EPA-AA-SDSB-80-7

Technical Report

The Effects of Tire Rolling Resistance on Automotive Emissions and Fuel Economy

by

Randy Jones

and

Terry Newell

May 1980

NOTICE

Technical Reports do not necessarily represent final EPA decisions or positions. They are intended to present technical analysis of issues using data which are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments which may form the basis for a final EPA decision, position or regulatory action.

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Emission Control Technology Division
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I. Introduction

Tires are an important factor in the energy required to operate a motor vehicle, since approximately 20-30 percent of the resistive forces experienced by a vehicle in motion are due to the rolling resistance of the tires. Consequently, tires with lower rolling resistance result in less vehicle fuel consumption.1/

Exhaust emissions are affected by the load placed on the engine. An increase in engine load will result in an increase in oxides of nitrogen emitted from the vehicle, and often will result in increased total hydrocarbon and carbon monoxide emissions.2/ Since tires affect the load placed on the vehicle, they would logically be expected to have an effect on vehicle exhaust emissions.

This study was conducted to quantify the effects of tires on vehicle exhaust emissions and fuel consumption. The test program involved one test vehicle with four different sets of tires; three types of radials and one type of bias ply tires.

In general the study was conducted in the manner in which a vehicle manufacturer would observe tire effects in the EPA certification process. A series of road coastdowns were performed, and the dynamometer power absorber adjustment was determined independently for each vehicle-tire combination by matching dynamometer coastdown characteristics to road coastdown characteristics.

The tires and rolling resistance data were provided to EPA by General Motors. The tires and their measured rolling resistance coefficients are listed in Appendix A. The following sections of the report discuss the test methods, test procedures, and results of the study.

II. Summary of Results

Highly significant correlations were found between rolling resistance, expressed in terms of the rolling resistance coefficient (RRC) of the tires, and fuel consumption; and between RRC and NOx emissions. Confidence that the observed relationships reflect the actual relationships, and were not simply the result of chance variation in the tests, is greater than 90 percent for RRC and NOx emissions. In the case of RRC and fuel consumption, this confidence approaches certainty, 100 percent.

Results of a comparison between RRC and CO emissions show a similar tendency: for higher levels of CO emission to be associated with higher RRCs. However, these results cannot be stated with as high a level of confidence as can those concerning NOx or fuel consumption.

Note: All references in this report are shown by _/.

The relationships between HC emissions and RRC were weaker. Implications found in the analysis were contradictory: results of the FTP tests show a tendency for greater emissions of HC to correspond to higher tire RRCs, while results from the HFET tests reveal a slight tendency for lowered HC emissions to be associated with higher RRCs. In both the FTP and HFET results, the tendencies were very weak, and of little statistical significance.

III. Discussion

The rolling resistance of tires, quantified by a rolling resistance coefficient (RRC), has a direct effect on the load under which a vehicle is operated. Since exhaust emissions and fuel consumption increase with vehicle load, they would logically be expected to increase with tire RRC. The purpose of this study was to quantify the relation between tire RRC, and exhaust emissions and fuel consumption.

The study was conducted similar to the EPA certification process, in which vehicles are tested for emissions and fuel economy. The results, therefore, are representative of the tire effects a vehicle manufacturer would observe in the certification process.

In order to have a dynamometer simulate the total road load of a vehicle, the dynamometer power absorber must be adjusted to reflect the road load characteristics of the vehicle. Currently, most certification vehicles are tested using dynamometer power absorption values obtained according to the methods in the "EPA Recommended Practice for Determination of Vehicle Road Load."3/ In this method the basic concept is to perform a series of road or track coastdowns with the vehicle. Coastdowns are then performed on the dynamometer at different power absorber settings, and the dynamometer power absorber adjustment is determined when the vehicle dynamometer coastdown time matches that of the road coastdown.

The important steps in this study were therefore:

1. The determination of a dynamometer power absorber adjustment for each vehicle-tire combination by matching road and dynamometer coastdown characteristics.

2. Fuel economy and emissions testing, based on the standard Federal Test Procedure (FTP) and Highway Fuel Economy Test (HFET).

These steps are discussed in detail in the following sections of the report.

A. Determination of Power Absorber Adjustment

The vehicle used in this study was a 1979 Chevrolet Nova. The vehicle was tested with four different sets of tires: a bias ply type, designated as tire "D", and three different radials, designated as tires "A", "B", and "C". The manufacturers and brand names of the tires tested are withheld by agreement with General Motors. Detailed vehicle and tire descriptions are given in Appendix A.

The road coastdown tests were conducted at the Transportation Research Center of Ohio. Trials were conducted on the straight, smooth, north-south section of the high speed oval test track.

The dynamometer portion of the study took place at the EPA Motor Vehicle Emission Laboratory in Ann Arbor, Michigan. All dynamometer testing was conducted in dyno cell D207.

The road coastdowns provided the speed vs. time characteristics of the vehicle when freely decelerating. The vehicle was accelerated to a speed slightly greater than 60 mph and allowed to stabilize for several seconds. The transmission was then shifted to the neutral postion, and speed vs. time data were collected on the strip chart recorder until the vehicle speed had dropped to 20 mph. Seven pairs of opposite direction coastdown trials were conducted for each vehicle-tire combination. A detailed description of the road coastdown procedure is listed in Appendix D.

The speed was read from the strip charts at five second intervals. Typical 60 mph to 20 mph coastdowns lasted between 60 and 90 seconds, resulting in 12 to 18 speed data points.

The data was analyzed to extract the acceleration versus velocity information from the speed versus time data points. The result was the calculation of a rolling resistance force coefficient, and an aerodynamic drag force coefficient for the decelerating vehicle. The force coefficients were then corrected to standard ambient conditions of 68.0°F, 29.0 in. Hg, and zero wind speed; and a dynamometer 55-45 mph coastdown time was calculated for the appropriate vehicle inertia weight class. Results of the coastdown calculations for each set of tires are shown in Appendix B and summarized in Table 1.

The road coastdown tests for the "B" and "D" sets of tires were conducted on the same day, and thus under similar ambient conditions. The coastdowns for the "A" and "C" sets of tires were likewise conducted on the same day, but about two weeks after the "B" and "D" tire tests and hence, under different ambient conditions. The most valid pairwise comparisons are therefore between the "B" and "D" sets of tires, and between the "A" and "C" sets of tires.

The vehicle was then tested to determine the vehicle-dynamometer coastdown characteristics and an appropriate dynamometer power absorber setting for representing the road experience of the vehicle. Several coastdowns were conducted and the 55-45 coastdown time was measured at different power absorber settings for each vehicle tire combination. The result was a mathematical expression of the form of equation (1), relating dynamometer AHP setting to dynamometer 55-45 coastdown time. The dynamometer coastdown procedure is described in Appendix E.

$$\frac{1}{\Delta T} = b_0 + b_1(AHP) \qquad (1)$$

where:

AHP = dynamometer 50 mph actual horsepower,
ΔT = dynamometer 55-45 coastdown time in seconds,
b_0, b_1 are regression coefficients.

The characteristic coastdown time vs. 50 mph dynamometer power adjustment curves resulting from the dynamometer coastdown tests are shown in Appendix F. The 50 mph AHP setting for emissions and fuel economy testing was then determined for each vehicle-tire combination. The 55-45 coastdown time calculated from the road coastdown tests is substituted in the appropriate mathematical expression, yielding the AHP setting. The results of this procedure are listed in Table 2.

B. Emissions and Fuel Economy Tests

The emissions tests in this study were conducted according to standard EPA testing methods. One day of testing consisted of a cold start Federal Test Procedure and a Highway Fuel Economy Test. Evaporative emissions were not measured. The procedure is outlined in Appendix D.

A total of five FTP-HFET sequences were conducted for each tire set used in the study. The five test sequence was originally planned to be conducted on consecutive test days before beginning testing on another set of tires. After completing the five test sequence on the bias-ply construction tires, it was decided to randomize the test order for the remaining tire sets. Randomization of test order was introduced to prevent the occurrence of any change in vehicle or dynamometer behavior over the course of the study being misinterpreted as an effect of tire type. Additional tests on the bias-ply tires were then conducted before the conclusion of the study.

IV. Results

This section of the report describes the data obtained during the dynamometer portion of the test program, the analysis of that data, and the results obtained from the analysis.

A. Data and Data Analysis

The standard EPA computer analyses of the results of FTP and HFET tests formed the basis of data used in the statistical analysis. From these computer outputs, gram-per-mile emission rates for hydrocarbons, carbon monoxide and oxides of nitrogen were taken, in addition to fuel consumption data measured in cm^3/km. These figures were reduced to obtain a mean value for each tire tested, for each of the test cycles used. This resulted in four mean data points for each variable (HC, CO, NOx, fuel consumption), for each of the drive cycles used.

For each variable studied, under the conditions of each driving cycle, an analysis of variance was performed using the unreduced data. This analysis tests the null hypothesis of equality of the means for each tire, against the alternative hypothesis, that for at least two of the tires tested the means are unequal. Rejection of the null hypothesis is evidence that variation in HC, CO, NOx, or fuel consumption is based on the tire used. The significance of rejecting the null hypothesis is stated in terms of the probability of being incorrect by doing so.

The mean values of each variable for each tire-test combination are graphed, against RRC, in figures I to VIII. Linear regressions were fitted to these mean data points, and are shown in the figures. These regressions represent the closest linear approximation to the functional relationship of each variable to rolling resistance. There was very little evidence of a non-linear component in any of these functional relationships. The correlation coefficients of these regressions are an indication of how closely the regression describes the data; a correlation coefficient of ± 1.0 represents a perfect fit.

B. <u>Results of Analysis</u>

1. <u>RRC and Fuel Consumption</u>

There is very strong evidence for concluding that the fuel consumed by the test vehicle is a direct function of the tires that are used. This relationship was observed with consistent strength in both the FTP and HFET driving cycles.

