation tests.

[1] The four models which became unavailable are:
- BF Goodrich Lifesaver LXII Radial (4)
- General Ameri-Sprint Bias Ply (4)
- General Ameri-Sprint Bias Belted (4)
- Uniroyal Fastrak Bias-Belted (4)

[2] All radial tires are P195/75R14, all bias-belted and bias-ply tires are E78-14 or ER78-14.

[3] Two of this sample are correlation tires and were retested periodically throughout the test program.

resistance test programs conducted by the Society of Automotive Engineers. Excellent correlations between tire test results obtained at STL, at the General Motors Proving Ground, and at the University of Michigan test laboratory have been demonstrated.[5] These correlations verify that observed variations in rolling resistance reflect differences in the test tires, not in the test labs or other undetermined factors.

## V. Test Procedure

The test procedure used was the spindle-force method described in "EPA Recommended Practice for the Determination of the Rolling Resistance Coefficients," which is attached as Appendix A. The procedure is outlined below.

### A. Test Equipment

The tires were tested using a 67.23-inch diameter tire dynamometer. This machine is equipped with a movable carriage, on which the tire/wheel assembly is mounted. This assembly applies the specified test load perpendicular to the test wheel. The tire and test wheel are then driven at the desired speed.

### B. Break-In

A break-in procedure was required, since automobile tires undergo a slight, permanent growth (increased circumference) when first run under operating conditions. The break-ins were performed by installing the tires on the test machine under the standard test conditions (load, inflation pressure, and ambient temperature), and running the tire at 50 miles per hour (the standard test speed) for a minimum of one hour.

### C. Test Conditions

Standard conditions for this test include an ambient temperature between 70°F and 80°F, and specific loads and inflation pressures. The cold inflation pressure is 32 psi for alphanumercially sized tires and 35 psi for P-metric sizes. The test load is defined as 80 percent of the Tire & Rim Association (T&RA) design load for the given tire, at the given cold inflation pressure. Since all tires were the same size, the test load on the tire was the same in all cases; the T&RA design load is 1400 pounds force (lbf),[6] thus the test load is 1120 lbf. Use of the same test load (within 5 lbf) on all of the tires permits direct comparisons to be made between the measured rolling resistances of different tires.

D. Thermal Conditioning

After the tire break-in is completed, the tire is left in the thermal environment of the test equipment for a minimum of three hours. At the end of this time, the inflation pressure is checked and readjusted to the prescribed cold inflation pressure, if necessary.

E. Tire Warm-Up

The tire/wheel assembly is then reinstalled on the test machine (if it was removed before thermal conditioning), loaded against the test surface at the specified test load, and run for at least 45 minutes. This allows the tire temperature and operating inflation pressure to reach equilibrium.

F. Test Measurements

When the warm-up is completed and with the tire/dynamometer system operating at the test speed of 50 mph, the following are measured and recorded: tire spindle force (which will be converted to rolling resistance force), normal load on the tire, ambient temperature, loaded tire radius, and final inflation pressure.

G. Parasitic Losses

A small amount of energy is absorbed parasitically by the test machine through bearing friction which may be inherent in the measurement. The parasitic losses must be subtracted from the spindle force to isolate the tire's rolling resistance.

To determine parasitic test machine losses, the load on the tire is reduced to a value just sufficient to maintain rotation at 50 mph without slippage (approximately 10 lbf); the spindle force is then measured. This value represents the parasitic test machine loss and is subtracted from the previously measured spindle force to yield the net spindle force.

H. Averaging Technique

An averaging technique was used to eliminate any possible effects of minute machine or tire misalignments. In this technique, developed by engineers at the General Motors Proving Grounds, the tire/dynamometer assembly is run both clockwise and counterclockwise. Spindle force readings are taken for each rotation direction and the parasitic losses are subtracted from each value, as described above. The two values of net spindle force are then averaged to obtain the final spindle force value. This averaging removes any systematic directional bias which might exist in the machine or measurement system. This is a slight deviation from the EPA Recommended Practice given in Appendix A, however, it is a desirable refinement for machines using the spindle-force method.

## VI. Data Reduction

After averaging the net spindle forces to obtain the final spindle force, the final spindle force must be converted to a rolling resistance (or energy dissipation) force. This is a necessary force conversion, and is not a correction for equivalent flat-surface rolling resistance. The conversion is given by the equation:[7]

$$F_d = F_x\ (1 + r/R) \tag{1}$$

where:

$F_x$ = final spindle force

r = loaded tire radius

R = test surface radius (33.615 in.)

$F_d$ = rolling resistance force.

Since all of the tires tested in this program were of similar sizes and load ranges, and were loaded to 1120±5 lbf, comparisons between different tires may be made on the basis of rolling resistance force. However, more general comparisons between tires having different load ranges, aspect ratios, or nominal diameters must be made on the basis of their rolling resistance coefficients (RRC). The dimensionless RRCs are obtained by dividing the rolling resistance force $F_d$ by the normal load on the tire during the test, L:

$$RRC = F_d/L \tag{2}$$

Computation of the tire RRCs was the extent of the data reduction conducted by STL. A sample STL data sheet, showing all of the information discussed so far, is included as Table 3.

The rolling resistance of an automobile tire is also dependent on the ambient temperature. The effect of temperature on rolling resistance is small as long as the ambient temperatures remain within a relatively narrow range: 70-80°F. All tests in this program were conducted within this temperature range, and the rolling resistance corrected to standard temperature (75°F) using the following correction formula:

Table 3

# POWER LOSS/ROLLING RESISTANCE TEST

STANDARD TESTING LABORATORIES INC.
P.O. BOX 592 • 1845 HARSH AVE., S.E. • MASSILLON, OHIO 44646
Massillon Telephone: (216) 833-8548
Direct Akron Telephone: (216) 253-1901

CUSTOMER E P A

TEST TECHNICIAN D. Langman

TIRE SIZE P195/75R14

STL JOB NO. J1-285

TIRE BRAND Goodyear

TEST RIM SIZE & CONTOUR 14 x 5.50

TEST NO. EPAR 347 (4243)

TIRE SERIAL NO. MDKATK0422

DATE June 22, 1983

CHECKED BY D. L. Fuller

TIRE NAME Tiempo

TIRE CONSTRUCTION

| IRE LOAD bs. (Fz) | TEST PRESSURE PSI. | TIRE ROLL. RADIUS In. (r) | TEST SPEED mph | AMBIENT TEMP. F° | NET SPINDLE FORCE CCW (F1) | NET SPINDLE FORCE CW (F2) | $\frac{F_1 + F_2}{2}$ | ROLLING RESISTANCE lbs. (FR) | REGRESSION VALUE | ROLLING RES. COEF. lbs. (FR |
|---|---|---|---|---|---|---|---|---|---|---|
| 1122 | 39.3 | 11.76 | 50.0 | 76 | +9.8 | -10.5 | -.35 | 13.70 | | .0122 |
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$$F_d^* = F_d\,[1 + c_t\,(t_x - t_s)], \qquad (3)$$

where:

$F_d^*$ = temperature-corrected rolling resistance force

$F_d$ = uncorrected rolling resistance force

$t_s$ = the standard test temperature (75°F)

$t_x$ = the measured test ambient temperature

$c_t$ = the temperature correction coefficient ($3.3\text{x}10^{-3}$/°F).

The relationship between rolling resistance and temperature within the specified temperature range is linear. However, the function may vary among tires of different construction or made with different materials. Therefore, when using the temperature correction formula, one must develop the temperature correction coefficient based on knowledge of the tire types and materials being used. The temperature correction coefficient ($c_t$) represents the amount of change in rolling resistance corresponding to a change in temperature of one degree Fahrenheit. For this test program, it was determined that $3.3 \times 10^{-3}$ was the optimal value for $c_t$.[6]

Explanations of the details of data reduction methods used with rolling resistance data can be found in reference [7].

## VII. Statistical Analysis

The data from the rolling resistance tests of 252 tires were analyzed to learn which characteristics affect rolling resistance using an analysis of variance. This analysis tests the hypothesis that N given population means are the same (i.e., the null hypothesis) against the alternate hypothesis that, for at least two of the tires tested, the means are unequal. Rejection of the null hypothesis is evidence that variation in rolling resistance is based on the tire characteristic. The significance of rejecting the null hypothesis is stated in terms of the probability of being incorrect by doing so. This probability leads to the percentage level of confidence that one can state that a tire characteristic has an effect on rolling resistance. The confidence levels given in the following discussion signify that the mean rolling resistance of a subset of tires sharing a characteristic (e.g., a subset of radials) does not equal the mean rolling resistance of the entire group of tires. Hence, the tire characteristic affects rolling resistance and a relationship exists.

An analysis of variance, as described in the previous paragraph, was performed for each of the following characteristics:

1. Model
2. Construction type
3. Body cord
4. Belt fiber

To investigate the consistency of tire manufacture as it affects rolling resistance, the means from the same models which had been manufactured at least one week apart were compared. To determine whether the price of a tire is related to its rolling resistance, a linear regression between purchase price and rolling resistance was performed. Finally, the standard deviations for all model lines tested were examined to determine the reliability of the test results.

## VIII. Results

The results for all 252 tires tested are shown in Appendix B. Table 4 provides an overview of all tire characteristics examined and their effects on rolling resistance; Tables 5-9 show the results of each of the analyses performed.

### A. Model

Through an analysis of variance of the 252 tires from 20 different companies constituting the final matrix, a relationship between model and rolling resistance was observed, with 99 percent confidence.

Mean RRC was calculated for each model. The three models with the lowest rolling resistance were:

1. BF Goodrich Lifesaver XLM
2. Uniroyal Steeler
3. Delta Radial II

The three models with the highest rolling resistance were:

1. Atlas Cushionaire
2. Multi-Mile Poly IV
3. Uniroyal Fastrak Poly

Table 5 lists, in increasing order, the rolling resistance force and mean RRC for each model tested, and other statistical results of this analysis.

