Prediction
of
Dynamometer Power Absorption
to Simulate
Light Duty Vehicle Road Load

by

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April 1977

Notice

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Office of Air and Waste Mangement
U.S. Environmental Protection Agency

ABSTRACT

When EPA vehicle exhaust emission tests or vehicle fuel consumption measurements are performed on a chassis dynamometer, the dynamometer is adjusted to simulate the road experience of the vehicle. Specifically, if the dynamometer measurements are to accurately reflect on-road operation of the vehicle, the dynamometer must supply the appropriate road load; that is, the force required to drive the vehicle on a level surface as a function of the vehicle speed. Current Federal Exhaust Emission Certification Test Procedures specify the dynamometer adjustment as a function of the vehicle weight.

This report uses the dynamometer power absorption information from the EPA technical support report, "Light Duty Vehicle Road Load Determination" to develop equations for predicting the small twin roll dynamometer power absorption necessary to simulate the road load of vehicles. The equations are developed by proposing model equations to predict the dynamometer power absorption, first based on vehicle weight, and then based on the vehicle reference frontal area. Most EPA testing is conducted on small twin roll dynamometers and most vehicles are now sold with radial tires. Consequently the estimates of the small twin roll dynamometer power absorption for vehicles equipped with radial ply tires were used for evaluating the prediction systems. It is concluded that the prediction model based on the vehicle reference frontal area is the preferred approach.

The reference frontal area based prediction system is then improved by separating vehicles into different classes and by including estimations of the effects of the total frontal area of the vehicle protuberances. This modified equation is proposed as the optimum equation to predict the dynamometer power absorption within the constraints of the available data, test equipment and desired simplicity. It is concluded that the errors associated with this prediction system are twenty percent less than the errors associated with a prediction system based on the vehicle weight only.

In the final section bias constructed tires and single large roll dynamometers are considered since these test conditions occasionally occur. The equations for predicting the small twin roll dynamometer power absorption for vehicles with bias tire construction and the equation for predicting the power absorption for single large roll dynamometers are presented. These equations are developed by incorporating correction terms in the aerodynamic based equations for predicting the small twin roll dynamometer power absorption for vehicles with radial tires. These correction terms are dependent on the type of tire construction and are proportional to the vehicle weight.

I. Purpose

This report proposes an equation to predict the adjustment of a small twin roll dynamometer to simulate the road experiences of light duty vehicles. The purpose is to develop the optimum equation for dynamometer power absorption prediction within the constraints of the available data and the limitations of the present test equipment. This report documents the data sources and decisions used in developing the proposed equation.

II. Introduction

When vehicle exhaust emission tests or vehicle fuel consumption measurements are performed on a chassis dynamometer, the dynamometer is usually adjusted to simulate the road experience of the vehicle. Specifically the dynamometer must simulate the road load of the vehicle. In this report the vehicle road load force is defined as the component of force in the direction of vehicle motion which is exerted by the road on the vehicle driving wheels. As defined, the road load force is the force which propels the vehicle. In the standard case, when a vehicle is moving with a constant velocity vector on a level surface, this force is equal in magnitude to the sum of the rolling resistance and the aerodynamic drag of the vehicle.

Historically, the dynamometer adjustment for light duty vehicle emission certification tests, and fuel economy measurements, has been specified in terms of the dynamometer absorption horsepower at a simulated vehicle speed of 50 mph. This report considers methods of predicting the vehicle experience in terms of the road load power, primarily because of the historical precidence of using power instead of force.

III. Discussion

A previous technical support report, "Light Duty Vehicle Road Load Determination"[1] reported the results of road load force measurements from sixty-four diverse light duty vehicles. The results of the previous report are repeated in Appendicies A and B of this report for consistancy and clarity. Table 1 of Appendix A describes the test vehicles, while Appendix B provides the coefficients of force versus speed equations of the form:

$$F = f_0 + f_1 v + f_2 v^2 \tag{1}$$

where

F = the force as a function of velocity
v = the vehicle velocity
f_0, f_1, f_2 = the force coefficients

Coefficients are presented for the total flat surface vehicle road load, and for the appropriate dynamometer adjustments to simulate the vehicle road experience on several types of dynamometers. Also included in Appendix B is the computed dynamometer power absorption requirements to simulate the road experience of each vehicle at 50 mph. The discussion of the data collection and data analysis methods are described in the referenced report and are not repeated.

This section will present models to predict the dynamometer power absorption, first based on the vehicle weight and then based on the vehicle reference frontal area as the prediction parameter. These prediction models are compared and evaluated. Attempts are then made to improve the reference frontal area based prediction system by separating vehicles into different classes and by including estimates of the effects of the vehicle protuberances.

The majority of tires sold in the U.S. are of radial ply construction, and the market predominance of the radial tire is increasing. Approximately 75% of the original equipment tires on 1976 vehicles were radials.[2] Because of the predominance of the radial tire, particularly for new vehicles, the estimates of the appropriate dynamometer adjustment for vehicles with radial ply tires are used for all comparisons of the dynamometer power prediction models.

A. Prediction Model Using Vehicle Weight as the Predictor of the Dynamometer Power Absorption

A theoretically based model can be developed from several logical assumptions. The first assumption is that, because of similarities in manufacturing technology, the density of light duty vehicles is approximately constant[3]. Stated as an equation, the assumption is:

$$W \sim V \qquad (2)$$

where

W = the weight of the vehicle
V = the volume of the vehicle

The vehicle volume is approximately equal to the product of the three major dimensions. The second assumption is that each of the major vehicle dimensions may be expected to increase approximately equally with an increase in weight. Consequently each major dimension is proportional to the cube root of the vehicle weight. That is:

$$L \sim W^{1/3} \qquad (3)$$

where

L = any of the major vehicle dimensions of height width and length

The total vehicle road load is the sum of the aerodynamic drag forces and the vehicle rolling resistance. The major source of the vehicle rolling resistance is the power dissipation in the tires.

One available reference[4] discusses power dissipation of radial ply tires on a small twin roll dynamometer. This reference indicated radial ply tires, inflated to 45 psi, dissipate more than twice as much power on a twin roll dynamometer as they dissipate on a flat surface. The data presented indicated two radial ply tires inflated to 45 psi, dissipate as much energy on a small twin roll dynamometer as four radial ply tires inflated to 25 psi dissipate on a flat surface. This supports the common assumption that two tires on the dynaomometer dissipate as much power as four tires dissipate on the road. Therefore the dynamometer power absorber primarily simulates the aerodynamic losses of the vehicle.

The aerodynamic drag is proportional to the vehicle reference frontal area, which is approximately equal to the product of the vehicle height and width. Consequently the twin roll dynamometer power absorption should be proportional to the weight of the vehicle to the two-thirds power.

$$P \sim W^{2/3} \qquad (4)$$

The previous arguments are hardly rigorous, therefore a model of the form:

$$P = aW^x \qquad (5)$$

was chosen which allowed the exponent to vary. This model will predict a dynamometer power of zero for a vehicle of zero weight, which is theoretically appropriate. Also, if x is less than 1, the model predicts the slope of the force versus weight curve will decrease as the weight increases. This is also theoretically logical; and consistent with the observed data.

Equation (5) was fitted to the data for the vehicle weight and the estimated small twin roll dynamometer power absorption at 50 mph for vehicles with radial ply tires. These data are presented in table 3 of Appendix B and are plotted in Figure 1. A generalized least squares fitting method, using a Gauss-Newton interation algorithm was used.* The results of this regression are:

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*A report discussing the techniques used by EPA for non-linear curve-fitting by the Generalized Least Squares Technique is being prepared.