Information gathered in this test program pertaining to fuel consumption and RRC is summarized in Table 3. These mean values are graphed, and shown with their respective regression lines, in Figures I and II.

Results from the analysis of variance firmly support the rejection of the null hypothesis, that the tire used has no effect on the fuel consumption of the test vehicle. In the case of the FTP tests, the significance attached to this rejection is 0.0004; in other words, there is less than one chance in 2000 that the observed differences in fuel consumption are due to chance variation or other random-effects errors. The significance of rejecting the null hypothesis as applied to the HFET results is zero to four decimal places, meaning that the observed differences in the means are virtually certain to have been an effect of the rolling resistance of the tires tested.

The equations of the regression lines shown in Figures I and II are listed below. Equation (2) describes the relation of RRC to fuel consumption (FC) for the test vehicle over the FTP driving cycle, and equation (3) does the same for the HFET cycle. The correlation coefficients, r, of the regressions are also given.

$$FC \text{ (in cm}^3\text{/km)} = 951.1(RRC) + 133.2 \qquad [r=.95] \qquad (2)$$

$$FC = 1276(RRC) + 83.8 \qquad [r=.91] \qquad (3)$$

These equations are vehicle-dependent, and may not be applicable to other makes or models without verification. Interpolations from these equations to predict the fuel consumption of the test vehicle will be reasonably accurate within the range of RRCs used to compute the regression, approximately 0.0095 to 0.0145. The predictive ability of the equations will decline when rolling resistance coefficients outside of that range are used.

The average speed of the FTP cycle is slightly below 20 mph. Under the conditions of that cycle, the regression projects an increase in FC of almost 2 cm^3/km for each increase of 0.0020 in the RRC of the tires used. For the test vehicle, this translates to a fuel economy penalty of about 0.2 MPG with an increase of 0.0020 in the RRC. In the HFET cycle, with an average speed of nearly 50 mph, the same 0.0020 increase in RRC causes a projected increase of about 2.6 cm^3/km in fuel consumption. The equivalent fuel economy penalty is approximately 0.6 MPG for the test vehicle, with its average highway fuel economy of 24 MPG.

These differences in fuel consumption are quite significant. The difference in the RRC of the highest and lowest rolling resistance tires used in this program was 0.0046, which is more than twice the increment used in the above projections. For the test vehicle, the fuel economy penalties resulting from the use of tires having an RRC of 0.0142, rather than 0.0096, range from 0.5 MPG in urban driving to 1.5 MPG in highway-rural driving. These fuel economy penalties are based on the test vehicle fuel economy averages of 16 MPG city and 24 MPG highway.

Fuel economy penalties of this magnitude, based on tires, have major implications for manufacturers and consumers alike. Consumers generally have no way of knowing whether the tires being considered for purchase are fuel-efficient, beyond the general rule that radials deliver better fuel economy than do nonradials. Manufacturers striving to meet increasingly stringent CAFE standards use the most fuel-efficient tires available, but consumers have no way of guaranteeing that equally fuel-efficient tires will be supplied to them when they purchase aftermarket replacement tires. The total dollar cost of even a 1 MPG penalty over the useful life of a set of tires is considerable, and rising steadily.

2. RRC and NOx Emissions

Of the emissions studied in this test program, those of NOx showed the closest correlation to rolling resistance. As in the case of fuel consumption, a direct linear dependence of NOx emission levels on the RRC of the tires used describes the data well.

A summary of the mean gram-per-mile NOx emission rates, by tire and driving cycle, appears in Table 4. Figures III and IV display these data graphically, with the computed regression lines also shown.

Performing an analysis of variance on the data allows rejection of the null hypothesis, for both driving cycles. It can be stated at the 90 percent level of confidence that tire rolling resistance has a significant effect on NOx emissions over the FTP cycle. In the highway driving cycle, the effect of RRC on NOx is even more pronounced. The probability that a test program would show the variation in mean NOx levels for different tires that was observed, when in reality no such relationship existed between RRC and NOx, is less than one in twenty thousand.

Computation of least-squares regressions on these data results in the equations below. Equation (4) is derived from the FTP tests, and equation (5) from the HFET cycles.

$$\text{NOx (gm/mi)} = 1.161 + 14.62(\text{RRC}) \qquad [r = .78] \qquad (4)$$

$$\text{NOx} = 0.521 + 78.12(\text{RRC}) \qquad [r = .87] \qquad (5)$$

The correlation coefficients of the above equations, while not as high as those for the equations relating fuel consumption to RRC, are still great enough to allow interpolations to be made from them with certain limitations; the equations are vehicle-dependent, and were determined from results of tests with tires having RRCs in the 0.0095 - 0.0145 range.

The projected difference in the NOx emission rate of the test vehicle, between using tires with very low and very high rolling resistances, is considerable. In urban driving as simulated by FTP cycles, the increase in NOx emissions for tires with RRC = 0.0170, as compared with tires having RRC = 0.0090, is projected as about 0.12 grams-per-mile. Extended high-speed driving, as simulated in HFET cycles, is far more seriously affected: Using the two hypothetical tires mentioned above causes a projected 0.62 gram-per-mile difference in NOx emissions.

3. Irregularity in the Data

The results already discussed were beginning to be evident early in the course of the program. Preliminary data analyses, undertaken after data became available from at least one test of each of the tires, showed higher fuel consumption and greater NOx emissions associated with the bias-ply tires than any of the radial tires. Early results concerning CO and HC emissions were mixed, with no clear indications of the relation of rolling resistance to these emissions.

As computer output of the standard EPA analyses of FTP and HFET cycles became available, generally a few days after the tests were conducted, information on fuel consumption and emissions rates was added to the existing data. An abrupt and unexpected change in this information was noted, beginning with the tests conducted on Monday 28 January 1980. This change was most readily apparent in the carbon monoxide figures, which showed a considerable drop from the range anticipated on the basis of the initial results. As additional results became available, continuing investigation revealed that the rate of emission of HC and NOx had also declined in the course of the test program, while fuel consumption appeared to be slightly increasing.

When possible reasons for this shift in the data were considered, most were quickly discounted. No significant variation was found to have occurred in any of the important control variables of the test program. The standard requirements for FTP and HFET testing were observed throughout the program. Tire inflation pressure was always checked, and consistently measured at 45.0 psi. Pre-test vehicle preparation consisted of running the vehicle through one LA4 driving cycle unless tests were scheduled on consecutive days, in which case one day's testing served as vehicle prep for the following day. No changes in the internal performance characteristics of the test vehicle were noted during the program. The same test driver, experienced in FTP and HFET cycle driving, was used in all of the tests in this program, thus eliminating another potential source of variability in the results.

The single isolable event was a change in instrumentation. The roll speed sensor on the dynomometer used for all testing (site D207) was replaced by a new unit on January 28.

When the data on fuel consumption and NOx emissions are divided by test date, into tests conducted with the old roll speed sensor and those conducted with its replacement, the results already discussed are virtually unchanged. The results concerning correlations of CO emissions to tire rolling resistance, and HC emissions to RRC, are considerably different when test date is taken into account. For this reason, the results and interpretation are presented in two parts in the following sections on RRC and CO emissions, and RRC and HC emissions.

The nature of the shift in the data can be seen in Table 7. This table summarizes the data from tests of the bias-ply tires over the FTP cycles. The decreased standard deviations in the means of each variable indicate greater repeatability in measurements taken after January 28. Proportionately similar changes occurred in data from HFET cycles for this set of tires. While there is some evidence that similar reductions in emissions and increases in fuel consumption took place for the various radial tires tested, the unequal number of tests conducted before and after January 28 preclude the use of those data to illustrate this shift.

4. RRC and CO Emissions

There is evidence to suggest that CO emissions, as well as those of NOx, are partially dependent on the tire used. When all of the data on CO emissions is analyzed, this evidence is inconclusive, and can best be described as a trend toward increased CO emission rates being associated with higher RRCs. No conclusions can be drawn from the analysis of variance of the complete data set. There is approximately a 40 percent probability of being in error by rejecting the hypothesis that the mean gram-per-mile emission rate of CO is equal regardless of the tire used.

If only the results of tests conducted on or after January 28 are used in the analysis, the aforementioned trend is considerably strengthened. In this case, the results are nearly as significant as those concerning fuel consumption or NOx emissions drawn from the full set of data.

The analysis of variance of the post-January 28 data yields much more information on the effect of tire rolling resistance on CO emissions. The hypothesis that the RRC of the tires has no effect on the rate of CO emissions can be rejected at the 90 percent confidence level for the HFET cycles, and can be rejected at the 95 percent level of confidence for the FTP cycles.

Consideration of all of the CO data gave only very slight evidence for concluding that tire RRC affects CO emissions. Consideration of only the post-January 28 data gave strong evidence for that conclusion. The fact that the standard deviations of the CO measurements decreased after January 28 lends added weight to the latter interpretation.

The results of all of the tests are summarized in Table 5. Graphs of mean CO emission rates against tire RRC, again using the full set of data, appear as figures V and VI. Regressions on these mean data points are drawn on the graphs.

Two things became apparent when least-squares regressions were fitted to these data. A relation of linear dependence of CO emission rates on tire RRC describes the HFET cycle data more closely than such a relation describes the FTP data. In both cases, linear regressions can be fitted much more closely to the means of the post-January 28 tests than can be fitted to the means of all of the tests.