Table 4

Summary of Effects of
Tire Characteristics On Rolling Resistance

| Tire Characteristics | Sample Used | Result Observed |
| --- | --- | --- |
| Model | 170 radial tires from 20 companies | ° Identity of model affects RRC.<br><br>Models with lowest RRC:<br><br>BF Goodrich Lifesaver XLM<br>Uniroyal Steeler<br>Delta Radial II |
| | 60 bias-ply tires from 12 companies | ° Identity of model affects RRC.<br><br>Models with lowest RRC:<br><br>Goodyear Power Streak<br>Laramie Easy Rider<br>Firestone Deluxe Champion |
| | 22 bias-belted tires from 4 companies | ° Identity of model affects RRC.<br><br>Models with lowest RRC:<br><br>Goodyear Cushion Belt Polyglas<br>Sears Super Guard |
| Construction | All tires tested. | ° Radial plies had 20.3% lower mean RRC than bias-belted tires and 26.1% lower mean RRC than bias-ply tires. |

Table 4 (cont'd)

Summary of Effects of Tire Characteristics On Rolling Resistance

| Tire Characteristics | Sample Used | Result Observed |
|---|---|---|
| Body Cord | Steel-belted radials only | ° Polyester body cord had 8.8% lower mean RRC than rayon body cord. |
| Belt Fiber | Radial-ply only | ° Steel + fiberglass -belted had 0.081% lower mean RRC than fiber-glass-belted tires, 1.27% lower mean RRC than steel -belted tires, and 13.93% lower mean RRC than aramid-belted tires. |
| Price | All construction types | ° Rolling resistance is not linearly dependent on price |
| Rolling Resistance Consistency Over Time | 4 groups of two models of steel-belted radials made in different weeks | ° RRC remains constant with date of manu-facture. |

Table 5

Rolling Resistance Data - Means by Brand and Model

| Brand and Model | N | Const. [1] | Rolling Resistance Force (lbf) x̄ [2] | s [3] | RRC x̄ | s | 90% Confidence Interval around RRC[4] |
|---|---|---|---|---|---|---|---|
| BF Goodrich Lifesaver XLM | 6 | R | 10.96 | 0.20014 | 0.00979 | 0.00018 | 0.00964-0.00994 |
| Uniroyal Steeler | 6 | R | 11.15 | 0.46529 | 0.00997 | 0.00042 | 0.00963-0.01031 |
| Delta Radial II | 4 | R | 11.30 | 0.23200 | 0.01009 | 0.00020 | 0.00985-0.01032 |
| Laramie Glass Rider | 4 | R | 11.41 | 0.12100 | 0.01018 | 0.00011 | 0.01005-0.01031 |
| Atlas Silveraire | 4 | R | 11.61 | 0.06300 | 0.01035 | 0.00007 | 0.01270-0.010430 |
| Firestone Deluxe Champion Radial | 6 | R | 11.67 | 0.25300 | 0.01041 | 0.00023 | 0.01023-0.01060 |
| Michelin XWW | 6 | R | 11.75 | 0.10700 | 0.01048 | 0.00010 | 0.01040-0.01056 |
| Multi-Mile XL | 4 | R | 11.79 | 0.24400 | 0.01052 | 0.00021 | 0.01028-0.01077 |
| M. Ward Runabout | 4 | R | 11.84 | 0.15800 | 0.01055 | 0.00014 | 0.01033-0.01067 |
| General Steel Radial | 6 | R | 11.85 | 0.40450 | 0.01059 | 0.00035 | 0.01029 0.01088 |
| Uniroyal Tigerpaw | 4 | R | 11.93 | 0.30522 | 0.01067 | 0.00026 | 0.01036-0.01098 |
| Penney Mileagemaker Plus | 4 | R | 12.08 | 0.15100 | 0.01078 | 0.00014 | 0.01061-0.01095 |
| Goodyear Arriva | 6 | R | 12.16 | 0.23811 | 0.01087 | 0.00022 | 0.01069-0.01105 |
| Kelly-Springfield Navigator | 4 | R | 12.18 | 0.02563 | 0.01087 | 0.00023 | 0.01060-0.01114 |

Table 5 (cont'd.)

Rolling Resistance Data - Means by Brand and Model

| Brand and Model | N | Const.[1] | Rolling Resistance Force (lbf) x̄ [2] | s [3] | RRC x̄ | s | 90% Confidence Interval around RRC[4] |
|---|---|---|---|---|---|---|---|
| General Dual Steel III | 6 | R | 12.22 | 0.28700 | 0.01091 | 0.00025 | 0.01071-0.01112 |
| Multi-Mile Supreme | 4 | R | 12.28 | 0.16800 | 0.01097 | 0.00014 | 0.01080-0.01113 |
| Goodyear Custom Poly-Steel | 6 | BB | 12.34 | 0.16967 | 0.01101 | 0.00016 | 0.01088 0.01113 |
| K-Mart KM-225 | 4 | R | 12.37 | 0.21700 | 0.01104 | 0.00020 | 0.01081-0.01127 |
| Dayton Quadra | 4 | R | 12.41 | 0.22400 | 0.01109 | 0.00019 | 0.01086-0.01131 |
| Delta Durasteel | 4 | R | 12.46 | 0.13800 | 0.01110 | 0.00013 | 0.01095-0.01126 |
| Firestone 721 | 6 | R | 12.58 | 0.21500 | 0.01122 | 0.00017 | 0.01108-0.01136 |
| Dayton Blue Ribbon | 4 | R | 12.87 | 0.14400 | 0.01149 | 0.00013 | 0.01134-0.01165 |
| Penney Mileagemaker XP | 4 | R | 12.92 | 0.23300 | 0.01152 | 0.00021 | 0.01123-0.01172 |
| Firestone Trax 12 | 4 | R | 12.52 | 0.08810 | 0.01167 | 0.00009 | 0.01107-0.01127 |
| Summit Steel | 4 | R | 13.17 | 0.35400 | 0.01176 | 0.00032 | 0.01139-0.01214 |
| Sears Road Handler 78 | 6 | R | 13.18 | 0.08900 | 0.01177 | 0.00008 | 0.01170-0.01183 |
| Dunlop Goldseal | 4 | R | 13.28 | 0.15300 | 0.01186 | 0.00015 | 0.01169-0.012044 |
| M. Ward Grappler | 4 | R | 13.54 | 0.93100 | 0.01208 | 0.00083 | 0.01110-0.01306 |
| Sears Weather Handler | 6 | R | 13.60 | 0.26900 | 0.01212 | 0.00025 | 0.01192-0.01233 |

Table 5 (cont'd.)

Rolling Resistance Data - Means by Brand and Model

| Brand and Model | N | Const.[1] | Rolling Resistance Force (lbf) | | RRC | | 90% Confidence |
|---|---|---|---|---|---|---|---|
| | | | $\bar{x}$ [2] | s [3] | $\bar{x}$ | s | Interval around RRC[4] |
| Goodyear Tiempo | 6 | R | 13.74 | 0.33482 | 0.01227 | 0.00028 | 0.01204-0.01250 |
| Cooper Lifeliner (glass belt) | 4 | R | 13.76 | 0.04900 | 0.01228 | 0.00005 | 0.01222-0.01233 |
| Armstrong SXA | 4 | R | 13.80 | 0.06700 | 0.01232 | 0.00005 | 0.01227-0.01238 |
| Dunlop Generation IV | 4 | R | 14.00 | 0.35800 | 0.01249 | 0.00032 | 0.01211-0.01287 |
| Cooper Lifeliner (steel belt) | 4 | R | 14.13 | 0.19500 | 0.01261 | 0.00017 | 0.01241-0.01280 |
| Michelin XVS | 6 | R | 14.59 | 0.09600 | 0.01363 | 0.00011 | 0.01354-0.01372 |
| Goodyear Cushion Belt Polyglas | 6 | BB | 15.35 | 0.16012 | 0.01371 | 0.00013 | 0.01360 0.01382 |
| Armstrong Coronet All-Season | 4 | R | 15.48 | 0.13700 | 0.01381 | 0.00014 | 0.01365-0.01397 |
| Kelly-Springfield Roadmark | 4 | BP | 15.62 | 0.31470 | 0.01393 | 0.00027 | 0.01361-0.01425 |
| Sears SuperGuard | 6 | BB | 15.80 | 0.25700 | 0.01409 | 0.00023 | 0.01390-0.01428 |
| Goodyear Power Streak | 6 | BP | 15.80 | 0.37244 | 0.01411 | 0.00036 | 0.01381-0.01440 |
| Laramie Easy Rider | 4 | BP | 16.00 | 0.52600 | 0.01428 | 0.00047 | 0.01372-0.01483 |
| Firestone Deluxe Champion Bias-Ply | 4 | BP | 16.04 | 0.29000 | 0.01431 | 0.00027 | 0.01399-0.01462 |
| Montgomery Ward Road Guard | 4 | BB | 16.08 | 0.21200 | 0.01433 | 0.00018 | 0.01411-0.01455 |

Table 5 (cont'd.)

Rolling Resistance Data - Means by Brand and Model

| Brand and Model | N | Const.[1] | Rolling Resistance Force (lbf) $\bar{x}$ [2] | Rolling Resistance Force (lbf) s [3] | RRC $\bar{x}$ | RRC s | 90% Confidence Interval around RRC[4] |
|---|---|---|---|---|---|---|---|
| BF Goodrich Belted CLM | 6 | BB | 16.18 | 0.09930 | 0.01445 | 0.00008 | 0.01438-0.01452 |
| Sears Guardsman | 6 | BP | 16.46 | 0.47700 | 0.01468 | 0.00043 | 0.01433-0.01503 |
| Dayton Deluxe 78 | 4 | BP | 16.55 | 0.11100 | 0.01477 | 0.00008 | 0.01467-0.01486 |
| Summit Supreme 120 | 4 | BP | 17.30 | 0.25400 | 0.01546 | 0.00021 | 0.01521-0.01570 |
| K-Mart Economizer | 4 | BP | 17.35 | 0.13600 | 0.01549 | 0.00014 | 0.01533-0.01565 |
| Kelly-Springfield Benchmark | 4 | BP | 17.21 | 0.87260 | 0.01558 | 0.00035 | 0.01517-0.01600 |
| K-Mart KM-78 | 4 | BP | 17.92 | 0.21100 | 0.01599 | 0.00020 | 0.01575-0.01623 |
| Cooper Trendsetter | 4 | BP | 18.21 | 0.54700 | 0.01624 | 0.00048 | 0.01568-0.01680 |
| Atlas Cushionaire | 4 | BP | 18.40 | 0.50300 | 0.01641 | 0.00045 | 0.01587-0.01694 |
| Multi-Mile Poly IV | 4 | BP | 18.41 | 0.08700 | 0.01644 | 0.00007 | 0.01635-0.01653 |
| Uniroyal Fastrak Poly | 4 | BP | 18.71 | 0.71616 | 0.01672 | 0.00061 | 0.01600-0.01743 |
| Combined | 252 | | 13.96 | 2.214 | 0.01248 | 0.00199 | 0.01227-0.01261 |

[1] Construction type:
R = radial-ply
BB = bias-belted
BP = bias-ply

[2] $\bar{x}$ = mean

[3] s = standard deviation

[4] 90 percent confidence interval means that one has 90 percent "confidence" that the variance of RRC is within the given limits.

B. Construction Type

All rolling resistance data were stratified by construction type and the mean for each type calculated. Table 6 shows the results.

A definite relationship between construction type and rolling resistance was observed. Of the three construction types tested (radial-ply; bias-belted; and bias-ply), the rolling resistance mean of radial-ply (N = 170) was 20.2 percent lower than bias-belted (N = 22) and 26.0 percent lower than bias-ply (N = 60). This relationship was observed with 99.9 percent confidence and confirmed previous findings.[3]

C. Body Cord

It was observed with 99.9 percent confidence that, among steel-belted radials, a relationship exists between body cord and rolling resistance. Tires of two different body cords were tested: polyester and rayon. Steel-belted radials with polyester body cord had lower mean rolling resistance (RRC = 0.011121, N = 100) than steel-belted radials with rayon body cord (RRC = 0.012100, N = 12). Table 7 shows the mean RRC for the two types of body cord.