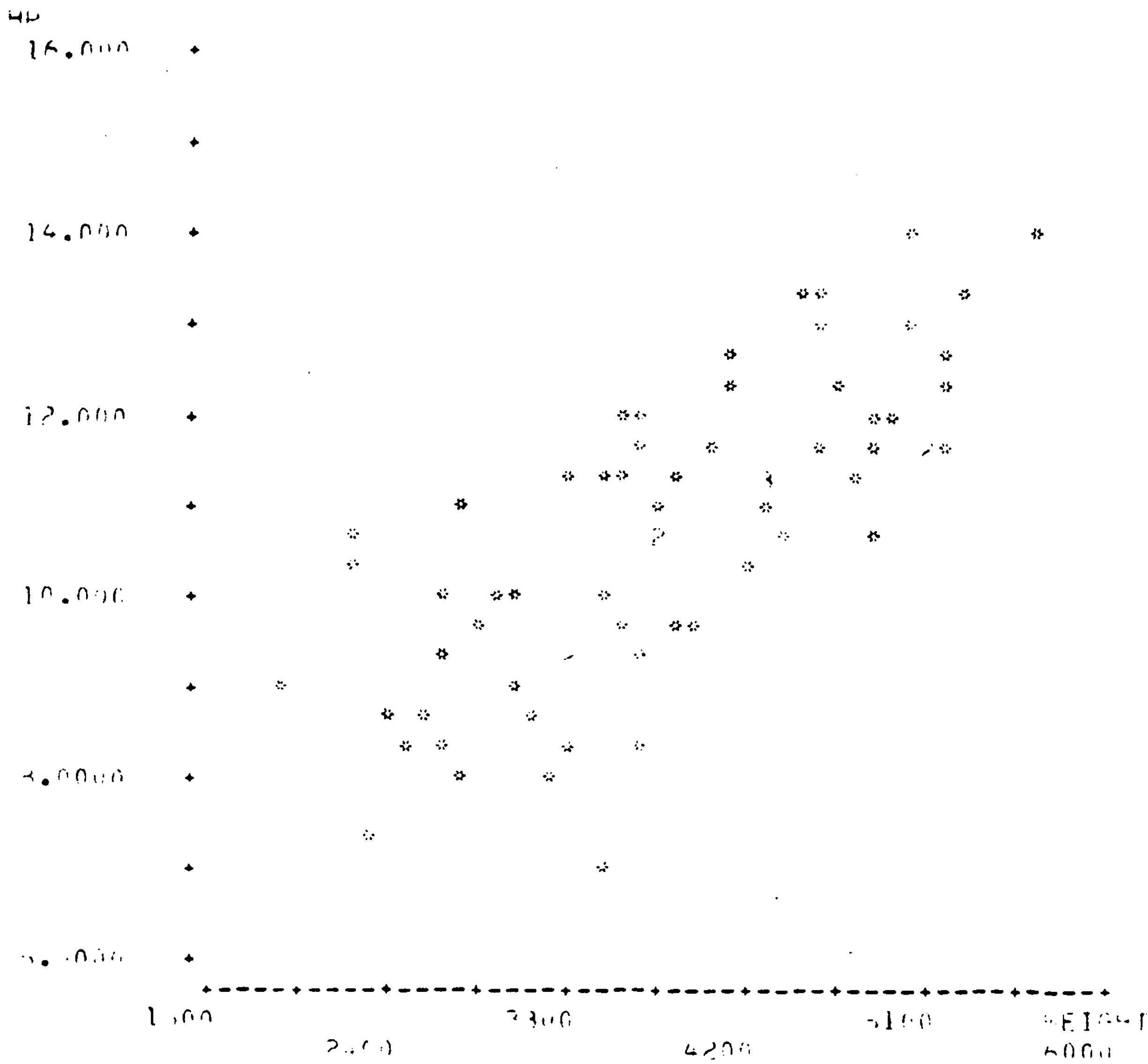


Figure 1

Regression of Twin Roll Dynamometer Power at 50 mph
for Vehicles With Radial Ply Tires
Versus
Vehicle Weight

Regression Model

$$P = aW^x$$

P = the dynamometer power absorbtion at 50 mph (horsepower)
W = the vehicle weight (pounds)
a = 0.253
x = 0.456
Sample size: 67

The accuracy of the regression may be assesed by observing the residuals between the regression line and each data point. These residuals are plotted versus the vehicle identification number in Figure 2. Figure 2 demonstrates the range of errors between the regression line and the data points is about three horsepower. The standard deviation of the residuals is about 1.2 horsepower, indicating that 68% of the data points fall within ± 1.2 horsepower from the regression line.

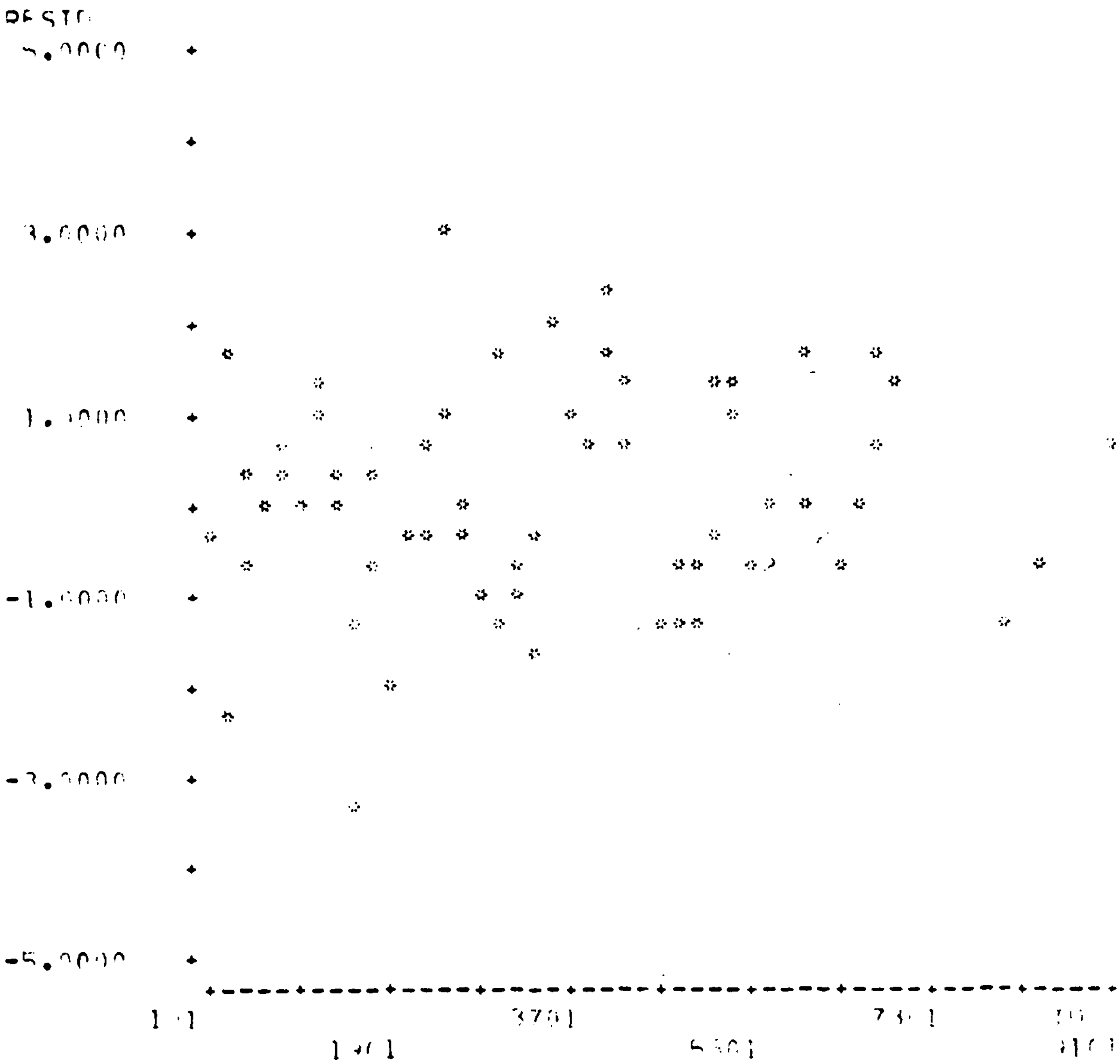


Figure 2

B. Prediction Models Using Aerodynamic Parameters to Predict the Dynamometer Power Absorption

The model equation for the dynamometer power absorption prediction was developed in the previous section using the argument that the dynamometer power absorption simulated the vehicle aerodynamic losses, and the assumption that the vehicle weight was an indirect predictor of the aerodynamic drag. Theoretically a better prediction equation should result if a parameter directly related to the vehicle aerodynamic drag were used instead of the vehicle weight in the prediction equation. The aerodynamic drag of a vehicle is given by:[5]

$$f_{aero} = \frac{1}{2} \rho C_D A v^2 \qquad (6)$$

where

ρ = the air density
C_D = the vehicle drag coefficient
A = the vehicle reference area
v = the vehicle velocity.

The reference area of equation (6) is the area of the orthogonal projection of the vehicle onto a plane perpendicular to the longitudinal axis of the vehicle. This is commonly called the frontal area in aircraft aerodynamics however, the term reference area has been adopted in the road vehicle literature[6,7] possibly because of confusion with the front surface of the vehicle.

The power is, of course, the product of the force and the velocity. Therefore, for a fixed standard-condition air density, the power at any speed is proportional to the product of the drag coefficient and the vehicle reference area, that is:

$$P \sim C_D A \qquad (7)$$

The drag coefficient, C_D, is not commonly known and is difficult to accurately estimate. Consequently the easiest aerodynamic parameter to consider is the vehicle reference area.

1. Prediction System Based on Vehicle Reference Area Only

Equation (7) indicates that the vehicle dynamometer power absorption should increase linearly with the vehicle reference area. The power versus reference area data are plotted in Figure 3. This plot indicates a linear fit appears reasonable.