The equations below are those of the regressions shown in figures V and VI. Equation (6) is the regression on the FTP cycle results, while equation (7) corresponds to the HFET cycle results.

$$\text{CO (g/mi)} = 11.384 + 225.3(\text{RRC}) \qquad [r = .44] \qquad (6)$$

$$\text{CO} = 0.371 + 27.1(\text{RRC}) \qquad [r = .88] \qquad (7)$$

It is interesting to note how these equations differ from the equations of the regressions on the mean data points computed using only tests conducted after the replacement of the speed sensor. As noted previously, when the results of tests conducted before January 28 are deleted, the mean rate of CO emission drops for each of the tested tires, and the associated standard deviations also decreased. When regressions are fitted to these "new" means, the constant terms decrease, and the effect of changes in tire RRC is heightened.

$$CO = 8.922 + 331.7(RRC) \qquad [r = .74] \qquad (6A)$$

$$CO = 0.119 + 42.9(RRC) \qquad [r = .99] \qquad (7A)$$

Equations (6A) and (7A) are those of the regression to the data collected after Janaury 28 on CO emissions. Equation (6A) is derived from results of FTP cycle testing, and thus should be contrasted to equation (6). The same connection exists between equations (7A) and (7), which are derived from the HFET cycle results.

Note that the changes in the rates of CO emission projected to occur with a given change in tire RRC are greater for the post-Janaury 28 data. This, together with the higher correlation coefficients of equations (6A) and (7A), implies that the dependence of CO emissions on tire RRC is stronger than is indicated by analysis of the complete set of data from the test program.

5. <u>RRC and HC Emissions</u>

There appears to be very little evidence to suggest that tire RRC has a direct effect on HC emission rates. The analysis of variance on all data suggests that chance, error, and experimental noise had more to do with the observed variations in mean HC emission rates than did the tires being tested. Restricting the analysis to the results of tests conducted after January 28 improves this situation only slightly; the hypothesis that the mean HC emission rate is the same for each tire still cannot be rejected with adequate statistical confidence.

Table 6 contains a summary of the data collected on HC emissions. The mean rate of HC emissions for each tire tested is plotted against the RRCs in figures VII and VIII.

The "scattered" nature of the data can be seen clearly in the table and the graphs. Regressions on these data were computed, and are shown on the graphs for reference. Very little information about HC emissions with different tires can be obtained from these equations. The correlation coefficients are very low, r = 0.45 for the FTP data and r = -0.39 for the HFET data. The FTP cycle testing showed a slight tendency for greater HC emissions to be associated with higher RRCs, while the HFET cycle testing showed a weak indication that the opposite relation holds.

When the results of tests conducted before January 28 are deleted and new mean rates of HC emissions computed, the change is in the direction of a stronger tendency for higher HC emissions to be associated with higher RRCs. The regression on the post-January 28 FTP data in this case has a correlation coefficient of r = 0.60. While this is not an excellent fit, it is a better fit than the regression on all data. The slight tendency toward lowered HC with higher RRC that was shown in all HFET data is further weakened in this case, r = -0.39 for all data and r = -0.31 for the partial set.

While no strong conclusions about HC emissions and tire RRC are possible from the results of this test program, there are indications that the effect of tires with higher rolling resistance, if any, is toward higher HC emission rates over the FTP cycle.

V. Conclusions

1) A strong correlation exists between automotive tire energy dissipation, quantified by the rolling resistance coefficient (RRC) of the tires as determined in general accordance with the SAE recommended procedure 4/, and vehicle fuel consumption rates as measured during the EPA dynamometer test procedures. In this test program, the vehicle experienced a 0.5 MPG fuel economy penalty on the FTP cycle and a 1.5 MPG penalty on the HFET cycle when the relatively high rolling resistance bias-ply tires were used, instead of the lowest rolling resistance radials.

2) The gram-per-mile emission rates of NOx correlate strongly with tire RRC, with greater NOx emission rates associated with the use of tires having greater rolling resistances. This effect was seen to be more pronounced over HFET cycles than over FTP cycles.

3) Emissions of CO are affected by the rolling resistance of the tires used. Data from HFET cycles show strong, significant evidence for increases in CO emission rates with increases in the RRC of the tires. Data from FTP cycles show a tendency toward higher CO emissions with higher RRCs, but not with the significance of the HFET cycle results.

4) In the case of HC emissions rates and tire RRCs, the analysis gave some indication that higher tire rolling resistance resulted in increased rates of HC emissions over the FTP cycles; however, the observed relationship was rather weak. Emissions of HC over the HFET cycle did not seem to be dependent on tire RRCs.

References

1/ "Tire Related Effects on Vehicle Fuel Economy," Yurko, John, EPA Technical Report, SDSB 79-27, July 1979.

2/ Patterson, D.J., Henein, N.A., Emissions from Combustion Engines and Their Control, Ann Arbor Science Publishers, Inc. 1979.

3/ "Determination and Use of Alternative Dynomometer Power Absorption Values," EPA OMSAPC Advisory Circular 55B, December 6, 1978.

4/ "Rolling Resistance Measurement Procedure for Passenger Car Tires," SAE J1269, and "The Measurement of Passenger Car Tire Rolling Resistance," SAE J1270, Society of Automotive Engineers, 1979.

Table 1

Target Dynamometer
Coastdown Time from Road Coastdown Tests

Tire	Vehicle	Inertia Weight Class	Target 55-45 Coastdown Time
Tire "A"	Nova	3750 lbs.	13.79 sec.
Tire "B"	Nova	3750 lbs.	14.10 sec.
Tire "C"	Nova	3750 lbs.	13.23 sec.
Tire "D"	Nova	3750 lbs.	12.42 sec.

Table 2

Proper AHP Setting for Dynamometer Testing

Tire	Vehicle - Inertia Weight	50 mph AHP Setting
Tire "A"	Nova - 3750 lbs.	10.6
Tire "B"	Nova - 3750 lbs.	9.9
Tire "C"	Nova - 3750 lbs.	10.3
Tire "D"	Nova - 3750 lbs.	12.9

Table 3

RRC and Fuel Consumption

Tire	RRC	FTP N	FTP Mean	HFET N	HFET Mean
		Fuel Consumption (cm3/km)			
Tire "A"	.0096	5	142.6	5	97.2
Tire "B"	.0109	5	142.8	5	96.7
Tire "C"	.0119	5	145.2	5	98.0
Tire "D"	.0142	8	146.6	10	102.6

Table 4

RRC and NOx Emissions

Tire	RRC	FTP N	FTP Mean	HFET N	HFET Mean
		NOx Emissions (g/mi)			
Tire "A"	.0096	5	1.322	5	1.364
Tire "B"	.0109	5	1.288	5	1.266
Tire "C"	.0119	5	1.342	5	1.418
Tire "D"	.0142	8	1.375	10	1.677

Table 5

RRC and CO Emissions

Tire	RRC	CO Emissions (g/mi) FTP N	FTP Mean	HFET N	HFET Mean
Tire "A"	.0096	5	14.474	5	0.654
Tire "B"	.0109	5	12.700	5	0.626
Tire "C"	.0119	5	13.844	5	0.706
Tire "D"	.0142	8	15.015	10	0.761

Table 6

RRC and HC Emissions

Tire	RRC	HC Emissions (g/mi) FTP N	FTP Mean	HFET N	HFET Mean
Tire "A"	.0096	5	0.998	5	0.1062
Tire "B"	.0109	5	0.936	5	0.1010
Tire "C"	.0119	5	0.976	5	0.1044
Tire "D"	.0142	8	1.019	10	0.1029

Table 7

Summary of the Shift in Data After 1/28/80

	FTP Test Date			
	Before 1/28/80 (N=4)		On-After 1/28/80 (N=4)	
	Mean	St. Dev.	Mean	Std. Dev.
HC (g/mi)	1.095	0.060	0.943	0.038
CO (g/mi)	16.182	1.905	13.847	0.923
NOx (g/mi)	1.445	0.047	1.297	0.025
Fuel cons.	145.75	0.50	147.50	0.58

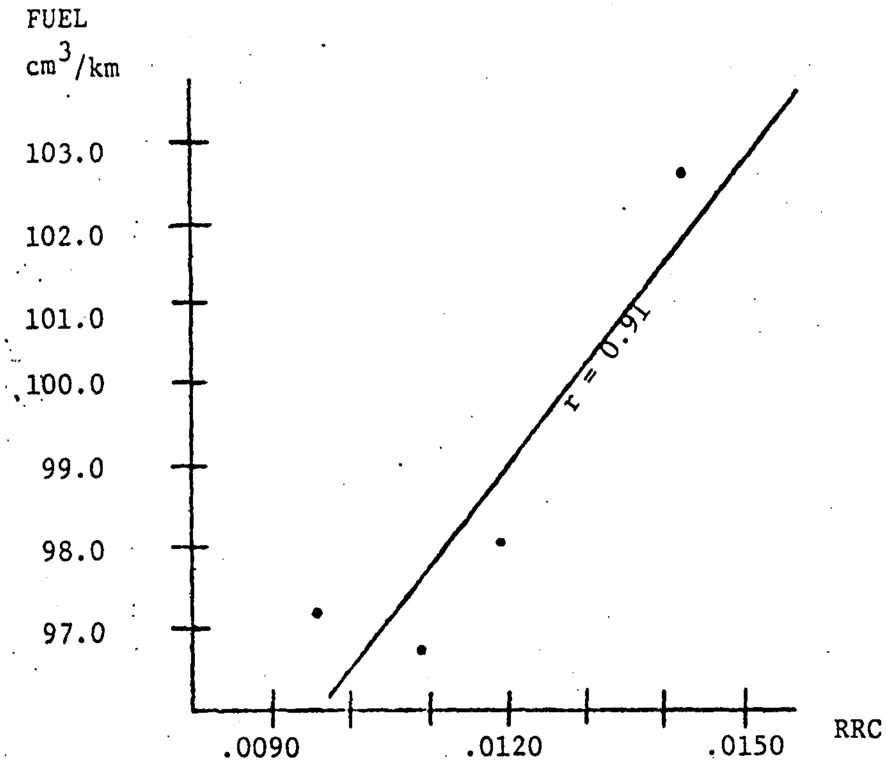


Fig I: FUEL CONSUMPTION VS RRC (HFET cycle)