Comparisons were made to test for the effect of body cord on rolling resistance only for steel-belted radials because all other types of tire were made exclusively of polyester body cord.

D. Belt Fiber

A relationship was observed, subject to the caveats given below, between the type of belt material in radial tires and its rolling resistance. Among radials, tires made with four different belt materials were tested: steel, fiberglass, aramid and steel + fiberglass. Steel + fiberglass-belted radials (N = 4) had the lowest mean rolling resistance followed by fiberglass-belted (N = 40), steel-belted (N = 110), and lastly, aramid-belted radials (N = 4). Table 8 shows the mean RRC and mean rolling resistance force for radial tires of different belt types.

One should note the small sample size of the above groups in interpreting these results. Although steel + fiberglass-belted and aramid-belted tires had the lowest and highest mean rolling resistance, respectively, only one model (four tires) was tested in each sample. Therefore, the observation really is only that the steel + fiberglass tires of one manufacturer were of slightly lower rolling resistance than the steel-belted tires of many manufacturers. The same can be said for aramid-belted tires. Thus, a larger sample is needed before any statistically valid conclusions are reached regarding the relative rolling resistance of steel + fiberglass- and aramid-belted tires.

Table 6

Rolling Resistance Data - Means by Construction

| Construction | N | Rolling Resistance Force (lbf) $\bar{x}$[1] | Rolling Resistance Force (lbf) s[2] | RRC $\bar{x}$ | RRC s | 90% Confidence Interval around RRC[3] |
|---|---|---|---|---|---|---|
| Radial | 170 | 12.62 | 1.059 | 0.01128 | 0.00099 | 0.01116-0.01141 |
| Bias-belted | 22 | 15.83 | 0.377 | 0.01413 | 0.00033 | 0.01401-0.01425 |
| Bias-ply | 60 | 17.07 | 1.1128 | 0.01525 | 0.00099 | 0.01504-0.01547 |
| Combined | 252 | 13.96 | 2.214 | 0.01248 | 0.00199 | 0.01227-0.01268 |

[1] $\bar{x}$ = mean
[2] s = standard deviation
[3] 90 percent confidence interval means that one has 90 percent "confidence" that the mean RRC of all tires of the specified category is within the given limits.

Table 7

Rolling Resistance Data - Means by Body Cord
(Steel-Belted Radials Only)[1]

| Body Cord | Force (lbf) N | Force (lbf) $\bar{x}$ | Force (lbf) s | RRC $\bar{x}$ | RRC s |
|---|---|---|---|---|---|
| Polyester | 100 | 12.456 | .8996 | 0.011121 | 0.000798 |
| Rayon | 12 | 13.221 | 1.5040 | 0.012100 | 0.001666 |
| Combined | 112 | 12.538 | 1.0012 | 0.011226 | 0.000968 |

[1] Only steel-belted radials were examined for the effect of body cord on rolling resistance, since all other types of tires were made exclusively of polyester body cord.

Table 8

Rolling Resistance Data - Means by Belt Fiber
(Radial Construction Only)[1]

| Belt Fiber | Rolling Resistance Force (lbf) | | | RRC | |
|---|---|---|---|---|---|
| | N[2] | $\bar{x}$ | s | $\bar{x}$ | s |
| Steel + Fiberglass | 4 | 12.437 | .14307 | 0.011085 | 0.000134 |
| Fiberglass | 40 | 12.434 | .94363 | 0.011094 | 0.000842 |
| Steel | 112 | 12.538 | 1.00120 | 0.011226 | 0.000967 |
| Aramid | 4 | 14.151 | .27535 | 0.012629 | 0.000243 |
| Combined | 160 | 12.550 | .99416 | 0.011225 | 0.000939 |

[1] Only radial tires were used in this analysis because among the 22 bias-belted tires, 12 were fiberglass-belted, and for 10 tires the information was not obtained. Bias-ply tires were not used in the analysis since they do not contain belts.

[2] Of 170 radials tested, only 160 were examined because the information was not obtained for 10 tires.

It should also be noted that while steel + fiberglass radials and fiberglass radials had the lowest mean rolling resistance, the three models with the lowest rolling resistance were steel belted (BF Goodrich Lifesaver XLM, Uniroyal Steeler and Delta Radial II). Furthermore, although steel + fiberglass-belted radials had the lowest mean RRC, the mean rolling resistance force of fiberglass-belted radials was slightly lower than steel + fiberglass-belted radials. Thus, the relationship between rolling resistance and belt fiber is not as conclusive as the others mentioned above.

E. Price

A linear regression of purchase price (1981 prices) against rolling resistance was performed for each of the three construction types to determine whether a relationship exists. It was observed for all types that tire price is not linearly dependent upon rolling resistance. That is, rolling resistance cannot be predicted by the price of a tire. Price accounts for only 10.8 percent of the variation in radial tires, 2.6 percent in bias-ply tires, and 8.7 percent of the variation in bias-belted tires. These results agree with an earlier analysis.[3] Table 9 lists all model lines, in order of increasing mean RRC, and the purchase price of each tire.

F. Rolling Resistance Consistency Over Time

It was concluded from the examination that rolling resistance is consistent over time and thus the rolling resistance test results reliably predict the rolling resistance of any tire from a particular model. To determine this, models were examined which were identical in every way except that they were manufactured on different dates (as indicated by the DOT tire identification). Table 10 gives the details of this examination.

The mean RRC of two models, each containing two groups of tires manufactured during different weeks, were examined. Tires of the first model, a steel-belted radial, were manufactured during the weeks of November 2-8, 1980, and February 8-14, 1981. The difference between the means of these two groups is 0.00004 and the pooled standard deviation (i.e., the standard deviation for the entire model) of the model is 0.00014. Tires of the second model, also a steel-belted radial, were made during the weeks of May 9-15 and May 30-June 5, 1982. The difference between the means of these two groups is 0.00023 and the pooled standard deviation is 0.00017. The means of the first model were not different at the 99 percent confidence level; the means of the second model were not different at the 95 percent confidence level. These figures are very consistent for the two models, and demonstrate that the rolling resistance of a tire could be relied upon as a stable manufacturing parameter, based upon our testing.

Table 9

Mean RRC and Purchase Price

| Brand and Model | $\overline{RRC}$ | Price* |
|---|---|---|
| BF Goodrich Lifesaver XLM | 0.00979 | $ 49.94 |
| Uniroyal Steeler | 0.00997 | 57.72 |
| Delta Radial II | 0.01009 | 47.60 |
| Laramie Glass Rider | 0.01018 | 45.75 |
| Atlas Silveraire | 0.01035 | 57.03 |
| Firestone Deluxe Champion Radial | 0.01041 | 47.17 |
| Michelin XWW | 0.01048 | 86.59 |
| Multi-Mile XL | 0.01052 | 46.95 |
| Montgomery Ward Runabout | 0.01055 | 80.08 |
| General Steel Radial | 0.01059 | 62.41 |
| Uniroyal Tigerpaw | 0.01067 | 54.39 |
| JC Penney Mileagemaker Plus | 0.01078 | 84.18 |
| Goodyear Arriva | 0.01087 | 67.13 |
| Kelly-Springfield Navigator | 0.01087 | 55.00 |
| General Dual Steel III | 0.01091 | 69.59 |
| Multi-Mile Supreme | 0.01097 | 49.94 |
| Goodyear Custom Poly-Steel | 0.01101 | 57.98 |
| K-Mart KM-225 | 0.01104 | 60.97 |
| Dayton Quadra | 0.01109 | 39.47 |
| Delta Durasteel | 0.01110 | 43.70 |
| Firestone 721 | 0.01122 | 62.17 |
| Dayton Blue Ribbon | 0.01149 | 51.64 |
| JC Mileagemaker XP | 0.01152 | 93.16 |
| Firestone Trax 12 | 0.01167 | 55.44 |
| Summit Steel | 0.01176 | 42.87 |
| Sears Road Handler 78 | 0.01177 | 117.49 |
| Dunlop Goldseal | 0.01186 | 54.95 |
| Montgomery Ward Grap-pler | 0.01208 | 109.08 |
| Sears Weather Handler | 0.01212 | 73.07 |
| Goodyear Tiempo | 0.01227 | 61.63 |
| Cooper Lifeliner (glass belt) | 0.01228 | 49.82 |
| Armstrong SXA | 0.01232 | 61.14 |
| Dunlop Generation IV | 0.01249 | 57.95 |
| Cooper Lifeliner (steel belt) | 0.01261 | 54.44 |

Table 9 (cont'd.)

Mean RRC and Purchase Price

| Brand and Model | $\overline{RRC}$ | Price* |
|---|---|---|
| Michelin XVS | 0.01363 | $ 90.00 |
| Goodyear Cushion Belt Polyglas | 0.01371 | 45.04 |
| Armstrong Coronet All-Season | 0.01381 | 63.83 |
| Kelly-Springfield Roadmark | 0.01393 | 41.00 |
| Sears Super Guard | 0.01409 | 60.07 |
| Goodyear Power Streak | 0.01411 | 41.25 |
| Laramie Easy Rider | 0.01428 | 34.21 |
| Firestone Deluxe Champion Bias-Ply | 0.01431 | 40.84 |
| Montgomery Ward Road Guard | 0.01433 | 69.08 |
| BF Goodrich Belted CLM | 0.01445 | 38.48 |
| Sears Guardsman | 0.01468 | 37.79 |
| Dayton Deluxe 78 | 0.01477 | 28.62 |
| Summit Supreme 120 | 0.01546 | 30.40 |
| K-Mart Economizer | 0.01549 | 34.97 |
| Kelly-Springfield Benchmark | 0.01558 | 38.00 |
| K-Mart KM-78 | 0.01599 | 41.00 |
| Cooper Trendsetter | 0.01624 | 32.98 |
| Atlas Cushionaire | 0.01641 | 28.00 |
| Multi-Mile Poly IV | 0.01644 | 34.95 |
| Uniroyal Fastrak Poly | 0.01672 | 41.19 |

* Prices given may not be representative of current prices.

Table 10

Rolling Resistance Consistency Over Time - Groups of Tires Manufactured During Different Weeks

Model 1

| | N | Date of Manufacture | RRC | Standard Deviation |
|---|---|---|---|---|
| Group 1 | 2 | Nov. 2-8, 1980 | 0.00979 | 0.00006 |
| Group 2 | 4 | Feb. 8-14, 1981 | 0.00975 | 0.00018 |
| | | Pooled standard deviation: | | 0.00014 |

Model 2

| | N | Date of Manufacture | RRC | Standard Deviation |
|---|---|---|---|---|
| Group 1 | 2 | May 9-15, 1982 | 0.01086 | 0.00016 |
| Group 2 | 4 | May 30- June 5,1982 | 0.01109 | 0.00012 |
| | | Pooled standard deviation: | | 0.00017 |

### G. Reliability

To further determine how reliably the rolling resistance of an individual tire from a model line reflects the rolling resistance of the entire model line, the standard deviation of the models were examined. The standard deviation ranged from 0.00006 to 0.00058, with a mean of 0.00022. The coefficient of variation for each model was typically 2 percent. The 90 percent confidence interval about the mean was typically only ±0.00035. These figures signify that the sample sizes of four and six were adequate to obtain sound statistics. These figures also indicate that testing only one tire of a given model gives a good indication of the mean rolling resistance of the model.