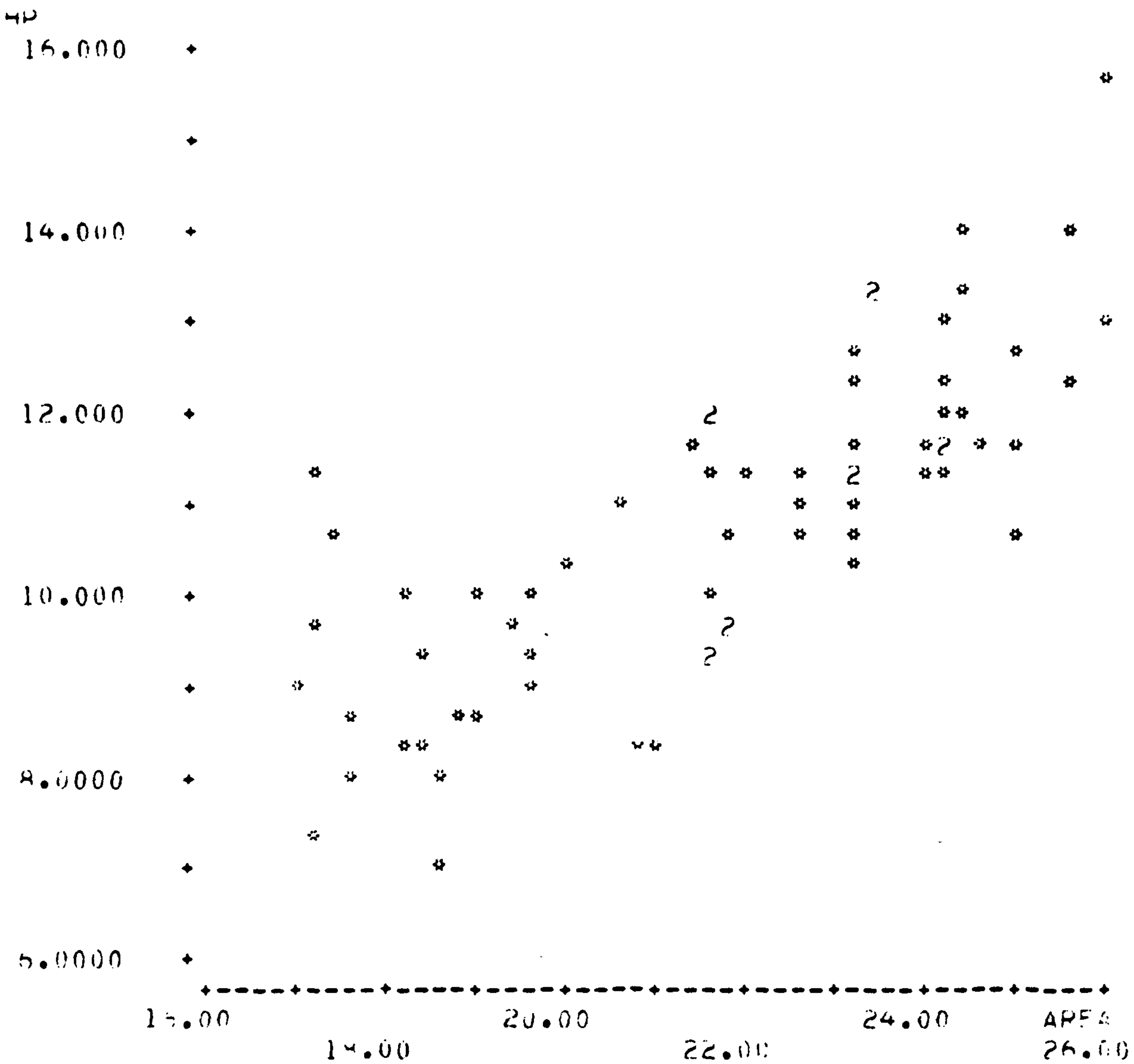

HP
16.000
14.000
12.000
10.000
8.0000
6.0000
16.00
18.00
20.00
22.00
24.00
26.00
AREA

Figure 3

A linear regression of this form was computed using reference area data supplied by the vehicle manufacturers. The results of this regression are:

Regression of Twin Roll Dynamometer Power at 50 mph
for Vehicles with Radial Ply Tires
Versus
Vehicle Reference Area

Regression Model

$$P = aA$$

P = the dynamometer power absorbtion at 50 mph
A = the vehicle reference area
a = 0.50
Estimate of the Standard Error = 1.1
Sample Size: 67

In order to provide comparisons between this regression and the previous weight-based regression, the residuals of the area regression are plotted in Figure 4. The maximum error between the regression line and any data point is about 2.5 horsepower. The estimate of the standard error which is equivalent to one standard deviation of the residuals is about 1.1 horsepower, indicating that 68% of the data lies within $\pm$ 1.1 horsepower of the regression lines.

The residuals of the area regression are 10 percent smaller than those from the weight based regression. This indicates that, as theortically expected, the vehicle reference area is a better predictor of the appropriate dynamometer adjustment than is the vehicle weight. Evidence supporting this conclusion was reported by General Motors.[8]

2. Prediction System Using Both Vehicle Reference Area and Vehicle Classes

The results of the reference area regression establishes that aerodynamic parameters are the preferred approach to predicting the dynamometer power absorption. It is therefore logical to consider what improvements, beyond the use of vehicle reference area are possible within this theoretical framework. Equation (7) demonstrates the true theoretical predictor of the dynamometer power absorption should be the product of the vehicle reference area and its drag coefficient. Utilizing the vehicle reference area only, in effect, assumes that all vehicles have equal drag coefficients. Vehicles have significantly different drag coefficients, therefore incorporation of methods to estimate the vehicle drag coefficient should improve the accuracy of the power prediction system.

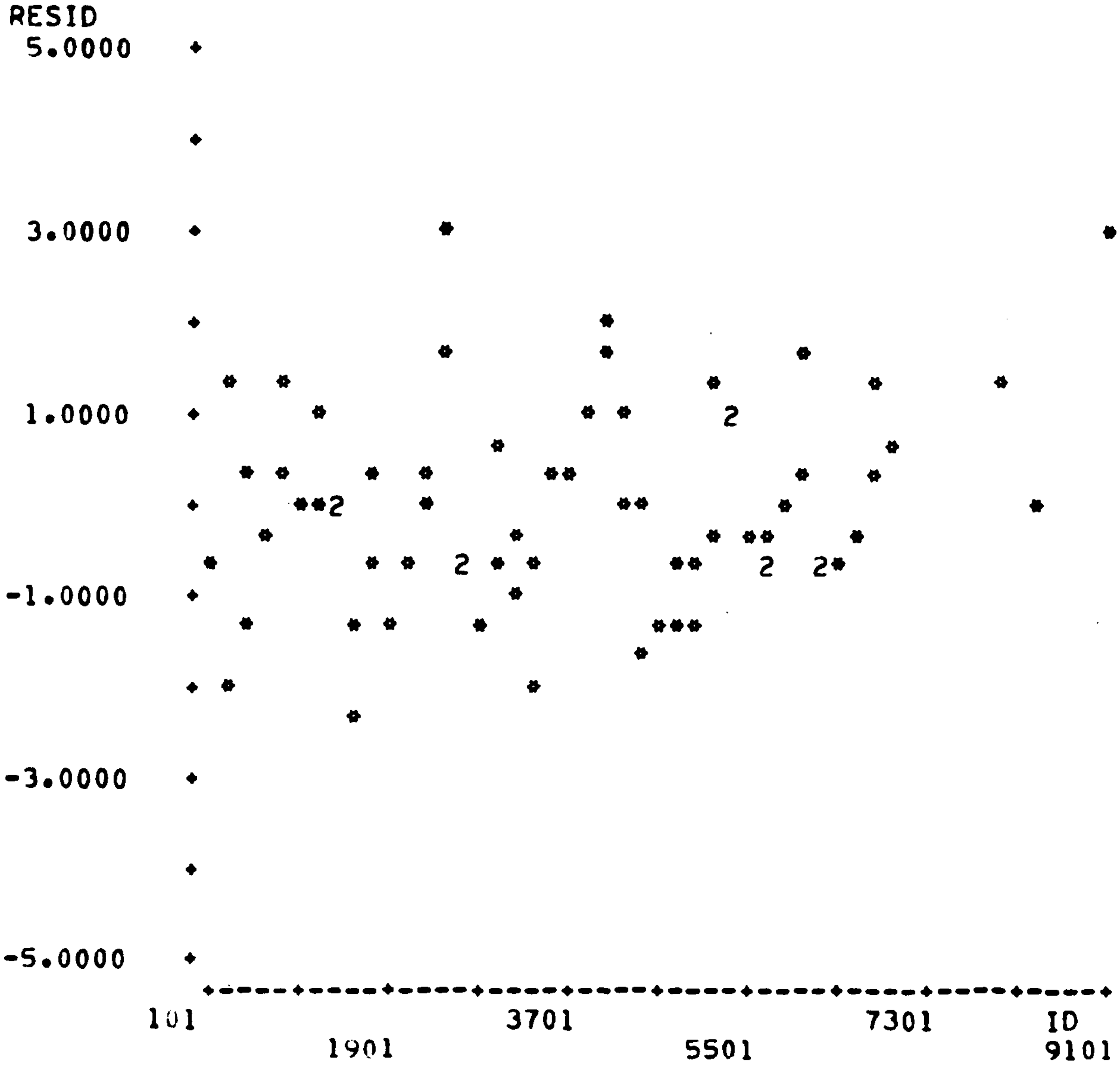


Figure 4

Several attempts have been made to develop systems to predict vehicle drag coefficients.[7,9,10] While good accuracy has been claimed for some of these systems, all are rather complex. In addition they are somewhat subjective, which is objectionable for a regulatory process. For these reasons a simpler approach of dividing vehicles into several classes was considered. While being corser in nature, this approach is much easier to quantify, and should remove some of the inequity of using the vehicle reference area only. This approach was used in the Light Duty Truck Regulation, where trucks were divided into the categories of open and closed bed vehicles for the purpose of determining the dynamometer power absorption.[11]

For light duty vehicles, an initial attempt was made to categorize vehicles as having aerodynamically "good" versus "bad" fore and aft body shapes.

Categorization of the fore body shape requires consideration of the details of several body regions. For example, the angle of the hood-windshield transition region, the curvature of the vehicle front to hood region, and the curvature of the front to side transitions. The windshield angle, its curvature, and its transition to the roof surface and the vehicle side surfaces also affect the drag of the vehicle fore body region. While it may be possible to quantify the criteria for these individual areas, and to develop a composite rating system; such an approach would be complex. An approach similar to this was proposed in the September Federal Register. The comments to this proposal were negative,[12] at least partially because of the complexity and the subjectivity of this method. Consequently further consideration of the vehicle fore body region was not considered at this time.