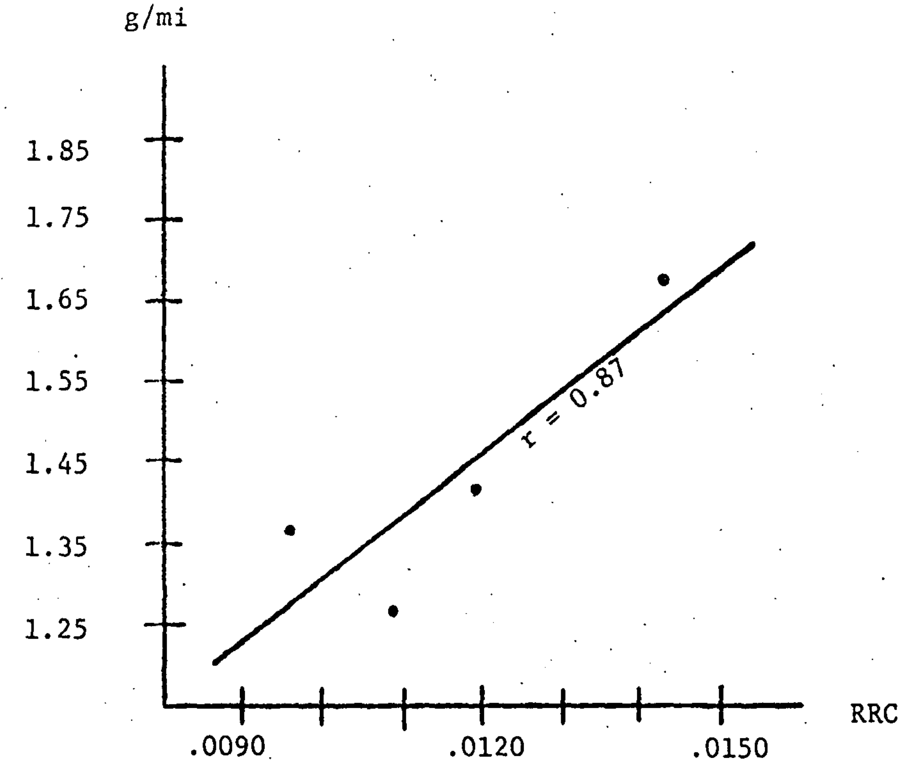


Fig III: NOx EMISSIONS VS RRC (HFET cycle)

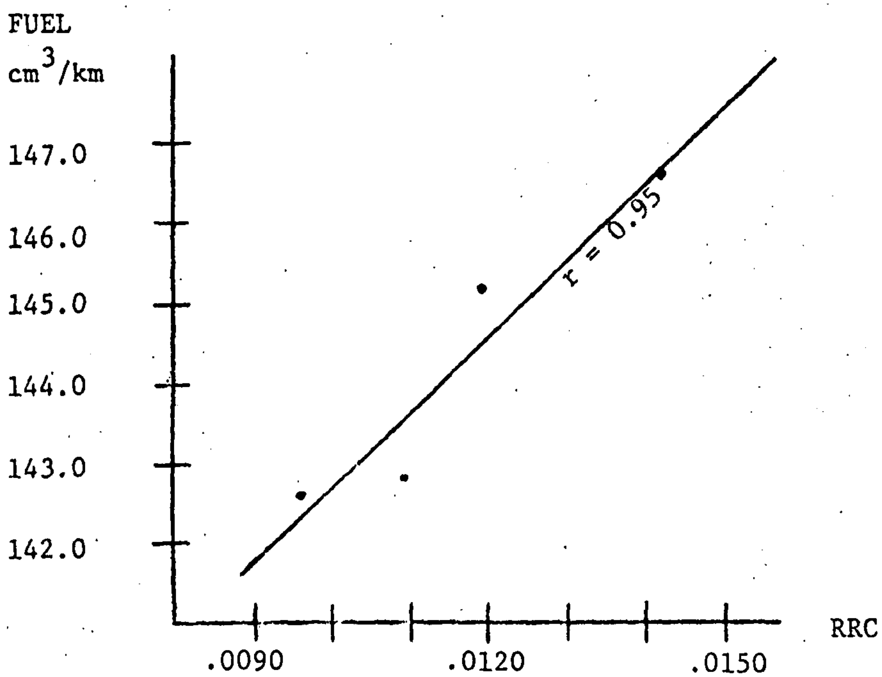


Fig II: FUEL CONSUMPTION VS RRC (FTP cycle)

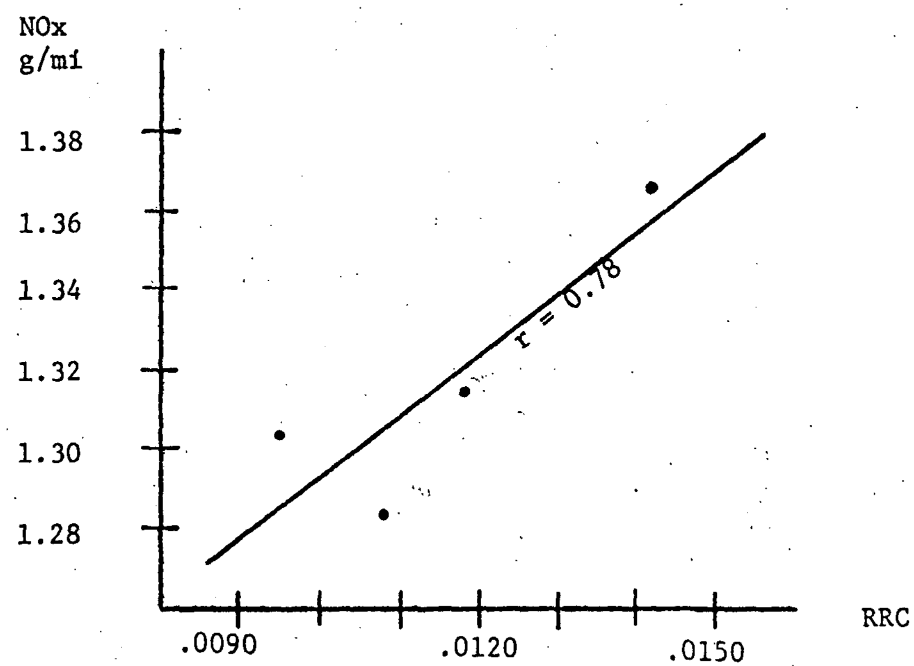


Fig IV: NOx EMISSIONS VS RRC (FTP cycle)

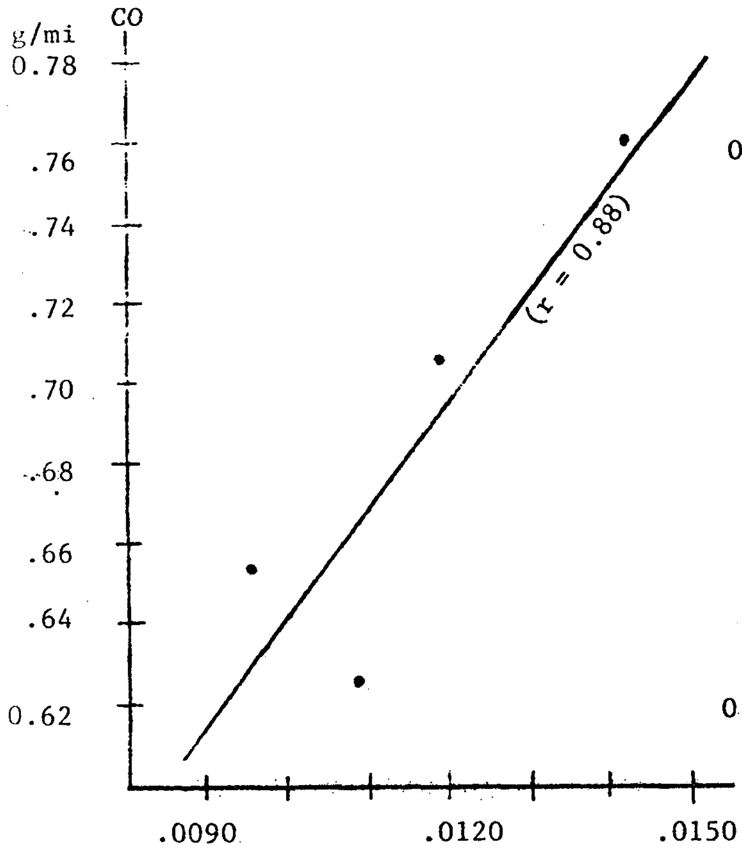


Figure V: CO EMISSIONS VS. RRC (HFET)