## IX. Quality Control

Two tires (Michelin XWWs) served as correlation tires and were each tested seven times as a means of checking for any variations in the test results as a function of time. Only minute changes in the test results were observed caused by time-dependent factors such as calibration drifts, lack of machine alignment, or other unknown factors. The RRC for these tires ranged from 0.0105 - 0.0108. The pooled standard deviation of these tires' test results, for test dates ranging from July 6, 1982 to March 15, 1984, was 0.00009. The low standard deviations for the models (given on the previous page) and for the correlation tires reflect precision testing, consistent test conditions, and again demonstrates the predictability of rolling resistance for an individual tire if a tire of the same model has been tested.

## X. Conclusions

### A. Summary of Results

Based on the test results from 252 tire tests, it was determined that the following characteristics influence tire rolling resistance:

1. Model
2. Construction
3. Body cord

Belt fiber was also observed to have some influence on rolling resistance, but the sample size of different belt fibers and the variation within this sample were small.

It was concluded that neither price nor date of manufacture (within a reasonable amount of time) is related to a tire's rolling resistance. Finally, an examination of the standard deviations from all models tested and from the correlation tires showed precise, uniform testing and demonstrated the reliability of the rolling resistance test to forecast the rolling resistance of tire models by testing an individual tire of that model.

For the most part, the lowest rolling resistance characteristics examined were actually present in the test tires which received the lowest rolling resistance. That is, the statistically "best" tires generally did have the lowest rolling resistance values in the test program.

Based on this analysis, the most fuel-efficient tire appears to be:

1. Radial-ply, and to have
2. Polyster body cords.

The three lowest rolling resistance models were:

1. BF Goodrich Lifesaver XLM
2. Uniroyal Steeler
3. Delta Radial II.

All three of the above models were:

1. Radials,
2. Steel-belted with
3. Polyester body cord.

Examination of the predicted best tires versus the observed best tires indicate that the prediction is adequate for the major macroscopic parameters such as construction type and body cord.

B. <u>Comparison with Previous Findings</u>

This analysis agreed, for the most part, with earlier findings.[3] Both studies found a relationship between construction type, belt fiber, and manufacturer; both studies also found that tires are manufactured consistently. Neither study found a relationship between purchase price and rolling resistance. Table 11 summarizes the previous study's findings. The previous study did not find a correlation between body cord and rolling resistance, while this study found some weak correlation. This can, most likely, be attributed to the substantially larger sample size used in this analysis.

Table 11

Summary of Results from a Previous Study[3]--
Effects of Tire Characteristics On Rolling Resistance

| Tire Characteristics | Sample Used | Result Observed |
|---|---|---|
| Manufacturer | 86 tires from 19 companies | ° Identity of the manufacturer does affect RRC. |
| Construction Type | 13-inch tires | ° Radials had 18.3% lower mean RRC than bias-belted and bias-ply tires. |
| | 15-inch tires | ° Radials had 27.5% lower mean RRC than bias-belted and 23.5% lower mean RRC than bias-ply tires. |
| Belt Fiber | 13-inch radials | Fiberglass had 4.7% lower mean RRC than steel, 10.1% lower mean RRC than aramid and 24.2% lower RRC than rayon. |
| Body Cord | 13-inch steel radials | ° Does not affect RRC. |
| Price | 13-inch radials | ° Price is not linearly dependent on rolling resistance. |
| | 13-inch bias-belted | ° Price is not linearly dependent on rolling resistance. |
| | 13-inch bias ply | ° Price is not linearly dependent on rolling resistance. |

Table 11 (cont'd.)

Summary of Results from a Previous Study[3]--
Effects of Tire Characteristics On Rolling Resistance

| Tire Characteristics | Sample Used | Result Observed |
| --- | --- | --- |
| RRC Consistency Over Time | 3 groups of one model of bias ply tire made on different dates | ° RRC of a model does not vary appreciably with date of manufacture. |
| | 2 groups of one model of fiberglass radial made on different dates | ° RRC of a model does not vary appreciably with date of manufacture. |

## References

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5. "Interim Report on the Characterization of the Rolling Resistance of Aftermarket Passenger Car Tires," Terry Newell, March 1983.

6. 1981 Yearbook and 1980 Yearbook, The Tire and Rim Association, Inc.

7. "The Measurement of Passenger Car Tire Rolling Resistance," SAE Information Report J1270, October 1979.

# Appendix A

"EPA Recommended Practice for the Determination of Tire Rolling Resistance Coefficients"

# EPA Recommended Practice for Determination of Tire Rolling Resistance Coefficients

Glenn Thompson

March 1980

Amended August 1980

Standards Development and Support Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Office of Air, Noise and Radiation
U.S. Environmental Protection Agency

## I. Introduction

This test procedure determines the tire rolling resistance coefficient for a free rolling tire at a steady speed. This procedure conforms to the SAE Recommended Practice, Rolling Resistance Measurement Procedure for Passenger Car Tires - SAE J1269, generally adopting the recommended conditions of J1269 as the required standard conditions. The SAE Recommended Practice J1269 and the accompanying SAE information report J1270 may be consulted for additional information.

## II. Test Equipment

The test equipment required is a tire dynamometer which measures the tire energy dissipative force as the tire is driven by a large cylindrical test wheel.

### A. Tire Dynamometer

The test dynamometer shall be a cylindrical surface machine of 67.23 in (1.7076m) diameter. The test machine shall be capable of supplying a force on the tire perpendicular to the test surface, and shall be able to measure the transverse reaction forces acting on the tire or the torque necessary to drive the test wheel. During this process the machine must be capable of maintaining the test surface at constant speed. The width of the test surface must exceed the width of all test tires, and the test surface shall be coated with a medium coarseness abrasive (80 grit). As an example, medium grit 3M Safety-Walk represents a satisfactory surface.*

#### 1. Test Machine Alignment

The direction of application of the tire load must be normal to the test surface within 0.03 deg (0.5 mrad). The wheel plan of the tire must be normal to the test surface within 0.03 deg (0.5 mrad) and parallel to the direction of motion of the test surface within 0.03 deg (0.5 mrad).

#### 2. Test Machine Control Accuracy

Exclusive of perturbations induced by the tire and rim nonuniformities, the test equipment must control the test variables within the following limits:

| | U.S. Customary Units | SI Units |
|---|---|---|
| Tire Load | 5 lbf | 22 N |
| Surface Speed | 1 mph | 2 km/h |

* The manufacturer of this product is identified to clarify the example and does not imply endorsement of the product.

3. Test Machine Instrumentation Accuracy

The instrumentation used for readout and recording of test data must be accurate within the following tolerances:

| | U.S. Customary Units | SI Units |
|---|---|---|
| Tire Load | 2 lbf | 8 N |
| Surface Speed | 0.5 mph | 0.8 km/h |
| Spindle Force | 0.1 lbf | 0.4 N |
| Loaded Radius | 0.1 in | 0.002 m |

B. The Test Cell Requirements

The primary requirement for the test cell is that the ambient temperature be well controlled. In addition, the support services of compressed air should be available for tire inflation as should the necessary gauges to measure tire inflation.

1. Thermal Control

The ambient temperature in the vicinity of the test tire shall be 75 ± 5°F (24 ± 3°C).

2. Temperature Measurement Precision

The instrumentation used to measure the ambient temperature must be accurate to within 1 °F (0.5 °C). This instrumentation shall be located approximately 15 inches from the tire, measured perpendicular to the sidewall.

III. Test Procedure

The test procedure consists of the following steps: tire mounting; tire break-in; equilibration of the tire to the test ambient temperature; adjustment of the cold inflation pressure; tire warm-up and then measurement of the tire rolling resistance.

A. Tire Mounting

1. Rims

The tire shall be mounted on test rims which have an approved contour and width as specified by the Tire & Rim Association, Inc., as "design rim width" ± one half inch for the size tire being rested. For tire sizes not standardized by the Tire & Rim Association, Inc., reference should be made to the appropriate standardizing organization as listed in the Federal Motor Vehicle Safety Standards (CFR Title 49 §571.109 Table I). These rims shall have a maximum radial runout of 0.035 in (0.88 mm) and a maximum lateral runout of 0.045 in (1.1 mm).

2. Inflation Pressure

The inflation pressure of the tires after mounting shall be:

| | |
|---|---|
| Alpha Numeric Size Tires | 32 psi (220 kPa) |
| "P" Type tires | 35 psi (240 kPa) |

The tire inflation pressure after mounting shall be correct to within 1 psi (6.8 kPa). The gauges used to measure this tire inflation pressure shall be accurate to within 0.5 psi (3.4 kPa).

B. Tire Break-in

Tires may undergo significant permanent growth upon first operation and therefore may require an initial break-in and cooling period prior to the start of the test. A break-in run consisting of installing the tire on the tire test machine and operating the system under the test conditions for a period of 1 hour is recommended.

C. Thermal Conditioning

After initial break-in the tire shall be placed in the thermal environment of the test conditions for a minimum period of 3 hours before the test. During this period the tire inflation pressure should be checked and adjusted if necessary, to the design cold inflation pressure of the tire.

D. The Rolling Resistance Measurement

The test consists of a final pressure check, loading the tire, the tire warm-up, during which the tire temperature and inflation are allowed to increase as they would in typical service; followed by the rolling resistance measurement.

1. Installation on the Test Machine

The inflation pressure of the tire shall be checked and adjusted if necessary. The inflation pressure immediately prior to the test shall be correct to within 0.25 psi (1.7 kPa). The gauges used to determine this pressure shall be accurate to within 0.25 psi (1.7 kPa). The tire shall then be installed on the test machine if not already installed, and the load on the tire perpendicular to the test surface shall be adjusted to 80 percent of the design load of the tire.

2. Tire Warm-up

The test tire shall be conditioned by operation at a speed of 50 mph for a minimum of 45 minutes.

$T_x$ = the test wheel drive torque of III D3.

$T_p$ = the parasitic test wheel drive torque of III D4.

B. Tire Energy Dissipation Force

The tire energy dissipation force shall be calculated from the net spindle reaction force by the following equation:

$$F_d = f(1 + r/R) \quad (2)$$

Where:

$F_d$ = the tire energy dissipation force lb (N),

F = the net tire spindle force lb (N),

r = the tire loaded radius, in (m),

R = the test surface radius, in (m).

In the case of the torque measurement method the energy dissipation force is to be calculated by:

$$F_d = T/R \quad (3)$$

3. Rolling Resistance Measurements

Following the tire warm-up and with the test dynamometer operating at 50 mph, the following parameters shall be recorded:

a. Tire spindle force or test wheel drive torque.
b. Normal load on the tire.
c. Loaded radius of the tire.