Consideration of the aft body region of the vehicle was more successful, primarily because a general vehicle shape could be recognized as "good". To reduce aerodynamic drag, the vehicle body should delay flow separation, and should reduce the area of the vehicle acted upon by the low pressure wake. In general, vehicles commonly called "fastback" models meet these objectives. A sketch of a "fastback" model is shown in Figure 5.

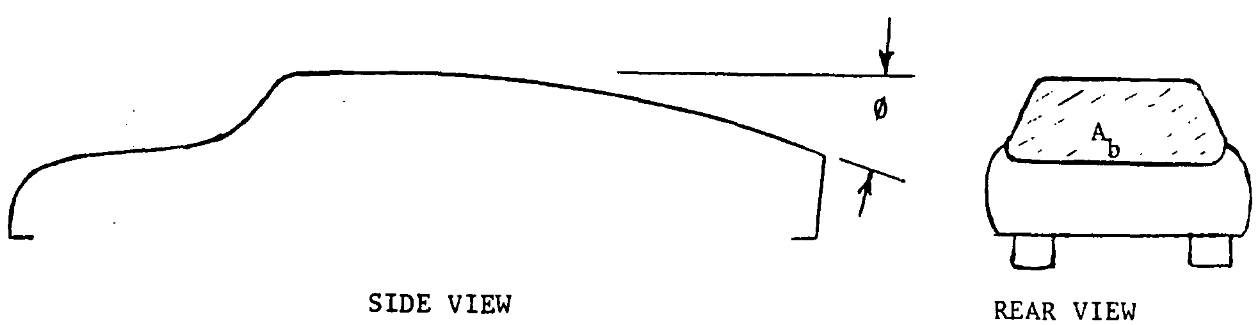


Figure 5

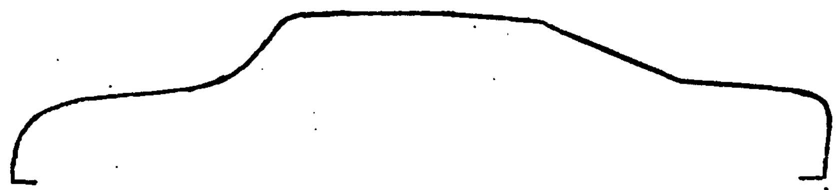
The aerodynamic literature provides several criteria for "good" aft body shapes which can be used to define quantitatively a fastback model. In general, aft of the maximum cross section of the vehicle there is a viscous boundary layer of increasing thickness. Associated with this boundary layer is a pressure gradient which, if it becomes sufficiently large, will cause flow stagnation and separation. To avoid flow separation at some local region forward of the end of the vehicle, any inclined aft body surfaces must be smooth and continuous. It is believed that local declinations of the surface should not exceed three to five degrees from the airstream[6].

The literature also indicates the general angle of declination of the inclined rear body surfaces affect the aerodynamic drag of the aft region. An angle of declination of 20 degrees appears to be a critical angle for transition of the aerodynamic flow into different general types of aerodynamic behavior.[7] When the angle of declination of the inclined surface is less than 20 degrees, the contribution to the vehicle drag coefficient from this surface increases as the angle increases. At an angle of declination of 20 degrees the drag contribution from this surface is approximately equal to the drag contribution from a vertical rear surface of the same reference area. Beyond a declination angle of 20 degrees the drag coefficient contribution continues to increase with increasing angle, until it peaks at about 30 degrees. Between 30 degrees and 35 degrees the drag contribution decreases with increasing angle until, at approximtely 35 degrees, the contribution is again the same as a verticle rear surface. It remains at this value for any further increase in the angle.

The continuity and angle criteria define the conditions believed necessary for low aerodynamic drag of the inclined rear body surfaces. If this region is to have a significant effect on the total aerodynamic drag of the vehicle, the inclined rear body surfaces must contribute some significant percentage of the total rearward projected area of the vehicle. A choice of significant area is somewhat arbitrary since, unlike the angle criterion, there is no critical value. Observation of vehicles generally described as fastbacks indicated that at least one fourth of the vehicle rear projected area resulted from this inclined surface. This is almost essential to assure reasonable rear visibility since the rear window is contained in this surface and its size is constrained by the available surface area.

From these theoretical and empirical considerations, a fastback was tentatively defined as a vehicle where the inclined rear body surface is smooth, continuous and free of any local transitions of greater than 4 degrees. In addition, this surface must slope at an angle of 20 degrees or less from the horizontal; and the rearward projected area of this surface must comprise at least 25 percent of the total vehicle reference area. For example, vehicles of the type shown in Figure 5 were considered fastback models if $\phi < 20°$ and $A_b \geq 0.25$ A.

Vehicles of the shape shown in Figure 6 were not considered as fastback models even if the rear window region did slope at an angle of 20 degrees or less since; these vehicles were not deemed to meet the criteria of a smooth and continuous surface with local transitions of less than 4 degrees.



SIDE VIEW

Figure 6

After choosing a set of criteria for defining a fastback vehicle, the logical step is to ascertain which of the test vehicles satisfied these criteria, and then to test if the appropriate dynamometer power absorption for these vehicles is statistically different from that of the remaining vehicles. To identify potential fastback vehicles, side view photographs of all the test vehicles were reviewed and those vehicles which appeared to meet the criteria were identified. Measurements were then obtained from these vehicles. The angles of the inclined rear body surfaces were obtained directly from the vehicles using an adjustable triangle and level. The projected reference area of this surface was estimated by measuring the horizontal dimension of the top and bottom of this surface, and then the verticle separation between the points of these measurements. The estimated area was then calculated by a trapezoidal approximation. The list of these vehicles and their measurements are given in Table 1 of Appendix C. Those vehicles which satisfied the fastback criteria are identified in this table.

In order to evaluate if the fastback vehicles did actually have lower aerodynamic drag than other vheicle shapes, a "drag coefficient" was computed from the calculated dynamometer power adjustment. The equation used to compute the "drag coefficient" was:

$$C_D = Hp/.81\ A \qquad (8)$$

where

Hp = the dynamometer adjustment power (horsepower)
A = the vehicle reference area (ft^2)
.81 = a units conversion factor including the density of air.

In equation (8) the constant term, 0.81, differs slightly from the more common value of 0.85. This results from using 1.16 kg/m^3 as the standard air density. This air density corresponds to the chosen standard conditions of the EPA Recommended Practice for Road Load Determination.[13] These ambient conditions are:

temperature	20°C (68°F)
barametric pressure	98 kPa (29.02 in Hg)
humidity	10 gm H_2O/kg dry air.

These standard conditions were used in the ambient air condition corrections to the original data and were chosen as typical of the Ann Arbor-Detroit area. The coefficient value of 0.85 results if sea level conditions are chosen as the standard ambient conditions.

The resulting C_D's are presumed to be a reasonable relative measure of the aerodynamic drag of vehicles, however these numbers may not exactly agree with wind tunnel measurements of aerodynamic drag coefficients. For exact agreement, the assumption that two tires on the dynamometer dissipate as much power as four tires dissipate on the road, must be exactly correct. Also since some cross wind was present during most road tests, these coefficients are not directly comparable to wind tunnel data at zero aerodynamic yaw conditions. The resulting coefficients are presented in Table 3 of Appendix C, as is fastback or non-fastback designation of the vehicle. An analysis of variance was performed on these drag coefficients after separation into fastback and non-fastback categories. The results of this analysis are:

Analysis of Variance of Computed Drag Coefficients

	Mean	Std. Dev.	Sample Size
Fastback	0.53	0.045	7
Non-fastback	0.62	0.062	60

A "Student's test" of the hypothesis that the mean C_D of the fastback vehicles is less than the mean C_D of the non-fastback vehicles indicates, with over 99% confidence, that this hypothesis cannot be rejected.

A visual observation of the calculated drag coefficients confirms the statistical results. A computed drag coefficient of 0.52 is the approximate demarcation between fastback and non-fastback vehicles. Of all the non-fastback vehicles only one, an AMC Pacer has a computed drag coefficient significantly lower than 0.52. The low drag coefficient of the Pacer, 0.50, probably results from the well rounded front of this vehicle. Conversely the two Ford Mustangs with computed drag coefficients of 0.57 and 0.60 are the only fastback vehicles where the computed drag coefficients were significantly greater than 0.52. It should be noted that these vehicles had a rear surface declination angle of 20 degrees, the maximum allowable angle under the chosen criteria for fastback vehicles.

3. Protuberances

Treatment of vehicle protuberances were considered as a final improvement of the aerodynamic based dynamometer adjustment prediction system. Vehicle protuberances were addressed in September 10, 1976 NPRM. The comments were generally negative; raising the following objections:[12]

1) A great proliferation of very similar dynamometer adjustments would occur because of minor changes in accessories.

2) Most protuberances have a small effect on the vehicle aerodynamic drag.

To eliminate the necessity of considering all small protuberances such as radio aerials individually, a system which considered only the total area of all protuberances was investigated. Also, in order to avoid the large proliferation of dynaometer adjustments, the approach of using discrete protuberance area categories was chosen. This is similar to the current treatment of vehicle inertia. The incremental vehicle drag caused by a vehicle protuberance can be theoretically predicted as equal to the aerodynamic drag of the protuberance object. This neglects the interaction of the vehicle and the protuberance. For such protuberances the aerodynamic drag may be predicted by:[7]

$$f = \frac{1}{2} \rho \ (1.1) A_p \qquad (9)$$

Assuming an air density of 1.16 kg/m^3, and converting to units of horsepower, equation (9) becomes:

$$Hp_p = 0.89 \ A_p \qquad (10)$$

where

Hp_p = the incremental power required by the vehicle protuberance (horsepower)
A_p = the protuberances area in ft^2.