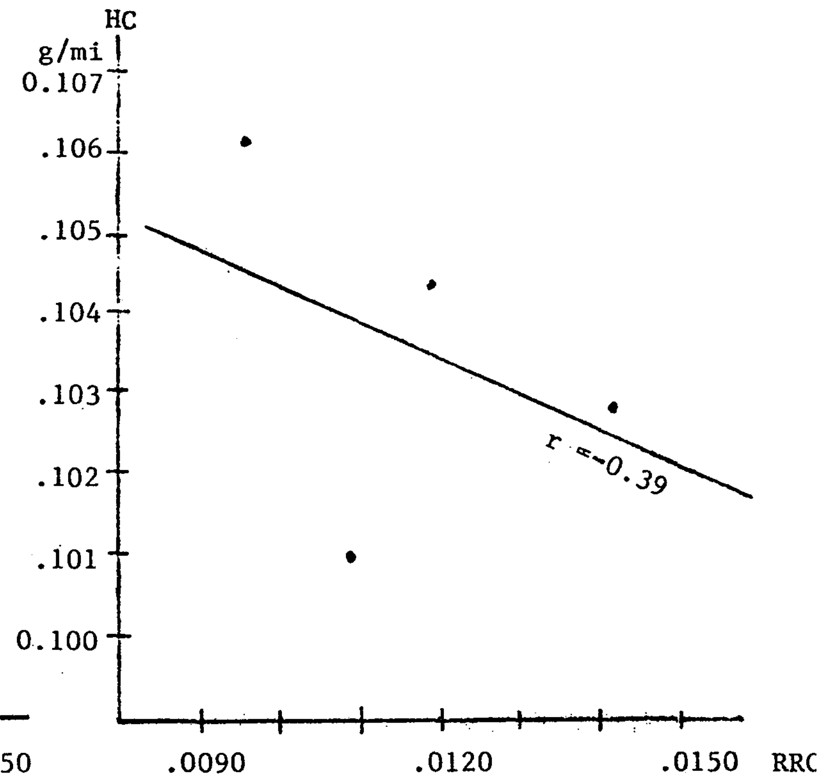


Figure VII: HC EMISSIONS VS. RRC (HFET)

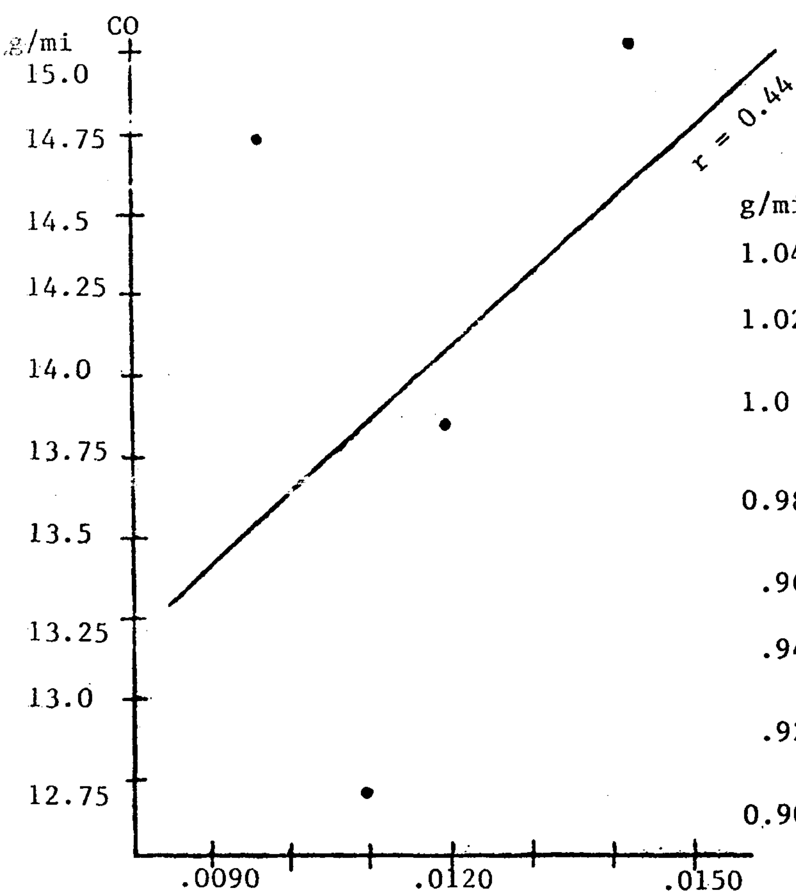


Figure VI: CO EMISSIONS VS. RRC (FTP)

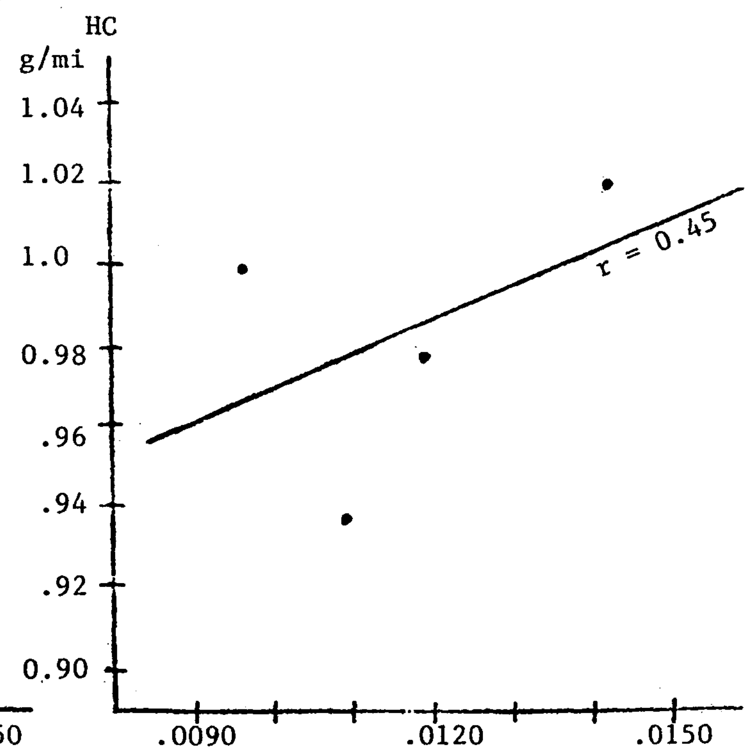


Figure: VIII: HC EMISSIONS VS. RRC (FTP)

Appendix A

Test Vehicle

1979 Chevrolet Nova Sedan

250 CID/ 1 bbl.

Model 350 turbo-hydramatic automatic transmission

Test Weight: 3,745 - 3,790 lbs.

Test Tires

Designation	Construction	Size	RRC*
Tire "D"	Bias-ply	E78-140	.0142
Tire "C"	Radial	P215/70 R14	.0119
Tire "B"	Radial	P195/75 R14	.0109
Tire "A"	Radial	P195/75 R14	.0096

* The reported rolling resistance coefficients are the ratio of the transverse spindle force to the normal load.

```
1                             ROAD COAST DOWN TEST
          TESTID:  610
         VEHICLE:  GM CHEVROLET        NOVA 610 SILVER
       TEST DATE:  11 08 77
   TIRE PRESSURE:  FRONT= 24.00     REAR= 24.00
TIRE DESCRIPTION:  TIRE "A" - RADIAL
 TEST CONDITIONS
 ---------------
 AMBIENT TEMP.-F:    57.
BAROMETER IN HG.:  29.10
 WT. (AFTER TEST):  3700.   (TOTAL)
DRIVEN AXLE WEIGHT:     0.
 NO OF RUN PAIRS:  7
            COEFFICIENTS IN TERMS OF A0,A2 (OBSERVED)
       A0                                   A2            RMS ERROR
0.35832037E+00                     0.17272570E-03   0.3377E+00
0.3284[illegible]E+00               0.16721772E-03   0.2394E+00
[illegible]                         0.13172753E-03   0.4201E+00
0.3[illegible]E+00                  0.1450[illegible]31E-03   0.2479E+00
0.2[illegible]0541665E+00           0.17324176E-03   0.2667E+01
0.3[illegible]2821E+00              0.1844722[illegible]E-03   0.3131E+00
0.29215872E+00                     0.17996413E-03   0.2[illegible]7E+00
0.37421137E+00                     0.16046279E-03   0.2397E+00
0.30314910E+00                     0.15866593E-03   0.2510E+00
0.39734082E+00                     0.14671497E-03   0.1794E+00
0.32311945E+00                     0.16707554E-03   0.2528E+00
0.3[illegible]724[illegible]E+00    0.14073221E-03   0.3607E+00
0.3[illegible]E+00                  0.18069279E-03   0.5376E+00
0.37[illegible]E+00                 0.1636801[illegible]E-03   0.2635E+00
      OBSERVED DATA AT TEST CONDITIONS (NO CORRECTIONS)
      OBSERVED COAST TIME    13.137
      AVERAGE COEFFICENTS                              STANDARD DEVIATIONS
      A0 =       0.34301075E+00  (MI/HR-SEC)       0.14154395E-01  (MI/HR-SEC)
      A2 =       0.16794735E-03  (HR/MI-SEC)       0.10112905E-04  (HR/MI-SEC)
      PAIR    3 HAS BEEN REJECTED DUE TO HIGH RMS
      PAIR    7 HAS BEEN REJECTED DUE TO HIGH RMS
     2 PAIR(S) OF RUNS HAVE BEEN REJECTED
      OBSERVED DATA AT TEST CONDITIONS (NO CORRECTIONS BUT AFTER RMS REJECTIONS)
      OBSERVED COAST TIME    13.193
      AVERAGE COEFFICENTS                              STANDARD DEVIATIONS
      A0 =       0.34715150E+00  (MI/HR-SEC)       0.84555195E-02  (MI/HR-SEC)
      A2 =       0.16497775E-03  (HR/MI-SEC)       0.10427245E-04  (HR/MI-SEC)
      PAIR       1  REJECTED DUE TO STANDARD DEVIATION
      NUMBER OF PAIRS REMAINING IS        4
      RESULTS AFTER STANDARD DEVIATION  REJECTIONS
      AVERAGE COEFFICENTS                              STANDARD DEVIATIONS
      A0 =       0.34556345E+00  (MI/HR-SEC)       0.1567671E+01  (LBS)
      A2 =       0.16122925E-03  (HR/MI-SEC)       0.1267683E-02  (LBS)
      PAIR       4  REJECTED DUE TO STANDARD DEVIATION
      NUMBER OF PAIRS REMAINING IS        3
      RESULTS AFTER STANDARD DEVIATION  REJECTIONS
      AVERAGE COEFFICENTS                              STANDARD DEVIATIONS
      A0 =       0.34768785E+00  (MI/HR-SEC)       0.6927773E+00  (LBS)
      A2 =       0.15823455E-03  (HR/MI-SEC)       0.8513816E-03  (LBS)
      OBSERVED COAST TIME AFTER REJECTION    13.444
      RESULTS AFTER WIND CORRECTIONS
      AVERAGE COEFFICENTS                              STANDARD DEVIATIONS
      A0 =       0.34715780E+00  (MI/HR-SEC)       0.39818145E-02  (MI/HR-SEC)
      A2 =       0.15823455E-03  (HR/MI-SEC)       0.48099145E-05  (HR/MI-SEC)
      WIND CORRECTED COAST TIME    13.490
                    WEATHER CORRECTED RESULTS
      WEATHER CORRECTED COAST TIME    14.018
      DATA WEATHER CORRECTED TO 68 F, 29.0" HG
      COEFFICENTS
      A0 =       0.32288279E+00  (MI/HR-SEC)
      A2 =       0.15440365E-03  (HR/MI-SEC)
                    MASS CORRECTED RESULTS
  TOTAL SYSTEM WEIGHT      3881.  LBS (TEST WT +          ROTATING EQUIVALENCES)
  FORMULA INERTIAS ARE BEING USED
  DRIVING ROTATING EQUIVALENT          67.
  NON-DRIVING ROTATING EQUIVALENT     64.
  INERTIA WEIGHT CLASS    3750.  LBS.
  MASS CORRECTIONS TO     3817.  LBS. MASS
  DYNAMOMETER COAST TIME(55-45 MPH)  13.789
  INERTIA WEIGHT   DYNAMOMETER
  CATEGORY          COAST-DOWN TIME
  --------------   ---------------

      3375              12.434
      3500              12.885
      3625              13.337
      3750              13.788
      3875              14.240
      4000              14.691
      4250              15.594
```