4. Measurement of Parasitic Losses

As a final measurement, the parasitic machine losses shall be determined. The test machine speed shall be maintained at 50 mph while the load onthe tire is reduced to approximately one percent of the test load. Under this condition the following parameters shall be determined:

a. Tire spindle force or test sheel drive torque.
b. Normal load on the tire.

IV. Data Analysis

The data reduction consists of the correction for the machine parasitic losses, conversion to a tire energy dissipation force, correction to the standard test temperature, and the computation of the tire rolling resistance coefficient.

A. Subtraction of Parasitic Losses

The spindle force or test wheel drive torque measurement of the machine parasitic losses obtained in III. D4, shall be subtracted from the spindle forces or test wheel drive torques measured during the test, III. D3, to obtain the net spindle reaction force or net drivewheel drive torque.

That is:

$$F = F_x - F_p \qquad (1)$$

$$T = T_x - T_p$$

Where:

$F$ = the net spindle reaction force.

$F_x$ = the spindle reactive force measured during the test, III. D3.

$F_p$ = the parasitic spindle reactive force of III. D4.

$T$ = the net test wheel drive torque.

C. Temperature Correction

The tire energy dissipation force shall be corrected to the standard test temperature of 75°F by the following equation:

$$F_d^* = F_d[1 + c_t(t_x - t_s)] \qquad (4)$$

$F_d^*$ = the tire dissipative force at the standard temperature,

$t_x$ = the average measured temperature over the duration of the test,

$t_s$ = the standard test temperature 75°F (24°C),

$c_t$ = the temperature correction coefficient, $5 \times 10^{-3}/°F$ $(9 \times 10^{-3}/°C)$.

The test ambient temperature shall always be within 75° ± 5°F (24 ± 3°C), as described in II.B.1.; therefore, this linear temperature correction will always be applied over a temperature range of less than 5°F (3°C) for any one test.

D. Net Load Force

The parasitic load force measured in III D4 shall be subtracted from the normal load force measured during the test IIID3 to obtain the net load force.

That is:

$$L = L_x - L_p \qquad (5)$$

Where:

L = the net load force,

$L_x$ = the tire load force measured during the test III D3.

$L_p$ = the tire load force during the parasitic measurement III D4.

E. Rolling Resistance Coefficient

The rolling resistance coefficient is calculated by dividing the energy dissipation force by the net load imposed in the tire:

$$C = F_d^*/L \qquad (6)$$

Where:

C = rolling resistance coefficient (RRC).

Equations 1, 2, 4, 5, and 6 may be combined into the following single equation:

$$C = \frac{(F_x - F_p)(1 + r/R)[1 + c_t(t_x - t_s)]}{(L_x - L_p)} \qquad (7)$$

Likewise, equations 1, 3, 4, 5, and 6 may be combined as:

$$C = \frac{(T_x - T_p)[1 + c_t(t_x - t_s)]}{R(L_x - L_p)} \qquad (8)$$

# Appendix B

## Individual Tire Rolling Resistance Test Results

## Rolling Resistance Test Results for Individual Tires

| EPA ID# | Mfr/Brand & Model | Test Date | RR Force (lbf) | RRC | Ambient Temp. (°F) | Temperature-Corrected RR Force (lbf) | Temperature-Corrected RRC |
|---|---|---|---|---|---|---|---|
| 4101 | Armstrong Coronet All-Season Radial | 10/27/82 | 15.62 | 0.01392 | 74 | 15.57 | 0.01388 |
| 4102 | Armstrong Coronet All-Season Radial | 10/27/82 | 15.29 | 0.01362 | 78 | 15.44 | 0.01375 |
| 4103 | Armstrong Coronet All-Season Radial | 10/28/82 | 15.50 | 0.01385 | 75 | 15.50 | 0.01385 |
| 4104 | Armstrong Coronet All-Season Radial | 10/28/82 | 15.50 | 0.01386 | 77 | 15.60 | 0.01396 |
| 4105 | Armstrong SXA Radial | 10/27/82 | 13.77 | 0.01228 | 74 | 13.72 | 0.01224 |
| 4106 | Armstrong SXA Radial | 10/27/82 | 13.90 | 0.01239 | 75 | 13.90 | 0.01239 |
| 4107 | Armstrong SXA Radial | 10/27/82 | 13.76 | 0.01230 | 75 | 13.76 | 0.01230 |
| 4108 | Armstrong SXA Radial | 10/27/82 | 13.77 | 0.01232 | 75 | 13.77 | 0.01232 |
| 4109 | Atlas Cushionaire Bias | 9/15/82 | 18.47 | 0.01648 | 75 | 18.47 | 0.01648 |
| 4110 | Atlas Cushionaire Bias | 9/15/82 | 19.05 | 0.01699 | 74 | 18.99 | 0.01694 |
| 4111 | Atlas Cushionaire Bias | 9/16/82 | 17.86 | 0.01592 | 73 | 17.74 | 0.01581 |
| 4112 | Atlas Cushionaire Bias | 9/16/82 | 18.20 | 0.01624 | 78 | 18.38 | 0.01640 |
| 4113 | Atlas Silveraire Radial | 9/23/83 | 11.56 | 0.01031 | 77 | 11.64 | 0.01038 |
| 4114 | Atlas Silveraire Radial | 9/29/83 | 11.56 | 0.01029 | 73 | 11.48 | 0.01023 |

Rolling Resistance Test Results for Individual Tires

| EPA ID# | Mfr/Brand & Model | Test Date | RR Force (lbf) | RRC | Ambient Temp. (°F) | Temperature-Corrected RR Force (lbf) | Temperature-Corrected RRC |
|---|---|---|---|---|---|---|---|
| 4115 | Atlas Silveraire Radial | 9/29/83 | 11.63 | 0.01035 | 78 | 11.75 | 0.01045 |
| 4116 | Atlas Silveraire Radial | 9/29/83 | 11.69 | 0.01045 | 75 | 11.69 | 0.01045 |
| 4117 | Cooper Lifeliner Radial (Glass belt) | 10/19/82 | 13.70 | 0.01221 | 78 | 13.84 | 0.01233 |
| 4118 | Cooper Lifeliner Radial (Glass belt) | 10/19/82 | 13.75 | 0.01230 | 77 | 13.84 | 0.01238 |
| 4119 | Cooper Lifeliner Radial (Glass belt) | 10/19/82 | 13.82 | 0.01232 | 78 | 13.96 | 0.01244 |
| 4120 | Cooper Lifeliner Radial (Glass belt) | 10/19/82 | 13.76 | 0.01229 | 72 | 13.62 | 0.01216 |
| 4121 | Cooper Lifeliner Radial (Steel belt) | 10/15/82 | 14.34 | 0.01277 | 77 | 14.43 | 0.01285 |
| 4122 | Cooper Lifeliner Radial (Steel belt) | 10/15/82 | 14.21 | 0.01268 | 77 | 14.30 | 0.01276 |
| 4123 | Cooper Lifeliner Radial (Steel belt) | 10/19/82 | 13.88 | 0.01238 | 75 | 13.88 | 0.01238 |
| 4124 | Cooper Lifeliner Radial (Steel belt) | 10/19/82 | 14.09 | 0.01259 | 77 | 14.18 | 0.01267 |
| 4125 | Cooper Trendsetter | 10/01/82 | 18.94 | 0.01687 | 78 | 19.13 | 0.01703 |
| 4126 | Cooper Trendsetter | 10/05/82 | 17.71 | 0.01577 | 77 | 17.83 | 0.01587 |

## Rolling Resistance Test Results for Individual Tires

| EPA ID# | Mfr/Brand & Model | Test Date | RR Force (lbf) | RRC | Ambient Temp. (°F) | Temperature-Corrected RR Force (lbf) | Temperature-Corrected RRC |
|---|---|---|---|---|---|---|---|
| 4127 | Cooper Trendsetter | 10/07/82 | 17.88 | 0.01599 | 77 | 18.00 | 0.01610 |
| 4128 | Cooper Trendsetter | 10/07/82 | 18.29 | 0.01632 | 75 | 18.29 | 0.01632 |
| 4129 | Dayton Blue Ribbon | 10/21/82 | 12.71 | 0.01135 | 73 | 12.63 | 0.01127 |
| 4130 | Dayton Blue Ribbon | 10/21/82 | 12.99 | 0.01159 | 74 | 12.95 | 0.01155 |
| 4131 | Dayton Blue Ribbon | 10/21/82 | 12.78 | 0.01142 | 74 | 12.74 | 0.01138 |
| 4132 | Dayton Blue Ribbon | 10/21/82 | 12.99 | 0.01162 | 73 | 12.90 | 0.01154 |
| 4133 | Dayton Deluxe 78 Bias | 10/25/82 | 16.41 | 0.01468 | 78 | 16.57 | 0.01482 |
| 4134 | Dayton Deluxe 78 Bias | 10/25/82 | 16.53 | 0.01472 | 76 | 16.58 | 0.01477 |
| 4135 | Dayton Deluxe 78 Bias | 10/25/82 | 16.67 | 0.01486 | 76 | 16.73 | 0.01491 |
| 4136 | Dayton Deluxe 78 Bias | 10/25/82 | 16.60 | 0.01481 | 79 | 16.82 | 0.01500 |
| 4137 | Dayton Quadra Radial | 10/25/82 | 12.47 | 0.01113 | 75 | 12.47 | 0.01113 |
| 4138 | Dayton Quadra Radial | 10/25/82 | 12.66 | 0.01128 | 76 | 12.70 | 0.01132 |
| 4139 | Dayton Quadra Radial | 10/26/82 | 12.40 | 0.01110 | 75 | 12.40 | 0.01110 |
| 4140 | Dayton Quadra Radial | 10/26/82 | 12.12 | 0.01082 | 76 | 12.16 | 0.01086 |
| 4141 | Delta Durasteel | 10/14/82 | 12.58 | 0.01122 | 75 | 12.58 | 0.01122 |
| 4142 | Delta Durasteel | 10/14/82 | 12.37 | 0.01102 | 75 | 12.37 | 0.01102 |