In a system of units convenient for the small size of most protuberances:

$$Hp_p = 957 \ A_{pcm} \qquad (11)$$

A_{pcm} = the area of the protuberance in cm^2.

In order to investigate the relative effect of common vehicle protuberances; mirrors, aerials, hood ornaments, and roof racks; the area of these protuberances were measured from a small diverse group of vehicles. The summaries of these data, computed to the nearest square centimeter, are:

	Mean Area (cm^2)	Max. Area (cm^2)	Min. Area (cm^2)	Sample Size
Hood ornament	19	29	6	11
Aerial	38	42	38	13
Mirror	117	135	81	12
Roof rack	194	237	166	9

From equation (11) the incremental horsepower anticipated for each protuberance, based on the mean area is:

	Incremental Power (horsepower)
Hood ornament	0.018
Aerial	0.036
Mirror	0.112
Roof Rack	0.184

Comments to the Fuel Economy NPRM by vehicle manufacturers included estimates of the power losses incurred by vehicle protuberances. Chrysler estimated the effect of an antenna at 50 mph as 0.1 hp, a hood ornament as 0.15 hp, and mirrors between 0.1 and 0.3 hp. Chrysler also reported measured values of .315 hp for the effect of a stationwagon roof rack at 50 mph. In approximate agreement with the Chrysler values, GM estimates the aerodynamic effect of a stationwagon roof rack as approximately 0.55 to 1.0 hp at 50 mph. Available wind tunnel data from one vehicle indicates the effect of a roof rack is 0.33 hp while the combined effect of a roof rack and rear air deflector is 0.8 hp. EPA coast down measurements on a vehicle with a roof rack and air deflector, versus a vehicle which was the same model without these devices indicated an effect of about 1.0 hp at 50 mph.

The empirical data indicate the power penalty for vehicle protuberances is greater than the calculated values. Much of these differences occur because the dynamic pressure, $1/2\ \rho v^2$, may be significantly higher at the protuberance site, than calculated from the free stream flow. Also items such as a roof rack have numerous verticle posts and cross bars which offer greater total air resistance than is estimated from the projected reference area of the device.

The incremental effects of the hood ornaments, aerials and mirrors are all small; and the effect of each is probably within the experimental error of normal road load measurements. Also the expected tolerance in the dyanomometer adjustment exceeds the effect of these small protuberances. The effect of the roof rack appears significant, and the combined effect of all protuberances is significant if the vehicle is equipped with a roof rack.

The following system of discrete steps was developed to avoid the problems associated with considering all vehicle protuberances individually, and still retain the ability to treat numerous or significantly large protuberances.

Since all vehicles have at least one external mirror, and the majority also have an external aerial, the minimum anticipated protuberance reference area is 150 cm^2. Therefore to allow the possibility of desirable safety options, such as a second mirror, within a standard vehicle protuberance reference area category, a demarcation point of approximately 280 cm^2 or 0.3 ft^2 was chosen. In the EPA test fleet 40 percent of the vehicles had a second external mirror, 60 percent had external aerials and 24 percent had hood ornaments. Consequently the "average" vehicle had a protuberance area of about 192 cm^2. The demarcation point of 280 cm^2 allows an additional 88 cm^2 increase above the computed average protuberance area before a vehicle is considered to be in a category of greater than average protuberance area. This tolerance will provide manufacturers flexibility in choosing larger than average mirrors, since this demarcation point allows a manufacturer to equip a vehicle with two of the largest measured mirrors, and still be within the average vehicle category.

A table was constructed by considering the total vehicle protuberance reference area in increments of 0.3 ft^2. Below the total protuberance reference area demarcation point of 0.3 ft^2 no additional dynamometer power adjustment penalty was assumed. In the interval between 0.3 ft^2 and 0.6 ft^2 the midpoint is 0.45 ft^2. The horsepower penalty for the midpoint area is, from equation (10), 0.4 hp. For a vehicle to fall in this category it would most likely be equipped with a roof rack only. This horsepower penalty is consistent with the data reported by manufacturers of between 0.315 hp and 0.55 hp.

A similar approach was taken for the 0.6 ft^2 and 0.9 ft^2 interval. The midpoint is 0.75 ft^2 with a calculated effect of 0.7 hp. For the interval 0.9 to 1.2 ft^2, the midpoint is 1.05 ft^2 with a calculated effect of 1.0 hp. For a vehicle to have this large a protuberance reference area, it would have to be equipped with both a roof rack and an air deflector. In this case, the 1.0 hp is also consistent with empirical data. The table was extended by considering further increments of 0.3 ft^2 in the protuberance reference area in the same manner. Table 1 gives the complete tabulation of total protuberance reference area versus the dynamometer power adjustment.

Table 1

Total Protuberance Reference Area, A_p (ft^2)	Power Adjustment, P (hp)
$A_p < 0.3$	0.0
$0.3 \leq A_p < 0.6$	0.4
$0.6 \leq A_p < 0.9$	0.7
$0.9 \leq A_p < 1.2$	1.0
$1.2 \leq A_p < 1.5$	1.3
$1.5 \leq A_p < 1.8$	1.6
$1.8 \leq A_p < 2.1$	1.9
$2.1 \leq A_p < 2.4$	2.2
$2.4 \leq A_p < 2.7$	2.5
$2.7 \leq A_p < 3.0$	2.8
$3.0 \leq A_p$	3.1

It should be noted that the previous theoretical discussion may somewhat over estimate the effect of mirrors since external mirrors are often "bullet" shaped or located in regions of separated aerodynamic flow. The effect of mirrors is correctly treated in the analysis since they are not included in the measurements of vehicle reference area, nor is any additional horsepower prescribed for these small probuterances. The effect of these protuberances will appear as a higher apparent drag of the vehicle as measured, and as included in the basic regression calculations.

The final composite equation to predict the dynamometer power absorption as a function of vehicle reference area, vehicle type and vehicle protuberance reference areas is:

$$Hp = aA + P \qquad (12)$$

where

Hp = the dynamometer power adjustment for vehicles with radial ply tires (horsepower)
A = the vehicle reference area (ft^2)
P = the proturberance power term from table 1 (horsepower)
a = a constant which has different values for fastback and non-fastback vehicles.

The coefficients, a, of equation (12) are determined from regression analyses after separating the sample space into the subsets of fastback vehicles, non-fastback vehicles without roof racks and non-fastback vehicles with roof racks. The equation is then evaluated by calculating the predicted dynamometer adjustment power from equation (12) using the appropriate value of the coefficient, a, for each type of vehicle and the estimated protuberance power, P, for each vehicle. The residuals, the differences between the measured and the predicted dynamometer power absorption, are then calculated. These residuals are then compared to the residuals of the previous prediction systems to evaluate this prediction equation.

The fastback vehicles have already been identified in Table 1 of Appendix C. The vehicles with roof racks were also identified from the vehicle photographs. The area of the protuberances of the vehicles were estimated, and the resulting horsepower increment at 50 mph was chosen from Table 1 of this report. This information is given in Table 3 of Appendix C.

Table 4 of Appendix C identifies each vehicle as either a fastback, non-fastback or non-fastback with roof rack. Also presented in Table 4 is the vehicle area and the dynamometer power absorption.

The dynamometer power absorption was first regressed against the reference area of the fastback vehicles only. The results of this regression are:

Regression of Dynamometer Power Adjustment for
Vehicles with Radial Tires
Versus
Reference Area of Fastback Vehicles

Model Equation $Hp = a_1 A_{fast}$

where

Hp = the dynamometer power adjustment (horsepower)
A_{fast} = the Reference Area for Fastback Vehicles (ft^2)
$a_1 = 0.43$
Estimate of the standard error = 0.70
Sample size = 7

In order to determine the area coefficient for non-fastback vehicles, the dynamometer power absorption for those non-fastback vehicles not equipped with a roof rack were regressed against the vehicle reference area. Removal of the vehicles with roof racks from the sample was necessary in order not to penalize all non-fastback vehicles by including the adverse effects of the roof rack in the general non-fastback regression. The results of this regression are:

Regression of Dynamometer Power Adjustment for Vehicles with Radial Tires Versus Reference Area of Non-Fastback Vehicles

Model Equation $\quad Hp = a_2 A_{non\text{-}fast}$

where

Hp = the dynamometer power adjustment (horsepower)
$A_{non\text{-}fast}$ = the Reference Area for Non-Fastback Vehicles (ft^2)
a_2 = 0.50
Estimate of the Standard Error = 1.0
Sample Size = 56

Equation (12) can now be used to predict the total dynamometer power adjustment for all vehicles in the test sample, using the coefficients of the previous regressions. The predicted powers are given in Table 4 of Appendix C.

The residuals between the predicted and the measured powers are plotted in Figure 7. The maximum error is about +2.8 to -2.0 horsepower and the standard deviation of these residuals is approximately 1.0 horsepower. This is a ten percent reduction in the standard error compared to the prediction system based on vehicle reference area only. It is, as expected, a significant improvement of twenty percent reduction in the standard error compared to the weight based prediction system.

C. Tires

The previous sections developed an optimum equation to predict the small twin roll dynamometer power absorption for vehicles with radial tires. This is definitely the most common test situation, however, other dynamometers and tires are used and these test conditions must be considered. Radial tires are recognized to have lower rolling resistance than do bias ply tires on a flat road surface, yet the radial tire does not have appreciably lower rolling resistance on the twin roll dynamometer. Therefore it is desirable to develop a tire type correction term, so that the bias ply tired vehicles are not under-loaded during small twin roll dynamometer tests.