1 ROAD COAST DOWN TEST

TEST ID: #10
VEHICLE: GM CHEVROLET NOVA #10 SILVER
TEST DATE: 10 16 79
TIRE PRESSURE: FRONT- 24.00 REAR- 24.00
TIRE DESCRIPTION: TIRE "B" - RADIAL
TEST CONDITIONS

AMBIENT TEMP.-F: 70.
BAROMETER IN HG.: 29.00
WT. (AFTER TEST): 3785. (TOTAL)
DRIVEN AXLE WEIGHT: 0.
NO OF RUN PAIRS: 7

COEFFICIENTS IN TERMS OF A0,A2 (OBSERVED)

A0	A2	RMS ERROR
0.22930212E+00	0.17713427E-03	0.3190E+00
0.37727130E+00	0.13594440E-03	0.2810E+00
0.22219691E+00	0.16410297E-03	0.2602E+00
0.30279449E+00	0.15986766E-03	0.2587E+00
0.21160612E+00	0.16681726E-03	0.2124E+00
0.21123350E+00	0.23242060E-03	0.2323E+00
0.22510762E+00	0.16212408E-03	0.3369E+00
0.31974106E+00	0.17538902E-03	0.2297E+00
0.21435417E+00	0.17602506E-03	0.2766E+00
0.33800538E+00	0.15651228E-03	0.1519E+00
0.22795112E+00	0.16039532E-03	0.2391E+00
0.35838450E+00	0.15143585E-03	0.2384E+00
0.40004766E+00	0.77508776E-05	0.1915E+01
0.51009929E+00	0.10801773E-21	0.2369E+01

OBSERVED DATA AT TEST CONDITIONS (NO CORRECTIONS)
OBSERVED COAST TIME 15.141
AVERAGE COEFFICENTS — STANDARD DEVIATIONS
A0 = 0.3003861E+00 (MI/HR-SEC) — 0.7446212E-01 (MI/HR-SEC)
A2 = 0.1446004E-03 (HR/MI-SEC) — 0.6379727E-04 (HR/MI-SEC)
PAIR 3 HAS BEEN REJECTED DUE TO HIGH RMS
PAIR 7 HAS BEEN REJECTED DUE TO HIGH RMS
2 PAIR(S) OF RUNS HAVE BEEN REJECTED

OBSERVED DATA AT TEST CONDITIONS (NO CORRECTIONS BUT AFTER RMS REJECTIONS)
OBSERVED COAST TIME 14.502
AVERAGE COEFFICENTS — STANDARD DEVIATIONS
A0 = 0.2859907E+00 (MI/HR-SEC) — 0.1368332E-01 (MI/HR-SEC)
A2 = 0.1617418E-03 (HR/MI-SEC) — 0.5496569E-05 (HR/MI-SEC)
OBSERVED COAST TIME AFTER REJECTION 14.502

RESULTS AFTER WIND CORRECTIONS
AVERAGE COEFFICENTS — STANDARD DEVIATIONS
A0 = 0.2844030E+00 (MI/HR-SEC) — 0.1375825E-01 (MI/HR-SEC)
A2 = 0.1617418E-03 (HR/MI-SEC) — 0.5496569E-05 (HR/MI-SEC)
WIND CORRECTED COAST TIME 14.557

WEATHER CORRECTED RESULTS
WEATHER CORRECTED COAST TIME 14.467
DATA WEATHER CORRECTED TO 68 F, 29.0" HG
COEFFICENTS
A0 = 0.2871332E+00 (MI/HR-SEC)
A2 = 0.1623548E-03 (HR/MI-SEC)

MASS CORRECTED RESULTS
TOTAL SYSTEM WEIGHT 3917. LBS (TEST WT + ROTATING EQUIVALENCES)
FORMULA INERTIAS ARE BEING USED
DRIVING ROTATING EQUIVALENT 68.
NON-DRIVING ROTATING EQUIVALENT 64.
INERTIA WEIGHT CLASS 3750. LBS.
MASS CORRECTIONS TO 3818. LBS. MASS
DYNAMOMETER COAST TIME(55-45 MPH) 14.100

INERTIA WEIGHT CATEGORY	DYNAMOMETER COAST-DOWN TIME
3375	12.716
3500	13.177
3625	13.639
3750	14.100
3875	14.562
4000	15.024
4250	15.947

```
           TESTID:  310
          VEHICLE:  GM CHEVROLET      NOVA #10 SILVER
        TEST DATE:  11 05 79
    TIRE PRESSURE:  FRONT- 24.00   REAR- 24.00
 TIRE DESCRIPTION:  TIRE "C"-RADIAL
  TEST CONDITIONS
  ---------------
  AMBIENT TEMP.-F:    57.
 BAROMETER IN HG.:  29.10
 WT. (AFTER TEST):  3780.   (TOTAL)
DRIVEN AXLE WEIGHT:    0.
  NO OF RUN PAIRS:  7
           COEFFICIENTS IN TERMS OF A0,A2 (OBSERVED)
        A0                                   A2              RMS ERROR
  0.32542923E+00                      0.17663907E-03   0.4220E+00
  0.35875630E+00                      0.16710619E-03   0.2733E+00
  0.30366357E+00                      0.19261113E-03   0.3424E+00
  0.35139173E+00                      0.16882329E-03   0.1702E+00
  0.32327226E+00                      0.18843495E-03   0.3696E+00
  0.37497509E+00                      0.15441375E-03   0.1298E+00
  0.31224018E+00                      0.17708886E-03   0.4584E+00
  0.30685745E+00                      0.18922451E-03   0.2611E+00
  0.29831940E+00                      0.17414178E-03   0.2964E+00
  0.30769012E+00                      0.12553517E-03   0.2962E+00
  0.29802761E+00                      0.17583753E-03   0.3298E+00
  0.16200142E+00                      0.25711561E-03   0.2537E+01
  0.29030027E+00                      0.17715406E-03   0.4932E+00
  0.36739415E+00                      0.15349971E-03   0.2176E+00
      OBSERVED DATA AT TEST CONDITIONS (NO CORRECTIONS)
      OBSERVED COAST TIME   13.157
      AVERAGE COEFFICENTS                          STANDARD DEVIATIONS
      A0 =      0.3195960E+00  (MI/HR-SEC)         0.4048320E-01  (MI/HR-SEC)
      A2 =      0.1769690E-03  (HR/MI-SEC)         0.2058079E-04  (HR/MI-SEC)
      PAIR     6 HAS BEEN REJECTED DUE TO HIGH RMS
      1 PAIR(S) OF RUNS HAVE BEEN REJECTED
      OBSERVED DATA AT TEST CONDITIONS (NO CORRECTIONS BUT AFTER RMS REJECTIONS)
      OBSERVED COAST TIME   13.180
      AVERAGE COEFFICENTS                          STANDARD DEVIATIONS
      A0 =      0.3345264E+00  (MI/HR-SEC)         0.9701941E-02  (MI/HR-SEC)
      A2 =      0.1703851E-03  (HR/MI-SEC)         0.1200314E-04  (HR/MI-SEC)
      PAIR       5  REJECTED DUE TO STANDARD DEVIATION
      NUMBER OF PAIRS REMAINING IS         5
      RESULTS AFTER STANDARD DEVIATION  REJECTIONS
      AVERAGE COEFFICENTS                          STANDARD DEVIATIONS
      A0 =      0.3326307E+00  (MI/HR-SEC)         0.1698978E+01  (LBS)
      A2 =      0.1744944E-03  (HR/MI-SEC)         0.1304569E-02  (LBS)
      PAIR       7  REJECTED DUE TO STANDARD DEVIATION
      NUMBER OF PAIRS REMAINING IS         4
      RESULTS AFTER STANDARD DEVIATION  REJECTIONS
      AVERAGE COEFFICENTS                          STANDARD DEVIATIONS
      A0 =      0.3376106E+00  (MI/HR-SEC)         0.1960521E+01  (LBS)
      A2 =      0.1767863E-03  (HR/MI-SEC)         0.1074479E-02  (LBS)
      PAIR       4  REJECTED DUE TO STANDARD DEVIATION
      NUMBER OF PAIRS REMAINING IS         3
      RESULTS AFTER STANDARD DEVIATION  REJECTIONS
      AVERAGE COEFFICENTS                          STANDARD DEVIATIONS
      A0 =      0.3369546E+00  (MI/HR-SEC)         0.1464289E+01  (LBS)
      A2 =      0.1746629E-03  (HR/MI-SEC)         0.9324690E-03  (LBS)
      OBSERVED COAST TIME AFTER REJECTION   12.957
      RESULTS AFTER WIND CORRECTIONS
      AVERAGE COEFFICENTS                          STANDARD DEVIATIONS
      A0 =      0.3306770E+00  (MI/HR-SEC)         0.8374055E-02  (MI/HR-SEC)
      A2 =      0.1746629E-03  (HR/MI-SEC)         0.5226209E-05  (HR/MI-SEC)
      WIND CORRECTED COAST TIME   13.064
                WEATHER CORRECTED RESULTS
      WEATHER CORRECTED COAST TIME   13.560
      DATA WEATHER CORRECTED TO 68 F, 29.0" HG
      COEFFICENTS
      A0 =      0.3132172E+00  (MI/HR-SEC)
      A2 =      0.1704343E-03  (HR/MI-SEC)
                MASS CORRECTED RESULTS
  TOTAL SYSTEM WEIGHT      3912.  LBS (TEST WT +        ROTATING EQUIVALENCES)
  FORMULA INERTIAS ARE BEING USED
  DRIVING ROTATING EQUIVALENT          68.
  NON-DRIVING  ROTATING EQUIVALENT       64.
  INERTIA WEIGHT CLASS      3750.  LBS.
  MASS CORRECTIONS TO       3818.  LBS. MASS
  DYNAMOMETER COAST TIME(55-45 MPH)  13.233
```