Rolling Resistance Test Results for Individual Tires

| EPA ID# | Mfr/Brand & Model | Test Date | RR Force (lbf) | RRC | Ambient Temp. (°F) | Temperature-Corrected RR Force (lbf) | Temperature-Corrected RRC |
|---|---|---|---|---|---|---|---|
| 4143 | Delta Durasteel | 10/14/82 | 12.57 | 0.01120 | 74 | 12.53 | 0.01117 |
| 4144 | Delta Durasteel | 10/14/82 | 12.31 | 0.01096 | 74 | 12.27 | 0.01093 |
| 4145 | Delta Radial II | 10/13/82 | 11.23 | 0.01004 | 78 | 11.34 | 0.01014 |
| 4146 | Delta Radial II | 10/13/82 | 11.37 | 0.01015 | 77 | 11.45 | 0.01022 |
| 4147 | Delta Radial II | 10/13/82 | 11.57 | 0.01031 | 75 | 11.57 | 0.01031 |
| 4148 | Delta Radial II | 10/13/82 | 11.02 | 0.00984 | 78 | 11.13 | 0.00994 |
| 4149 | Dunlop Generation IV | 9/14/82 | 13.70 | 0.01221 | 75 | 13.70 | 0.01221 |
| 4150 | Dunlop Generation IV | 9/14/82 | 13.96 | 0.01248 | 75 | 13.96 | 0.01248 |
| 4151 | Dunlop Generation IV | 9/14/82 | 14.51 | 0.01294 | 74 | 14.46 | 0.01290 |
| 4152 | Dunlop Generation IV | 9/14/82 | 13.82 | 0.01233 | 76 | 13.87 | 0.01237 |
| 4153 | Dunlop Goldseal | 5/27/83 | 13.47 | 0.01205 | 76 | 13.51 | 0.01209 |
| 4154 | Dunlop Goldseal | 5/27/83 | 13.13 | 0.01170 | 74 | 13.09 | 0.01166 |
| 4155 | Dunlop Goldseal | 5/27/83 | 13.19 | 0.01179 | 74 | 13.15 | 0.01175 |
| 4156 | Dunlop Goldseal | 5/27/83 | 13.34 | 0.01192 | 75 | 13.34 | 0.01192 |
| 4157 | Firestone 721 | 9/16/83 | 12.70 | 0.01130 | 73 | 12.62 | 0.01122 |
| 4158 | Firestone 721 | 9/16/83 | 12.29 | 0.01099 | 75 | 12.29 | 0.01099 |

Rolling Resistance Test Results for Individual Tires

| EPA ID# | Mfr/Brand & Model | Test Date | RR Force (lbf) | RRC | Ambient Temp. (°F) | Temperature-Corrected RR Force (lbf) | Temperature-Corrected RRC |
|---|---|---|---|---|---|---|---|
| 4159 | Firestone 721 | 9/16/83 | 12.42 | 0.01112 | 75 | 12.42 | 0.01112 |
| 4160 | Firestone 721 | 9/16/83 | 12.49 | 0.01111 | 78 | 12.61 | 0.01122 |
| 4161 | Firestone 721 | 9/16/83 | 12.83 | 0.01141 | 74 | 12.79 | 0.01138 |
| 4162 | Firestone 721 | 9/16/83 | 12.77 | 0.01137 | 76 | 12.81 | 0.01141 |
| 4163 | Firestone Deluxe Champion Radial | 9/16/83 | 11.71 | 0.01047 | 73 | 11.63 | 0.01040 |
| 4164 | Firestone Deluxe Champion Radial | 9/16/83 | 11.51 | 0.01025 | 74 | 11.47 | 0.01022 |
| 4165 | Firestone Deluxe Champion Radial | 9/22/83 | 11.85 | 0.01059 | 78 | 11.97 | 0.01069 |
| 4166 | Firestone Deluxe Champion Radial | 9/22/83 | 11.44 | 0.01022 | 74 | 11.40 | 0.01019 |
| 4167 | Firestone Deluxe Champion Radial | 9/22/83 | 12.07 | 0.01076 | 76 | 12.11 | 0.01079 |
| 4168 | Firestone Deluxe Champion Radial | 9/22/83 | 11.45 | 0.01020 | 77 | 11.53 | 0.01026 |
| 4169 | Firestone Deluxe Champion Bias | 9/22/83 | 16.10 | 0.01435 | 78 | 16.26 | 0.01449 |
| 4170 | Firestone Deluxe Champion Bias | 9/22/83 | 16.16 | 0.01445 | 78 | 16.32 | 0.01460 |

## Rolling Resistance Test Results for Individual Tires

| EPA ID# | Mfr/Brand & Model | Test Date | RR Force (lbf) | RRC | Ambient Temp. (°F) | Temperature-Corrected RR Force (lbf) | Temperature-Corrected RRC |
|---|---|---|---|---|---|---|---|
| 4171 | Firestone Deluxe Champion Bias | 9/22/83 | 15.62 | 0.01392 | 79 | 15.83 | 0.01411 |
| 4172 | Firestone Deluxe Champion Bias | 9/23/83 | 16.28 | 0.01451 | 76 | 16.33 | 0.01456 |
| 4173 | Firestone Trax 12 | 9/23/83 | 12.62 | 0.01128 | 78 | 12.74 | 0.01139 |
| 4174 | Firestone Trax 12 | 9/23/83 | 12.55 | 0.01119 | 75 | 12.55 | 0.01119 |
| 4175 | Firestone Trax 12 | 9/23/83 | 12.42 | 0.01108 | 79 | 12.58 | 0.01123 |
| 4176 | Firestone Trax 12 | 9/23/83 | 12.47 | 0.01112 | 76 | 12.51 | 0.01116 |
| 4185 | General "Steel" Radial | 9/29/83 | 11.82 | 0.01058 | 78 | 11.94 | 0.01069 |
| 4186 | General "Steel" Radial | 9/29/83 | 12.64 | 0.01128 | 79 | 12.81 | 0.01142 |
| 4187 | General "Steel" Radial | 9/29/83 | 11.69 | 0.01043 | 74 | 11.65 | 0.01039 |
| 4188 | General "Steel" Radial | 9/29/83 | 11.81 | 0.01054 | 78 | 11.93 | 0.01064 |
| 4189 | General "Steel" Radial | 9/29/83 | 11.68 | 0.01044 | 75 | 11.68 | 0.01044 |
| 4190 | General "Steel" Radial | 9/30/83 | 11.48 | 0.01026 | 77 | 11.56 | 0.01033 |
| 4191 | General Dual Steel III | 6/16/83 | 12.44 | 0.01110 | 77 | 12.52 | 0.01117 |
| 4192 | General Dual Steel III | 6/16/83 | 12.37 | 0.01105 | 75 | 12.37 | 0.01105 |
| 4193 | General Dual Steel III | 6/16/83 | 12.43 | 0.01110 | 75 | 12.43 | 0.01110 |

## Rolling Resistance Test Results for Individual Tires

| EPA ID# | Mfr/Brand & Model | Test Date | RR Force (lbf) | RRC | Ambient Temp. (°F) | Temperature-Corrected RR Force (lbf) | Temperature-Corrected RRC |
|---|---|---|---|---|---|---|---|
| 4194 | General Dual Steel III | 6/16/83 | 11.68 | 0.01045 | 72 | 11.56 | 0.01034 |
| 4195 | General Dual Steel III | 6/16/83 | 12.15 | 0.01083 | 74 | 12.11 | 0.01079 |
| 4196 | General Dual Steel III | 6/16/83 | 12.24 | 0.01095 | 75 | 12.24 | 0.01095 |
| 4197 | BF Goodrich CLM | 6/16/83 | 16.15 | 0.01443 | 79 | 16.36 | 0.01462 |
| 4198 | BF Goodrich CLM | 6/17/83 | 16.23 | 0.01448 | 78 | 16.39 | 0.01462 |
| 4199 | BF Goodrich CLM | 6/17/83 | 16.30 | 0.01455 | 75 | 16.30 | 0.01455 |
| 4200 | BF Goodrich CLM | 6/17/83 | 16.01 | 0.01432 | 77 | 16.12 | 0.01441 |
| 4201 | BF Goodrich CLM | 6/20/83 | 16.15 | 0.01442 | 74 | 16.10 | 0.01437 |
| 4202 | BF Goodrich CLM | 6/20/83 | 16.22 | 0.01450 | 74 | 16.17 | 0.01445 |
| 4209 | BF Goodrich Lifesaver XLM | 6/20/83 | 11.27 | 0.01004 | 73 | 11.20 | 0.00998 |
| 4210 | BF Goodrich Lifesaver XLM | 6/20/83 | 10.68 | 0.00952 | 76 | 10.72 | 0.00955 |
| 4211 | BF Goodrich Lifesaver XLM | 6/20/83 | 10.82 | 0.00967 | 77 | 10.89 | 0.00973 |
| 4212 | BF Goodrich Lifesaver XLM | 6/20/83 | 11.02 | 0.00986 | 73 | 10.95 | 0.00979 |
| 4213 | BF Goodrich Lifesaver XLM | 6/20/83 | 11.01 | 0.00985 | 72 | 10.90 | 0.00975 |

## Rolling Resistance Test Results for Individual Tires

| EPA ID# | Mfr/Brand & Model | Test Date | RR Force (lbf) | RRC | Ambient Temp. (°F) | Temperature-Corrected RR Force (lbf) | Temperature-Corrected RRC |
|---|---|---|---|---|---|---|---|
| 4214 | BF Goodrich Lifesaver XLM | 6/20/83 | 10.95 | 0.00980 | 76 | 10.99 | 0.00984 |
| 4215 | Goodyear Arriva | 6/21/83 | 11.85 | 0.01059 | 73 | 11.77 | 0.01052 |
| 4216 | Goodyear Arriva | 6/21/83 | 12.33 | 0.01104 | 73 | 12.25 | 0.01097 |
| 4217 | Goodyear Arriva | 6/21/83 | 12.06 | 0.01082 | 75 | 12.06 | 0.01082 |
| 4218 | Goodyear Arriva | 6/21/83 | 12.53 | 0.01121 | 76 | 12.57 | 0.01124 |
| 4219 | Goodyear Arriva | 6/21/83 | 12.06 | 0.01075 | 75 | 12.06 | 0.01075 |
| 4220 | Goodyear Arriva | 6/21/83 | 12.12 | 0.01080 | 75 | 12.12 | 0.01080 |
| 4221 | Goodyear Cushion Belt Polyglas | 6/21/83 | 15.13 | 0.01353 | 73 | 15.03 | 0.01344 |
| 4222 | Goodyear Cushion Belt Polyglas | 6/21/83 | 15.32 | 0.01370 | 75 | 15.32 | 0.01370 |
| 4223 | Goodyear Cushion Belt Polyglas | 6/21/83 | 15.39 | 0.01374 | 73 | 15.29 | 0.01365 |
| 4224 | Goodyear Cushion Belt Polyglas | 6/21/83 | 15.26 | 0.01364 | 77 | 15.36 | 0.01373 |
| 4225 | Goodyear Cushion Belt Polyglas | 6/21/83 | 15.61 | 0.01393 | 73 | 15.51 | 0.01383 |
| 4226 | Goodyear Cushion Belt Polyglas | 6/21/83 | 15.39 | 0.01372 | 75 | 15.39 | 0.01372 |