The rolling resistance of a tire is very nearly proportional to the verticle load force on the tire.[14] Therefore the vehicle weight is the logical parameter to use to predict the tire type correction term. Assuming the tire losses are proportional to the vehicle weight, the tire type correction term should have the form:

$$T_p = cW \qquad (13)$$

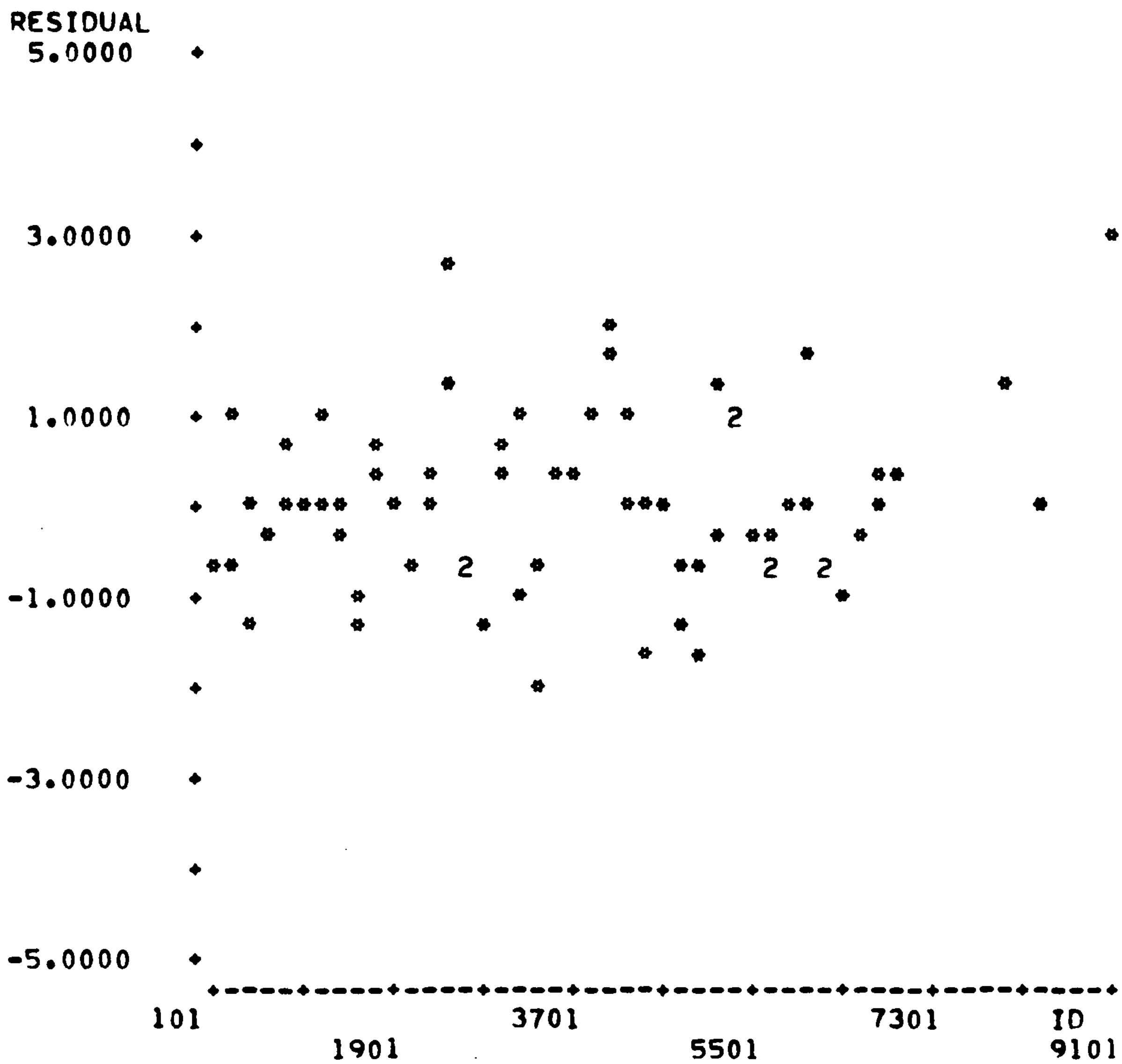

RESIDUAL
5.0000
3.0000
1.0000
-1.0000
-3.0000
-5.0000
101
1901
3701
5501
7301
ID
9101

Figure 7

where

T_p = the tire type power correction term (horsepower)
c = zero for radial tire and a constant for bias ply tires or bias-belted tires
W = the vehicle weight (pounds)

The coefficient, c, was determined by regressing equation (13) against the differences between the small twin roll dynamometer power absorption for vehicles with bias ply tires, Table 2 of Appendix B, and the small twin roll dynamometer power absorption for vehicles with radial ply tires, Table 3 of Appendix B. The value of the coefficient from this regression is: $c = 2.3 \times 10^{-4}$.

Analysis of the comments to the Fuel Economy NPRM indicate such a coefficient is reasonable. Analysis of data submitted by General Motors in response to the fuel economy NPRM indicate the coefficient should be 3.75×10^{-4}.

A coefficient of 3×10^{-4} was chosen as a compromise value. At the present time the available data do not appear comprehensive enough to allow specification of this coefficient to more than one significant digit. While it would be desirable to be able to specify this coefficient more precisely, it should be recognized that even for a heavy 5000 lb. vehicle, the total effect is only 1.5 hp. Changing the current coefficient by one unit in the most significant digit will only affect the predicted vehicle road load by 0.5 hp. In addition since radial tires currently command almost 80 percent of the OEM market, the correction term will only be applied to a small percentage of the total EPA test vehicle population.

When testing on a large single roll dynamometer the drive tires dissipate significantly less power than is dissipated on a small twin roll dynamometer. In this case the tire assumption "two tires on the dynamometer dissipate as much as four tires dissipate on the road" is invalid. Consequently a term must be added to the dynamometer power absorption to compensate for the non-driving tire power dissipation which occurs on the road, but not on the dynamometer.

A prediction model based on the vehicle weight was again chosen because the rolling resistance of a tire is very nearly proportional to the verticle load force on the tire. To maintain similarity to equation (13), a model of the following type was chosen

$$D = dW + etW \qquad (14)$$

where

D = tire correction for large roll dynamometer power absorption (horsepower)
W = the vehicle weight (pounds)
t = 0 for radial tires; 1 for bias tires.

d and e are coefficients to be determined.

Table 2 of Appendix A gives the vehicle weight and the tire types when tested. Table 4 of Appendix B gives the calculated dynamometer power absorption for testing on a large single roll dynamometer, while Table 3 gives the dynamometer power absorption for testing vehicles with radial ply tires on a small twin roll dynamometer. The differences between these dynamometer absorptions represent the tire correction necessary when testing on a large single roll dynamometer. A regression analysis of the dynamometer power difference data was calculated to yield the coefficients, d and e, of equation (14). The results of this regression are:

Regression of Dynamometer Type
Power Correction
Versus
Vehicle Weight

Regression Model

$D = (d + et)W$

D = dynamometer type power correction (horsepower)
W = vehicle weight (pounds)
t = 0 for radial tires; 1 for bias tires
$d = 5 \times 10^{-4}$
$e = 1 \times 10^{-4}$
Estimate of the Standard Error = 0.5
Sample Size = 67

The value of the coefficients in the above regression were rounded to the nearest most significant digit. The variations in the data are sufficiently large compared to the small size of the correction term that further precision is not warranted.

No comments regarding the prediction of large roll dynamometer adjustment forces were received in response to the Fuel Economy NPRM.

IV. Conclusions

It is concluded that vehicle aerodynamic parameters are the preferred predictors of the dynamometer power absorption. This approach has a stronger physical science foundation and affords greater accuracy than prediction systems based on the vehicle weight. The proposed equation to predict the dynamometer power absorption using the vehicle reference area, fastback and non-fastback vehicle categories, and consideration of the total vehicle protuberance area has a standard error which is twenty percent less than the standard error associated with the prediction system based on the vehicle weight.

The tire-dynamometer roll interaction is still an area of uncertainity. More information about this interaction is desirable even though the tire type correction terms are small in magnitude.

An equation to predict the power absorption setting for a single large roll dynamometer is provided even though this type of dynamometer is not commonly used in current certification or fuel economy testing. This equation is structured in a manner similar to the equation for predicting the power absorption of a small twin roll dynamometer because of the prevalence of the small twin roll dynamometer in emissions and fuel economy testing. The equation for the single large roll dynamometer should provide significant guidance in the use of this type of dynamometer.