INERTIA WEIGHT CATEGORY	DYNAMOMETER COAST-DOWN TIME
3375	11.934
3500	12.367
3625	12.800
3750	13.233
3875	13.667
4000	14.100
4250	14.966

ROAD COAST DOWN TEST

TESTID: 410
VEHICLE: GM CHEVROLET NOVA810 SILVER
TEST DATE: 10 16 79
TIRE PRESSURE: FRONT- 24.00 REAR- 24.00
TIRE DESCRIPTION: TIRE "D" - BIAS-PLY
TEST CONDITIONS

AMBIENT TEMP.,F: 65.
BAROMETER IN HG.: 29.00
WT. (AFTER TEST): 3745. (TOTAL)
DRIVEN AXLE WEIGHT: 0.
NO OF RUN PAIRS: 7

COEFFICIENTS IN TERMS OF A0,A2 (OBSERVED)

A0	A2	RMS ERROR
0.37445733E+00	0.16787510E-03	0.2092E+00
0.39312673E+00	0.15724200E-03	0.3057E+00
0.38442025E+00	0.17588948E-03	0.4699E+00
0.39787745E+00	0.15928755E-03	0.2512E+00
0.37095949E+00	0.17271235E-03	0.3509E+00
0.43236831E+00	0.15524203E-03	0.2839E+00
0.37319279E+00	0.16813735E-03	0.5860E+00
0.44946999E+00	0.13993835E-03	0.3546E+00
0.36794756E+00	0.17402890E-03	0.5075E+00
0.41617485E+00	0.14884716E-03	0.2830E+00
0.40412425E+00	0.16674349E-03	0.3179E+00
0.30520565E+00	0.20214205E-03	0.3081E+00
0.39017932E+00	0.17110855E-03	0.3879E+00
0.41275167E+00	0.16078024E-03	0.3135E+00

OBSERVED DATA AT TEST CONDITIONS (NO CORRECTIONS)
OBSERVED COAST TIME 12.431
AVERAGE COEFFICENTS STANDARD DEVIATIONS
A0 = 0.3877465E+00 (MI/HR-SEC) 0.1813008E-01 (MI/HR-SEC)
A2 = 0.1672766E-03 (HR/MI-SEC) 0.9158708E-05 (HR/MI-SEC)
PAIR 4 HAS BEEN REJECTED DUE TO HIGH RMS
PAIR 5 HAS BEEN REJECTED DUE TO HIGH RMS
2 PAIR(S) OF RUNS HAVE BEEN REJECTED
OBSERVED DATA AT TEST CONDITIONS (NO CORRECTIONS BUT AFTER RMS REJECTIONS)
OBSERVED COAST TIME 12.443
AVERAGE COEFFICENTS STANDARD DEVIATIONS
A0 = 0.3816770E+00 (MI/HR-SEC) 0.1773006E-01 (MI/HR-SEC)
A2 = 0.1694022E-03 (HR/MI-SEC) 0.8615294E-05 (HR/MI-SEC)
PAIR 6 REJECTED DUE TO STANDARD DEVIATION
NUMBER OF PAIRS REMAINING IS 4
RESULTS AFTER STANDARD DEVIATION REJECTIONS
AVERAGE COEFFICENTS STANDARD DEVIATIONS
A0 = 0.3884301E+00 (MI/HR-SEC) 0.1895783E+01 (LBS)
A2 = 0.1656421E-03 (HR/MI-SEC) 0.3839608E-03 (LBS)
OBSERVED COAST TIME AFTER REJECTION 12.483
RESULTS AFTER WIND CORRECTIONS
AVERAGE COEFFICENTS STANDARD DEVIATIONS
A0 = 0.3884301E+00 (MI/HR-SEC) 0.1072460E-01 (MI/HR-SEC)
A2 = 0.1656421E-03 (HR/MI-SEC) 0.2172097E-05 (HR/MI-SEC)
WIND CORRECTED COAST TIME 12.483
WEATHER CORRECTED RESULTS
WEATHER CORRECTED COAST TIME 12.608
DATA WEATHER CORRECTED TO 68 F, 29.0" HG
COEFFICENTS
A0 = 0.3828367E+00 (MI/HR-SEC)
A2 = 0.1647004E-03 (HR/MI-SEC)
MASS CORRECTED RESULTS
TOTAL SYSTEM WEIGHT 3876. LBS (TEST WT + ROTATING EQUIVALENCES)
FORMULA INERTIAS ARE BEING USED
DRIVING ROTATING EQUIVALENT 67.
NON-DRIVING ROTATING EQUIVALENT 64.
INERTIA WEIGHT CLASS 3750. LBS.
MASS CORRECTIONS TO 3817. LBS. MASS
DYNAMOMETER COAST TIME(55-45 MPH) 12.418

INERTIA WEIGHT CATEGORY	DYNAMOMETER COAST-DOWN TIME
3375	11.198
3500	11.604
3625	12.011
3750	12.418
3875	12.824
4000	13.231
4250	14.044

Appendix C

Dynamometer 55-45 Coastdown Data

Tire: "C" - Radial
Test Weight: 3,790 lbs.
Date: 01/24/80
Target Dyno Coastdown Time: 13.23 sec.

50 mph Horsepower Setting: (Trial)	55-45 Coastdown Times (sec.) 11 AHP	10AHP	12AHP	9AHP
1	12 54	13.42	12.09	14.20
2	12.63	13.51	12.16	14.38
3	12.63	13.57	12.15	14.43
4	12.70	13.59	12.21	14.44
$\overline{T}$	12.63	13.52	12.15	14.36

Tire: "D" - Bias-ply
Test Weight: 3,745 lbs.
Date: 01/04/80
Target Dyno Coastdown Time: 12.42 sec.

50 mph Horsepower Setting: (Trial)	55-45 Coastdown Times (sec.) 10.9AHP	10AHP	11.9AHP	9AHP	12.9AHP
1	13.50	14.36	13.02	15.57	12.44
2	13.56	14.22	13.03	15.54	12.50
3	13.61	14.51	13.09	15.56	12.51
$\overline{T}$	13.56	14.36	13.05	15.56	12.48

Appendix C (con't)

Tire: "B" - Radial
Test Weight: 3,785 lbs.
Date: 01/04/80
Target Dyno Coastdown Time: 14.10 sec.

50 mph Horsepower Setting: (Trial)	55-45 Coastdown Times (sec.) 10.9AHP	10AHP	11.9AHP	9AHP	13AHP
1	13.07	13.87	12.57	-	12.08
2	13.12	13.84	12.66	14.91	12.11
3	13.18	13.90	12.69	14.95	12.14
$\overline{T}$	13.12	13.87	12.64	14.93	12.11

Tire: "A" - Radial
Test Weight: 3,750 lbs.
Date: 01/03/80
Target Dyno Coastdown Time: 13.79 sec.

50 mph Horsepower Setting: (Trial)	55-45 Coastdown Times (sec.) 10.9AHP	10AHP	11.9AHP	9AHP
1	13.63	14.30	12.98	15.36
2	13.61	14.38	12.85	15.25
3	13.61	14.37	12.87	15.30
$\overline{T}$	13.62	14.35	12.90	15.30

Appendix D

Road Coastdown Procedure

a. Tires inflated to manufacturer's recommended pressure.

b. Vehicle driven over warm-up cycle consisting of steady speed operation at 50 mph for about 45 minutes.

c. Vehicle accelerated to stable speed of slightly greater than 60 mph.

d. Transmission shifted to neutral position and strip chart recorder activated.

e. Coastdown terminated at 20 mph.

f. Coastdown repeated immediately in opposite direction.

g. Seven pairs of opposite direction coastdown trials for each tire set.

h. Ambient wind speed, wind direction, barometric pressure, and temperature recorded before and after each set of coastdowns.

i. Vehicle weighed before and after each set of coastdowns.