## Rolling Resistance Test Results for Individual Tires

| EPA ID# | Mfr/Brand & Model | Test Date | RR Force (lbf) | RRC | Ambient Temp. (°F) | Temperature-Corrected RR Force (lbf) | Temperature-Corrected RRC |
|---|---|---|---|---|---|---|---|
| 4227 | Goodyear Custom Polysteel | 6/21/83 | 12.29 | 0.01097 | 75 | 12.29 | 0.01097 |
| 4228 | Goodyear Custom Polysteel | 6/21/83 | 12.09 | 0.01079 | 74 | 12.05 | 0.01075 |
| 4229 | Goodyear Custom Polysteel | 6/22/83 | 12.29 | 0.01094 | 77 | 12.37 | 0.01102 |
| 4230 | Goodyear Custom Polysteel | 6/22/83 | 12.50 | 0.01117 | 74 | 12.46 | 0.01113 |
| 4231 | Goodyear Custom Polysteel | 6/22/83 | 12.56 | 0.01120 | 76 | 12.60 | 0.01124 |
| 4232 | Goodyear Custom Polysteel | 6/22/83 | 12.29 | 0.01095 | 76 | 12.33 | 0.01099 |
| 4233 | Goodyear Power Streak | 6/22/83 | 16.07 | 0.01432 | 78 | 16.23 | 0.01446 |
| 4234 | Goodyear Power Streak | 6/22/83 | 15.41 | 0.01372 | 76 | 15.46 | 0.01377 |
| 4235 | Goodyear Power Streak | 6/22/83 | 15.99 | 0.01426 | 79 | 16.20 | 0.01445 |
| 4236 | Goodyear Power Streak | 6/22/83 | 15.25 | 0.01358 | 77 | 15.35 | 0.01367 |
| 4237 | Goodyear Power Streak | 6/22/83 | 16.06 | 0.01438 | 79 | 16.27 | 0.01457 |
| 4238 | Goodyear Power Streak | 6/22/83 | 16.05 | 0.01437 | 76 | 16.10 | 0.01442 |
| 4239 | Goodyear Tiempo | 6/22/83 | 13.36 | 0.01195 | 73 | 13.27 | 0.01187 |

## Rolling Resistance Test Results for Individual Tires

| EPA ID# | Mfr/Brand & Model | Test Date | RR Force (lbf) | RRC | Ambient Temp. (°F) | Temperature-Corrected RR Force (lbf) | Temperature-Corrected RRC |
|---|---|---|---|---|---|---|---|
| 4240 | Goodyear Tiempo | 6/22/83 | 14.24 | 0.01269 | 73 | 14.15 | 0.01261 |
| 4241 | Goodyear Tiempo | 6/22/83 | 13.63 | 0.01216 | 72 | 13.50 | 0.01204 |
| 4242 | Goodyear Tiempo | 6/22/83 | 13.49 | 0.01208 | 73 | 13.40 | 0.01200 |
| 4243 | Goodyear Tiempo | 6/22/83 | 13.70 | 0.01221 | 76 | 13.75 | 0.01225 |
| 4244 | Goodyear Tiempo | 6/23/83 | 14.04 | 0.01254 | 74 | 13.99 | 0.01249 |
| 4245 | Laramie Easy Rider | 10/26/82 | 16.10 | 0.01436 | 77 | 16.21 | 0.01446 |
| 4246 | Laramie Easy Rider | 10/26/82 | 15.81 | 0.01414 | 76 | 15.86 | 0.01419 |
| 4247 | Laramie Easy Rider | 10/26/82 | 15.41 | 0.01373 | 72 | 15.26 | 0.01360 |
| 4248 | Laramie Easy Rider | 10/26/82 | 16.66 | 0.01486 | 74 | 16.61 | 0.01481 |
| 4249 | Laramie Glass Rider | 10/26/82 | 11.54 | 0.01029 | 72 | 11.43 | 0.01018 |
| 4250 | Laramie Glass Rider | 10/26/82 | 11.46 | 0.01026 | 75 | 11.46 | 0.01026 |
| 4251 | Laramie Glass Rider | 10/27/82 | 11.34 | 0.01013 | 75 | 11.34 | 0.01013 |
| 4252 | Laramie Glass Rider | 10/27/82 | 11.27 | 0.01004 | 76 | 11.31 | 0.01008 |
| 4253 | Kelly-Springfield Benchmark | 4/07/83 | 17.38 | 0.01549 | 76 | 17.44 | 0.01554 |
| 4254 | Kelly-Springfield Benchmark | 4/07/83 | 17.65 | 0.01577 | 77 | 17.77 | 0.01588 |

## Rolling Resistance Test Results for Individual Tires

| EPA ID# | Mfr/Brand & Model | Test Date | RR Force (lbf) | RRC | Ambient Temp. (°F) | Temperature-Corrected RR Force (lbf) | Temperature-Corrected RRC |
|---|---|---|---|---|---|---|---|
| 4255 | Kelly-Springfield Benchmark | 4/08/83 | 17.88 | 0.01594 | 77 | 18.00 | 0.01604 |
| 4256 | Kelly-Springfield Benchmark | 4/08/83 | 15.94 | 0.01514 | 76 | 15.99 | 0.01519 |
| 4257 | Kelly-Springfield Navigator | 5/27/83 | 12.23 | 0.01092 | 72 | 12.11 | 0.01081 |
| 4258 | Kelly-Springfield Navigator | 5/27/83 | 11.89 | 0.01061 | 73 | 11.81 | 0.01054 |
| 4259 | Kelly-Springfield Navigator | 6/14/83 | 12.50 | 0.01115 | 73 | 12.42 | 0.01108 |
| 4260 | Kelly-Springfield Navigator | 6/15/83 | 12.09 | 0.01080 | 74 | 12.05 | 0.01077 |
| 4261 | Kelly-Springfield Roadmark | 4/08/83 | 15.23 | 0.01360 | 75 | 15.23 | 0.01360 |
| 4262 | Kelly-Springfield Roadmark | 4/08/83 | 15.91 | 0.01419 | 73 | 15.80 | 0.01410 |
| 4263 | Kelly-Springfield Roadmark | 4/11/83 | 15.83 | 0.01410 | 75 | 15.83 | 0.01410 |
| 4264 | Kelly-Springfield Roadmark | 5/26/83 | 15.49 | 0.01383 | 77 | 15.59 | 0.01392 |
| 4265 | K-Mart Economizer | 10/15/82 | 17.16 | 0.01529 | 78 | 17.33 | 0.01545 |

## Rolling Resistance Test Results for Individual Tires

| EPA ID# | Mfr/Brand & Model | Test Date | RR Force (lbf) | RRC | Ambient Temp. (°F) | Temperature-Corrected RR Force (lbf) | Temperature-Corrected RRC |
|---|---|---|---|---|---|---|---|
| 4266 | K-Mart Economizer | 10/15/82 | 17.33 | 0.01550 | 77 | 17.44 | 0.01560 |
| 4267 | K-Mart Economizer | 10/15/82 | 17.47 | 0.01561 | 75 | 17.47 | 0.01561 |
| 4268 | K-Mart Economizer | 10/15/82 | 17.42 | 0.01554 | 78 | 17.59 | 0.01569 |
| 4269 | K-Mart KM225 | 10/12/82 | 12.28 | 0.01093 | 76 | 12.32 | 0.01097 |
| 4270 | K-Mart KM225 | 10/12/82 | 12.69 | 0.01133 | 75 | 12.69 | 0.01133 |
| 4271 | K-Mart KM225 | 10/12/82 | 12.28 | 0.01094 | 75 | 12.28 | 0.01094 |
| 4272 | K-Mart KM225 | 10/13/82 | 12.22 | 0.01093 | 78 | 12.34 | 0.01104 |
| 4273 | K-Mart KM-78 | 10/20/82 | 18.00 | 0.01606 | 75 | 18.00 | 0.01606 |
| 4274 | K-Mart KM-78 | 10/20/82 | 17.65 | 0.01573 | 76 | 17.71 | 0.01578 |
| 4275 | K-Mart KM-78 | 10/20/82 | 18.15 | 0.01622 | 76 | 18.21 | 0.01627 |
| 4276 | K-Mart KM-78 | 10/20/82 | 17.88 | 0.01596 | 73 | 17.76 | 0.01586 |
| 4277 | Michelin XWW | 7/06/82 | 11.89 | 0.01061 | 76 | 11.93 | 0.01064 |
| 4278 | Michelin XWW | 7/06/82 | 11.89 | 0.01061 | 76 | 11.93 | 0.01064 |
| 4279 | Michelin XWW | 9/25/82 | 11.69 | 0.01040 | 76 | 11.73 | 0.01043 |
| 4280 | Michelin XWW | 9/26/82 | 11.68 | 0.01042 | 75 | 11.68 | 0.01042 |
| 4281 | Michelin XWW | 9/26/82 | 11.68 | 0.01043 | 75 | 11.68 | 0.01043 |

## Rolling Resistance Test Results for Individual Tires

| EPA ID# | Mfr/Brand & Model | Test Date | RR Force (lbf) | RRC | Ambient Temp. (°F) | Temperature-Corrected RR Force (lbf) | Temperature-Corrected RRC |
|---|---|---|---|---|---|---|---|
| 4282 | Michelin XWW | 9/26/82 | 11.68 | 0.01041 | 77 | 11.76 | 0.01048 |
| 4283 | Michelin XVS | 9/23/82 | 14.75 | 0.01381 | 76 | 14.80 | 0.01386 |
| 4284 | Michelin XVS | 9/23/82 | 14.61 | 0.01368 | 76 | 14.66 | 0.01372 |
| 4285 | Michelin XVS | 9/25/82 | 14.54 | 0.01358 | 77 | 14.64 | 0.01367 |
| 4286 | Michelin XVS | 9/23/82 | 14.54 | 0.01354 | 77 | 14.64 | 0.01363 |
| 4287 | Montgomery Ward Grappler All-Season | 6/15/83 | 13.93 | 0.01245 | 78 | 14.07 | 0.01257 |
| 4288 | Montgomery Ward Grappler All-Season | 7/06/82 | 13.77 | 0.01228 | 78 | 13.91 | 0.01241 |
| 4289 | Montgomery Ward Grappler All-Season | 7/06/82 | 13.90 | 0.01240 | 79 | 14.08 | 0.01256 |
| 4290 | Montgomery Ward Grappler All-Season | 7/06/82 | 14.31 | 0.01277 | 80 | 14.55 | 0.01298 |
| 4291 | Montgomery Ward Road Guard | 7/13/82 | 16.16 | 0.01442 | 78 | 16.32 | 0.01456 |
| 4292 | Montgomery Ward Road Guard | 7/13/82 | 16.16 | 0.01440 | 79 | 16.37 | 0.01459 |
| 4293 | Montgomery Ward Road Guard | 7/13/82 | 15.76 | 0.01406 | 77 | 15.86 | 0.01415 |