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APPENDIX A

TEST FLEET IDENTIFICATION

Table 1

Test Fleet

Vehicle Identification Number	Model Year	Manufacturer	Model Name	Body Style	Test Weight (lbs)
101	1974	Chevrolet	Impala	Sedan	4560
201	1975	Chevrolet	Chevelle	Sedan	4100
301	1975	Pontiac	Firebird	Sedan	3640
401	1975	Pontiac	Ventura	Sedan	3520
502	1975	Ford	Pinto	Sedan	2800
601	1975	Oldsmobile	Cutlass	Sedan	4250
804	1974	American Motors	Gremlin	Sedan	2970
901	1975	Chevrolet	Impala	Stationwagon	5250
1001	1975	Chevrolet	Vega	Sedan	2680
1102	1975	Ford	Granada	Sedan	3510
1201	1975	Buick	Century	Sedan	4140
1301	1975	Buick	Special	Sedan	4020
1401	1975	Buick	Skylark	Sedan	3720
1501	1975	Buick	Apollo	Sedan	3910
1601	1975	Chevrolet	Monza	Sedan	3490
1702	1975	Ford	Mustang Mach I	Sedan	3000
1802	1975	Ford	Mustang	Sedan	3020
1901	1975	Buick	Skyhawk	Sedan	3200
2102	1975	Mercury	Capri II	Sedan	2570
2203	1975	Plymouth	Valiant	Sedan	3600
2301	1975	Buick	LeSabre	Sedan	4870
2401	1975	Buick	Estate	Stationwagon	5590
2502	1975	Lincoln	Continental	Sedan	5450
2602	1973	Mercury	Capri	Sedan	2350
2706	1975	Toyota	Corolla	Sedan	2470
2802	1975	Mercury	Comet	Sedan	3320
2906	1975	Toyota	Celica	Sedan	2760
3011	1975	Saab	99	Sedan	2710
3102	1975	Ford	Mustang Mach I	Sedan	3320
3212	1975	Triumph	TR6	Convertible	2650
3304	1975	American Motors	Pacer	Sedan	3330
3402	1975	Ford	Maverick	Sedan	3320
3505	1975	Volkswagon	Rabbit	Sedan	2170
3613	1975	Honda	CVCC	Sedan	1900
3908	1975	Mazda	RX-3	Stationwagon	2680
4014	1975	Fiat	128	Sedan	2180
4102	1975	Mercury	Montego	Sedan	4560
4202	1975	Ford	Gran Torino	Sedan	4570
4302	1975	Mercury	Marquis	Sedan	4990
4402	1975	Ford	LTD	Sedan	4860
4507	1975	Datsun	280Z	Sedan	3110

Table 1 con't.

Vehicle Identification Number	Model Year	Manufacturer	Model Name	Body Style	Test Weight (lbs)
4607	1975	Datsun	B210	Sedan	2310
4701	1975	Pontiac	Lemans	Sedan	4230
4801	1975	Oldsmobile	Cutlass Supre.	Sedan	4330
4903	1975	Dodge	Dart	Sedan	3610
5001	1975	Pontiac	Lemans	Sedan	4260
5103	1975	Plymouth	Valiant Custom	Sedan	3580
5203	1975	Plymouth	Gran Fury	Sedan	4840
5303	1975	Plymouth	Scamp	Sedan	3680
5403	1975	Plymouth	Valiant	Sedan	3620
5503	1975	Chrysler	New Yorker	Sedan	5120
5603	1975	Chrysler	Newport	Sedan	4840
5601	1975	Pontiac	Lemans (1)	Sedan	4320
5701	1975	Oldsmobile	Delta 88	Sedan	4770
5802	1975	Ford	Granada	Sedan	3760
6002	1975	Mercury	Montego	Sedan	4500
6102	1975	Ford	LTD	Sedan	5020
6202	1975	Ford	Torino	Sedan	4420
6302	1975	Ford	Granada (2)	Sedan	3800
6402	1975	Ford	LTD	Sedan	5060
6502	1975	Ford	Torino	Stationwagon	5210
6702	1975	Ford	Gran Torino	Stationwagon	5000
6802	1975	Ford	Gran Torino	Sedan	4600
6909	1976	Volvo	264DL	Sedan	3290
8101	1975	Chevrolet	Corvette	Sedan	3850
8401	1975	Oldsmobile	Toronado	Sedan	5170
9101	1975	Chevrolet	Corvette (3)	Sedan	3820

(1) Same vehicle as 5001.

(2) Same vehicle as 5802.

(3) Same vehicle as 8101, however head lamps up.

TABLE 2
IDENTIFICATION OF VEHICLE TIRE TYPES

ID	TIRE DESCRIPTION		CODE*
101	G 78-15	GOODRICH	2
201	G 78-14	UNIROYAL	2
301	F 78-14	UNIROYAL	2
401	F 78-14	GENERAL	2
502	BR78-13	FIRESTONE	1
601	GR78-15	FIRESTONE	1
804	6.45-14	FIRESTONE	2
901	L 78-15	GOODYEAR	2
1001	A 78-13	GENERAL	2
1102	DR78-14	FIRESTONE	1
1201	GR78-15	UNIROYAL	1
1301	FR78-15	FIRESTONE	1
1401	FR78-14	UNIROYAL	1
1501	E 78-14	UNIROYAL	2
1601	BR78-13	GOODYEAR	1
1702	195/70R13	FIRESTONE	1
1802	190/70R13	FIRESTONE	1
1901	BR78-13	UNIROYAL	1
2102	155SR13	GOODYEAR	1
2203	DR78-14	GOODYEAR	1
2301	HR78-15	UNIROYAL	1
2401	LR78-15	FIRESTONE	1
2502	230SR15	MICHELIN	1
2602	165SR13	CONTINENTAL	1
2706	185/70HR13	TOYO	1
2802	DR78-14	FIRESTONE	1
2906	185/70HR14	TOYO	1
3011	165SR15	SEMPERIT	1
3102	DR70-13	MICHELIN	1
3212	185SR15	MICHELIN	1
3304	6.95-14	FIRESTONE	2
3402	DR78-14	FIRESTONE	1
3505	155SR13	CONTINENTAL	1
3613	6.00S12	BRIDGESTONE	2
3712	185SR15	MICHELIN	1
3803	H 78-14	GOODYEAR	2
3908	155SR13	BRIDGESTONE	1
4014	145SR13	MICHELIN	1
4102	HR78-14	UNIROYAL	1
4202	HR78-14	UNIROYAL	1
4302	JR78-15	MICHELIN	1
4402	HR78-15	FIRESTONE	1

TABLE 2 (CONTINUED)
IDENTIFICATION OF VEHICLE TIRE TYPES

ID	TIRE DESCRIPTION		CODE*
4507	195/70HR14	TOYO	1
4607	155/6.15/13	BRIDGESTONE	2
4701	GR78-15	UNIROYAL	1
4801	GR78-15	GOODRICH	1
4903	D 78-14	GOODYEAR	2
5001	GR78-15	UNIROYAL	1
5103	D 78-14	GOODYEAR	2
5203	LR78-15	GOODYEAR	1
5303	E 78-14	GOODYEAR	2
5403	E 78-14	GOODYEAR	2
5503	JR78-15	GOODYEAR	1
5601	GR78-15	UNIROYAL	1
5603	HR78-15	GOODYEAR	1
5701	H 78-15	UNIROYAL	2
5802	FR78-14	FIRESTONE	1
6002	HR78-14	GOODYEAR	1
6102	HR78-15	FIRESTONE	1
6202	HR78-14	FIRESTONE	1
6302	FR78-14	FIRESTONE	1
6402	LR78-15	FIRESTONE	1
6502	HR78-14	GOODYEAR	1
6702	HR78-14	GENERAL	1
6802	JR78-14	GENERAL	1
6909	135SR14	MICHELIN	1
8101	GR78-15	GOODYEAR	1
8401	JR78-15	FIRESTONE	1
9101	GR78-15	GOODYEAR	1

* 1 = Radial Ply Tires

2 = Bias or Bias-Belted Tires

APPENDIX B

VEHICLE ROAD LOAD

AND

DYNAMOMETER ADJUSTMENT TO SIMULATE VEHICLE ROAD LOAD

TABLE 1
TOTAL VEHICLE ROAD LOAD

ID	F0 (NT)	F1 (KG/SEC)	F2 (KG/M)	F@50 (NT)	HP@50 (HP)
101	0.2404E+03	0.4126E+01	0.5860E+00	0.6253E+03	18.742
201	0.3208E+03	-0.7530E+01	0.9936E+00	0.6488E+03	19.446
301	0.1449E+03	0.1164E+02	0.2000E+00	0.5050E+03	15.135
401	0.2714E+03	-0.2887E+01	0.6926E+00	0.5528E+03	16.569
502	0.2081E+03	-0.3156E+01	0.7195E+00	0.4970E+03	14.896
601	0.3200E+03	-0.9857E+01	0.9457E+00	0.5721E+03	17.147
804	0.1102E+03	0.1706E+02	0.1032E+00	0.5430E+03	16.275
901	0.2096E+03	0.6818E+01	0.6562E+00	0.6898E+03	20.673
1001	0.1885E+03	0.4893E+01	0.4068E+00	0.5011E+03	15.020
1102	0.1359E+03	0.9923E+01	0.4610E+00	0.5880E+03	17.622
1201	0.1096E+03	0.1662E+02	0.3270E+00	0.6444E+03	19.313
1301	0.1231E+03	0.1204E+02	0.3936E+00	0.5887E+03	17.645
1401	0.1109E+03	0.1443E+02	0.2255E+00	0.5460E+03	16.364
1501	0.1847E+03	0.9384E+01	0.3596E+00	0.5741E+03	17.207
1601	0.2040E+03	-0.1268E+01	0.4953E+00	0.4231E+03	12.680
1702	0.1368E+03	0.5324E+01	0.4373E+00	0.4742E+03	14.213
1802	0.1826E+03	0.4903E+01	0.4544E+00	0.5191E+03	15.560
1901	0.1976E+03	-0.2344E+01	0.5647E+00	0.4273E+03	12.807
2102	0.1549E+03	0.1807E+01	0.5188E+00	0.4544E+03	13.620
2203	0.2275E+03	-0.3676E+01	0.7477E+00	0.5188E+03	15.551
2301	0.1918E+03	0.8005E+01	0.5202E+00	0.6306E+03	18.899
2401	0.1920E+03	0.8139E+01	0.6615E+00	0.7043E+03	21.110
2502	0.2947E+03	0.4943E+01	0.5077E+00	0.6588E+03	19.744
2602	0.1227E+03	0.4918E+01	0.3366E+00	0.4007E+03	12.011
2706	0.9967E+02	0.6409E+01	0.3499E+00	0.4177E+03	12.514
2802	0.1778E+03	0.4672E+01	0.4602E+00	0.5121E+03	15.348
2906	0.1771E+03	-0.4749E+01	0.6477E+00	0.3945E+03	11.823
3011	0.2152E+03	-0.5071E+01	0.6943E+00	0.4487E+03	13.449
3102	0.1704E+03	0.6461E+01	0.3735E+00	0.5014E+03	15.025
3212	0.2481E+03	-0.9665E+01	0.7864E+00	0.4249E+03	12.734
3304	0.1747E+03	0.6645E+01	0.3760E+00	0.5110E+03	15.316
3402	0.1055E+03	0.1556E+02	0.1693E+00	0.5378E+03	16.116
3505	0.1441E+03	-0.3787E+00	0.5202E+00	0.3955E+03	11.854
3613	0.6532E+02	0.1006E+02	0.2122E+00	0.3961E+03	11.871
3908	0.1847E+03	0.5347E+00	0.6015E+00	0.4971E+03	14.89[illegible]
4014	0.1553E+03	-0.2685E+01	0.6859E+00	0.4379E+03	13.126
4102	0.2456E+03	0.6986E+01	0.4874E+00	0.6452E+03	19.339
4202	0.1648E+03	0.2019E+02	0.1744E+00	0.7031E+03	21.074
4302	0.6598E+03	-0.3749E+02	0.1658E+01	0.6504E+03	19.493
4402	0.2665E+03	0.5826E+00	0.6670E+00	0.6127E+03	18.365