Appendix E

Dynamometer Coastdown Procedure

a. Vehicle mass adjusted to corresponding mass for road coastdown trials.

b. Tires inflated to 45 psig.

c. Dyno inertia weight set at 3750 lb.

d. Vehicle loosely secured on dynamometer.

e. Vehicle operated over 2 HFET driving cycles for tire-vehicle warm-up.

f. Vehicle accelerated to 62 mph.

g. Transmission shifted to neutral.

h. Timer which sensed speed from the front roll (roll coupled to inertia weights and power absorber) recorded 55 mph - 45 mph free deceleration time interval.

i. Coastdown repeated 3 times for 4-5 different power absorber settings.

j. Surface tire temperatures monitored so temperature did not exceed 200°F.

Appendix F

Figure I

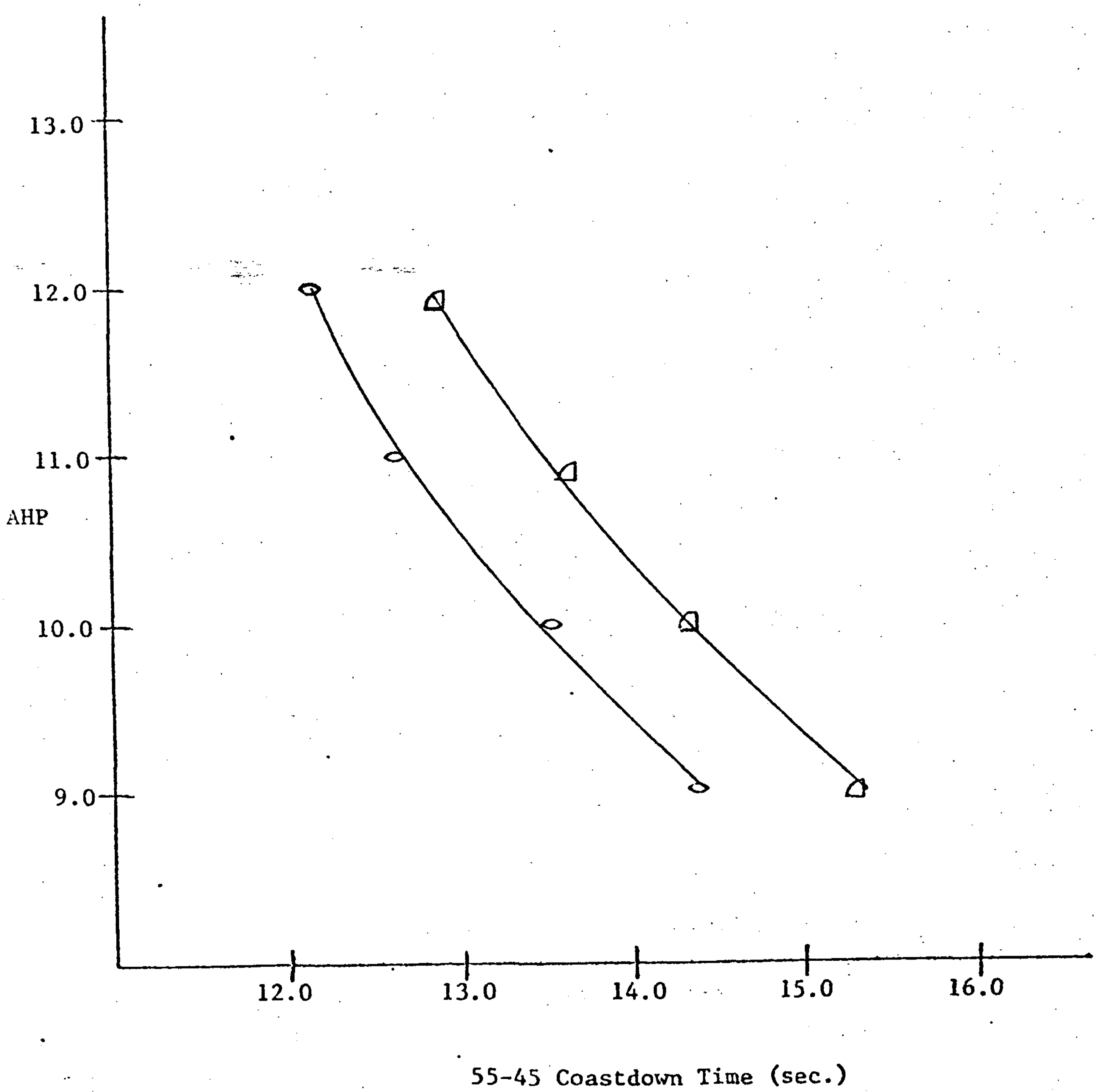
Dyno AHP Settings vs. Dyno 55-45 Coastdown Time

Tires "A" and "C" (Both Radials)

Legend:

▢ - Tire "A": $\frac{1}{\Delta T}$ = .00419 (AHP) + .0277

○ - Tire "C": $\frac{1}{\Delta T}$ = .00432 (AHP) + .0309



Appendix F

Figure II

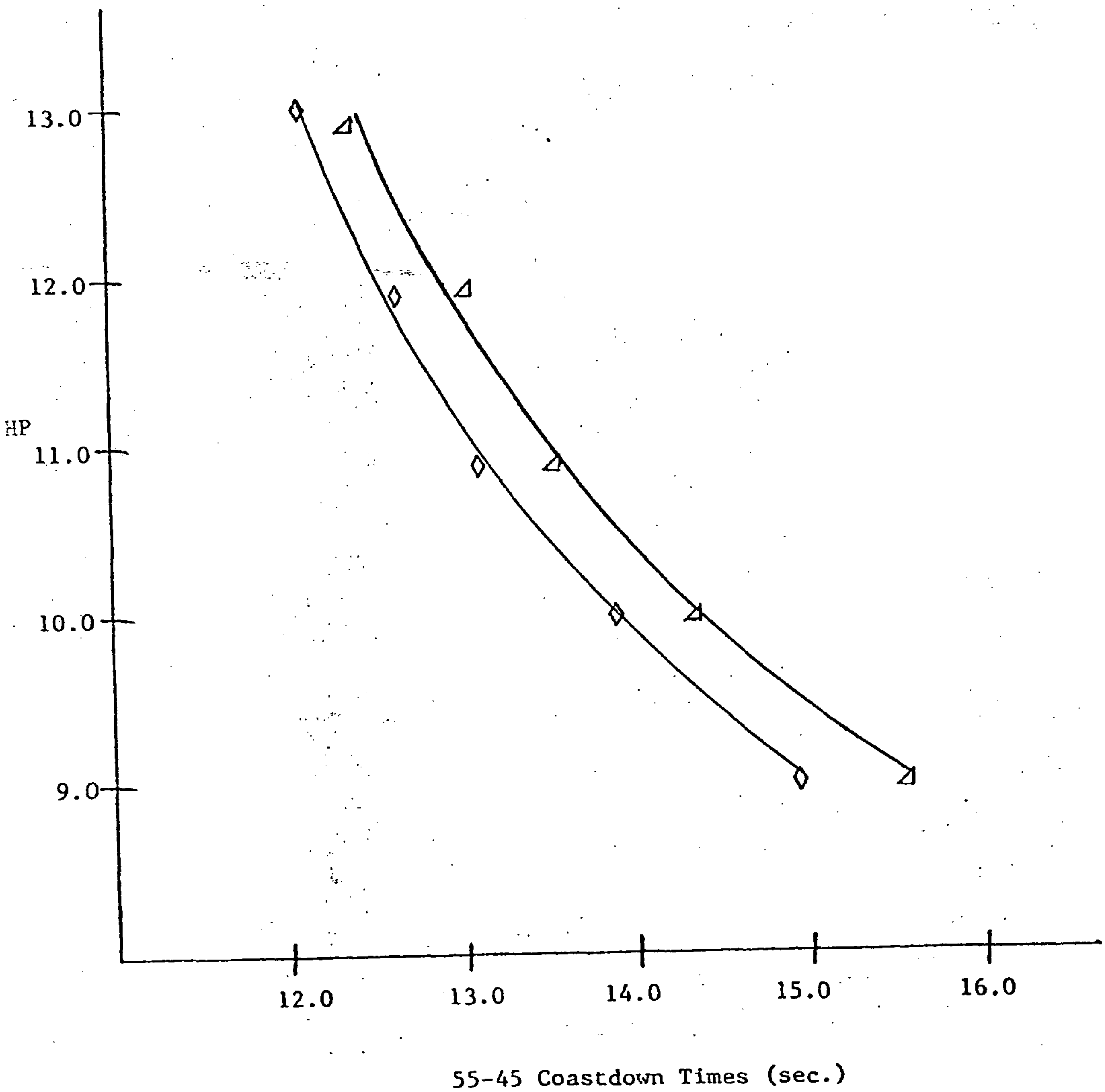
Dyno AHP Settings vs. Dyno 55-45 Coastdown Time

Tires "B" (Radial) and "D" (Bias-ply)

Legend:

◊ - Tire "D": $\frac{1}{\Delta T} = .00385\,(AHP) + .0332$

⊿ - Tire "B": $\frac{1}{\Delta T} = .00399\,(AHP) + .0293$



Appendix G

Emissions Test Procedure

a) Tires changed when necessary and inflated to 45 psig.

b) Fuel tank topped every two days of testing.

c) Vehicle mass adjusted to corresponding mass when road coast-downs were conducted.

d) One day test sequence:

1. 1 cold start FTP
2. 1 HWFET
3. 3 quick check coastdowns after HWFET

e) One days testing serves as prep for next day;

f) or 1 LA-4 driving cycle serves as prep for next day.

g) 12-24 hour soak between prep and tests.

h) Propane injection diagnostics performed on sampling equipment every day of testing.

i) Same driver for all tests.

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