## Rolling Resistance Test Results for Individual Tires

| EPA ID# | Mfr/Brand & Model | Test Date | RR Force (lbf) | RRC | Ambient Temp. (°F) | Temperature-Corrected RR Force (lbf) | Temperature-Corrected RRC |
|---|---|---|---|---|---|---|---|
| 4294 | Montgomery Ward Road Guard | 7/13/82 | 16.22 | 0.01446 | 77 | 16.33 | 0.01455 |
| 4295 | Montgomery Ward Runabout All-Season | 7/07/82 | 11.86 | 0.01056 | 78 | 11.98 | 0.01067 |
| 4296 | Montgomery Ward Runabout All-Season | 7/08/82 | 11.73 | 0.01045 | 75 | 11.73 | 0.01045 |
| 4297 | Montgomery Ward Runabout All-Season | 7/08/82 | 12.06 | 0.01075 | 75 | 12.06 | 0.01075 |
| 4298 | Montgomery Ward Runabout All-Season | 7/08/82 | 11.72 | 0.01045 | 76 | 11.76 | 0.01048 |
| 4299 | Michelin XVS | 9/23/82 | 14.47 | 0.01351 | 78 | 14.61 | 0.01364 |
| 4300 | Michelin XVS | 9/25/82 | 14.61 | 0.01364 | 75 | 14.61 | 0.01364 |
| 4301 | Multi-Mile Poly IV | 9/15/82 | 18.47 | 0.01648 | 73 | 18.35 | 0.01637 |
| 4302 | Multi-Mile Poly IV | 9/14/82 | 18.48 | 0.01651 | 78 | 18.66 | 0.01668 |
| 4303 | Multi-Mile Poly IV | 9/14/82 | 18.41 | 0.01642 | 78 | 18.59 | 0.01659 |
| 4304 | Multi-Mile Poly IV | 9/14/82 | 18.29 | 0.01634 | 77 | 18.41 | 0.01645 |
| 4305 | Multi-Mile Supreme | 9/13/82 | 12.24 | 0.01092 | 78 | 12.36 | 0.01103 |
| 4306 | Multi-Mile Supreme | 9/13/82 | 12.51 | 0.01116 | 78 | 12.63 | 0.01127 |
| 4307 | Multi-Mile Supreme | 9/13/82 | 12.24 | 0.01095 | 74 | 12.20 | 0.01091 |

## Rolling Resistance Test Results for Individual Tires

| EPA ID# | Mfr/Brand & Model | Test Date | RR Force (lbf) | RRC | Ambient Temp. (°F) | Temperature-Corrected RR Force (lbf) | Temperature-Corrected RRC |
|---|---|---|---|---|---|---|---|
| 4308 | Multi-Mile Supreme | 9/13/82 | 12.11 | 0.01083 | 77 | 12.19 | 0.01090 |
| 4309 | Multi-Mile XL | 9/15/82 | 11.56 | 0.01033 | 76 | 11.60 | 0.01036 |
| 4310 | Multi-Mile XL | 9/15/82 | 11.64 | 0.01040 | 74 | 11.60 | 0.01037 |
| 4311 | JC Penney Mileagemaker XP | 7/08/82 | 13.12 | 0.01170 | 78 | 13.25 | 0.01182 |
| 4312 | JC Penney Mileagemaker XP | 7/08/82 | 12.58 | 0.01122 | 76 | 12.62 | 0.01126 |
| 4313 | JC Penney Mileagemaker XP | 7/08/82 | 12.98 | 0.01157 | 76 | 13.02 | 0.01161 |
| 4314 | JC Penney Mileagemaker XP | 7/08/82 | 12.98 | 0.01157 | 76 | 13.02 | 0.01161 |
| 4315 | JC Penney Mileagemaker Plus | 7/06/82 | 11.92 | 0.01065 | 78 | 12.04 | 0.01076 |
| 4316 | JC Penney Mileagemaker Plus | 7/07/82 | 12.13 | 0.01081 | 77 | 12.21 | 0.01088 |
| 4317 | JC Penney Mileagemaker Plus | 7/07/82 | 11.99 | 0.01069 | 76 | 12.03 | 0.01072 |
| 4318 | JC Penney Mileagemaker Plus | 7/07/82 | 12.26 | 0.01097 | 76 | 12.30 | 0.01100 |
| 4319 | Sears Guardsman | 7/09/82 | 16.78 | 0.01500 | 77 | 16.89 | 0.01509 |

## Rolling Resistance Test Results for Individual Tires

| EPA ID# | Mfr/Brand & Model | Test Date | RR Force (lbf) | RRC | Ambient Temp. (°F) | Temperature-Corrected RR Force (lbf) | Temperature-Corrected RRC |
|---|---|---|---|---|---|---|---|
| 4320 | Sears Guardsman | 7/09/82 | 16.38 | 0.01464 | 77 | 16.49 | 0.01473 |
| 4321 | Sears Guardsman | 7/09/82 | 16.65 | 0.01484 | 77 | 16.76 | 0.01494 |
| 4322 | Sears Guardsman | 7/09/82 | 15.55 | 0.01387 | 78 | 15.70 | 0.01401 |
| 4323 | Sears Guardsman | 7/09/82 | 16.86 | 0.01504 | 77 | 16.97 | 0.01514 |
| 4324 | Sears Guardsman | 7/09/82 | 16.51 | 0.01471 | 78 | 16.67 | 0.01486 |
| 4325 | Sears Road Handler 78 | 7/09/82 | 13.03 | 0.01162 | 78 | 13.16 | 0.01174 |
| 4326 | Sears Road Handler 78 | 7/13/82 | 13.16 | 0.01174 | 75 | 13.16 | 0.01174 |
| 4327 | Sears Road Handler 78 | 7/13/82 | 13.17 | 0.01177 | 76 | 13.21 | 0.01181 |
| 4328 | Sears Road Handler 78 | 7/13/82 | 13.17 | 0.01179 | 77 | 13.26 | 0.01187 |
| 4329 | Sears Road Handler 78 | 7/13/82 | 13.30 | 0.01185 | 76 | 13.34 | 0.01189 |
| 4330 | Sears Road Handler 78 | 7/13/82 | 13.23 | 0.01182 | 77 | 13.32 | 0.01190 |
| 4331 | Sears Super Guard | 7/08/82 | 15.86 | 0.01414 | 77 | 15.96 | 0.01423 |
| 4332 | Sears Super Guard | 7/08/82 | 15.99 | 0.01424 | 78 | 16.15 | 0.01438 |
| 4333 | Sears Super Guard | 7/08/82 | 15.30 | 0.01365 | 78 | 15.45 | 0.01378 |
| 4334 | Sears Super Guard | 7/09/82 | 15.86 | 0.01414 | 77 | 15.96 | 0.01423 |
| 4335 | Sears Super Guard | 7/09/82 | 15.78 | 0.01408 | 79 | 15.99 | 0.01426 |

## Rolling Resistance Test Results for Individual Tires

| EPA ID# | Mfr/Brand & Model | Test Date | RR Force (lbf) | RRC | Ambient Temp. (°F) | Temperature-Corrected RR Force (lbf) | Temperature-Corrected RRC |
|---|---|---|---|---|---|---|---|
| 4336 | Sears Super Guard | 7/09/82 | 15.99 | 0.01430 | 76 | 16.04 | 0.01435 |
| 4337 | Sears Weather Handler | 7/07/82 | 13.73 | 0.01225 | 78 | 13.87 | 0.01237 |
| 4338 | Sears Weather Handler | 7/07/82 | 13.26 | 0.01182 | 79 | 13.44 | 0.01197 |
| 4339 | Sears Weather Handler | 7/07/82 | 13.87 | 0.01237 | 77 | 13.96 | 0.01245 |
| 4340 | Sears Weather Handler | 7/07/82 | 13.66 | 0.01219 | 77 | 13.75 | 0.01227 |
| 4341 | Sears Weather Handler | 7/07/82 | 13.79 | 0.01230 | 77 | 13.88 | 0.01238 |
| 4342 | Sears Weather Handler | 7/07/82 | 13.26 | 0.01181 | 78 | 13.39 | 0.01192 |
| 4343 | Multi-Mile XL | 9/15/82 | 12.11 | 0.01080 | 77 | 12.19 | 0.01087 |
| 4344 | Multi-Mile XL | 9/15/82 | 11.83 | 0.01054 | 76 | 11.87 | 0.01058 |
| 4345 | Summit Steel | 10/12/82 | 13.43 | 0.01196 | 75 | 13.43 | 0.01196 |
| 4346 | Summit Steel | 10/12/82 | 12.68 | 0.01132 | 74 | 12.64 | 0.01128 |
| 4347 | Summit Steel | 10/12/82 | 13.15 | 0.01175 | 74 | 13.11 | 0.01171 |
| 4348 | Summit Steel | 10/12/82 | 13.43 | 0.01202 | 75 | 13.43 | 0.01202 |
| 4349 | Summit Supreme 120 | 10/07/82 | 16.98 | 0.01519 | 74 | 16.92 | 0.01514 |
| 4350 | Summit Supreme 120 | 10/07/82 | 17.29 | 0.01545 | 73 | 17.18 | 0.01535 |
| 4351 | Summit Supreme 120 | 10/07/82 | 17.33 | 0.01550 | 79 | 17.56 | 0.01571 |

## Rolling Resistance Test Results for Individual Tires

| EPA ID# | Mfr/Brand & Model | Test Date | RR Force (lbf) | RRC | Ambient Temp. (°F) | Temperature-Corrected RR Force (lbf) | Temperature-Corrected RRC |
|---|---|---|---|---|---|---|---|
| 4352 | Summit Supreme 120 | 10/07/82 | 17.60 | 0.01569 | 77 | 17.72 | 0.01579 |
| 4357 | Uniroyal Fastrak Poly | 12/09/83 | 17.83 | 0.01596 | 75 | 17.83 | 0.01596 |
| 4358 | Uniroyal Fastrak Poly | 12/09/83 | 18.78 | 0.01683 | 70 | 18.47 | 0.01655 |
| 4359 | Uniroyal Fastrak Poly | 12/09/83 | 18.66 | 0.01665 | 75 | 18.66 | 0.01665 |
| 4360 | Uniroyal Fastrak Poly | 12/09/83 | 19.58 | 0.01744 | 74 | 19.52 | 0.01738 |
| 4361 | Uniroyal Steeler | 6/23/83 | 11.18 | 0.01000 | 76 | 11.22 | 0.01003 |
| 4362 | Uniroyal Steeler | 6/23/83 | 11.50 | 0.01026 | 77 | 11.58 | 0.01033 |
| 4363 | Uniroyal Steeler | 6/23/83 | 10.76 | 0.00962 | 75 | 10.76 | 0.00962 |
| 4364 | Uniroyal Steeler | 6/23/83 | 11.65 | 0.01043 | 77 | 11.73 | 0.01050 |
| 4365 | Uniroyal Steeler | 6/23/83 | 10.44 | 0.00933 | 78 | 10.54 | 0.00942 |
| 4366 | Uniroyal Steeler | 6/23/83 | 11.38 | 0.01018 | 77 | 11.46 | 0.01025 |
| 4367 | Uniroyal Tiger Paw | 6/23/83 | 11.77 | 0.01054 | 78 | 11.89 | 0.01064 |
| 4368 | Uniroyal Tiger Paw | 6/24/83 | 11.79 | 0.01054 | 73 | 11.71 | 0.01047 |
| 4369 | Uniroyal Tiger Paw | 6/24/83 | 11.78 | 0.01053 | 77 | 11.86 | 0.01060 |
| 4370 | Uniroyal Tiger Paw | 6/24/83 | 12.39 | 0.01106 | 75 | 12.39 | 0.01106 |