TABLE 1 (CONTINUED)
TOTAL VEHICLE ROAD LOAD

ID	F0 (NT)	F1 (KG/SEC)	F2 (KG/M)	F@50 (NT)	HP@50 (HP)
4507	0.1219E+03	0.9159E+01	0.2515E+00	0.4522E+03	13.554
4607	0.1275E+03	0.3935E+01	0.3359E+00	0.3833E+03	11.487
4701	0.2164E+03	0.2275E+00	0.6013E+00	0.5219E+03	15.641
4801	0.2186E+03	-0.5525E+00	0.7274E+00	0.5696E+03	17.072
4903	0.1376E+03	0.1354E+02	0.1701E+00	0.5253E+03	15.745
5001	0.3866E+03	-0.1570E+02	0.1039E+01	0.5546E+03	16.623
5103	0.1549E+03	0.1490E+02	0.2431E+00	0.6093E+03	18.262
5203	0.2448E+03	0.6799E+01	0.4845E+00	0.6388E+03	19.146
5303	0.1736E+03	0.1283E+02	0.2600E+00	0.5902E+03	17.689
5403	0.2835E+03	-0.3427E+01	0.7847E+00	0.5989E+03	17.949
5503	0.3347E+03	-0.3877E+01	0.8128E+00	0.6541E+03	19.604
5601	0.1974E+03	0.7108E+01	0.4269E+00	0.5695E+03	17.068
5603	0.1448E+03	0.1667E+02	0.2314E+00	0.6329E+03	18.969
5701	0.2278E+03	0.7702E+01	0.4750E+00	0.6372E+03	19.097
5802	0.1740E+03	0.7805E+01	0.4446E+00	0.5706E+03	17.101
6002	0.2486E+03	0.1023E+02	0.3783E+00	0.6661E+03	19.963
6102	0.1494E+03	0.1807E+02	0.2086E+00	0.6574E+03	19.703
6202	0.1580E+03	0.1733E+02	0.2446E+00	0.6676E+03	20.004
6302	0.2231E+03	-0.1301E+01	0.7182E+00	0.5528E+03	16.559
6402	0.1487E+03	0.1430E+02	0.3583E+00	0.6473E+03	19.401
6502	0.2053E+03	0.8997E+01	0.5551E+00	0.6837E+03	20.492
6702	0.2097E+03	0.5246E+01	0.7385E+00	0.6958E+03	20.856
6802	0.2965E+03	-0.7523E+01	0.9875E+00	0.6216E+03	18.631
6909	0.1059E+03	0.1201E+02	0.3338E+00	0.5411E+03	16.218
8101	0.3492E+03	-0.9181E+01	0.7654E+00	0.5263E+03	15.774
8401	0.2487E+03	0.6112E+01	0.5472E+00	0.6586E+03	19.741
9101	0.2331E+03	0.4870E+01	0.4822E+00	0.5828E+03	17.468

TABLE 2
TWIN SMALL ROLL DYNAMOMETER ESTIMATES
FOR VEHICLES WITH BIAS-BELTED TIRES

ID	F0 (NT)	F1 (KG/SEC)	F2 (KG/M)	F@50 (NT)	HP@50 (HP)
101	0.1015E+03	0.1685E+01	0.5860E+00	0.4319E+03	12.945
201	0.2037E+03	-0.1011E+02	0.9936E+00	0.4741E+03	14.211
301	0.2052E+02	0.9058E+01	0.2000E+00	0.3229E+03	9.677
401	0.1296E+03	-0.4815E+01	0.6926E+00	0.3680E+03	11.030
502	0.1071E+03	-0.5158E+01	0.7195E+00	0.3513E+03	10.528
601	0.1978E+03	-0.1194E+02	0.9457E+00	0.4033E+03	12.088
804	-0.7893E+01	0.1492E+02	0.1032E+00	0.3772E+03	11.305
901	0.5659E+02	0.4743E+01	0.6562E+00	0.4904E+03	14.698
1001	0.8486E+02	0.2733E+01	0.4068E+00	0.3491E+03	10.465
1102	0.4561E+02	0.5472E+01	0.4610E+00	0.3982E+03	11.935
1201	-0.1181E+02	0.1311E+02	0.3270E+00	0.4445E+03	13.323
1301	0.9527E+01	0.9118E+01	0.3936E+00	0.4099E+03	12.286
1401	0.1644E+01	0.1204E+02	0.2255E+00	0.3835E+03	11.493
1501	0.2758E+02	0.7142E+01	0.3596E+00	0.3668E+03	10.995
1601	0.9307E+02	-0.3595E+01	0.4953E+00	0.2601E+03	7.797
1702	0.3273E+02	0.3253E+01	0.4373E+00	0.3239E+03	9.707
1802	0.5781E+02	0.3557E+01	0.4544E+00	0.3643E+03	10.918
1901	0.1005E+03	-0.3998E+01	0.5647E+00	0.2932E+03	8.788
2102	0.6581E+02	-0.4870E+00	0.5188E+00	0.3141E+03	9.414
2203	0.1620E+03	-0.6571E+01	0.7477E+00	0.3886E+03	11.649
2301	0.2384E+02	0.6549E+01	0.5202E+00	0.4301E+03	12.890
2401	0.6028E+02	0.4722E+01	0.6615E+00	0.4963E+03	14.874
2502	0.2148E+03	0.3391E+01	0.5077E+00	0.5442E+03	16.311
2602	0.6236E+02	0.3134E+01	0.3366E+00	0.3005E+03	9.008
2706	0.9372E+01	0.5096E+01	0.3499E+00	0.2981E+03	8.933
2802	0.7893E+02	0.1186E+01	0.4602E+00	0.3353E+03	10.050
2906	0.1120E+03	-0.6826E+01	0.6477E+00	0.2830E+03	8.481
3011	0.1673E+03	-0.6081E+01	0.6943E+00	0.3782E+03	11.334
3102	0.4028E+02	0.5142E+01	0.3735E+00	0.3418E+03	10.244
3212	0.1445E+03	-0.1102E+02	0.7864E+00	0.2910E+03	8.720
3304	0.4589E+02	0.4198E+01	0.3760E+00	0.3275E+03	9.817
3402	-0.2927E+02	0.1398E+02	0.1693E+00	0.3677E+03	11.021
3505	0.1110E+03	-0.1008E+01	0.5202E+00	0.3484E+03	10.441
3613	0.1810E+02	0.8392E+01	0.2122E+00	0.3117E+03	9.341
3908	0.7705E+02	-0.1233E+01	0.6015E+00	0.3500E+03	10.489
4014	0.1059E+03	-0.3536E+01	0.6859E+00	0.3695E+03	11.075
4102	0.8789E+02	0.6804E+01	0.4874E+00	0.4834E+03	14.489
4202	-0.2253E+02	0.1840E+02	0.1744E+00	0.4759E+03	14.263
4302	0.5221E+03	-0.3959E+02	0.1658E+01	0.4654E+03	13.950
4402	0.9291E+02	-0.1397E+01	0.6670E+00	0.3949E+03	11.835

TABLE 2 (CONTINUED)
TWIN SMALL ROLL DYNAMOMETER ESTIMATES
FOR VEHICLES WITH BIAS-BELTED TIRES

ID	F0 (NT)	F1 (KG/SEC)	F2 (KG/M)	F@50 (NT)	HP@50 (HP)
4507	0.7320E+01	0.7829E+01	0.2515E+00	0.3079E+03	9.229
4607	0.4625E+02	0.2488E+01	0.3359E+00	0.2697E+03	8.082
4701	0.1086E+03	-0.1966E+01	0.6013E+00	0.3650E+03	10.940
4801	0.7880E+02	-0.2395E+01	0.7274E+00	0.3886E+03	11.647
4903	0.1699E+02	0.1114E+02	0.1701E+00	0.3508E+03	10.515
5001	0.2949E+03	-0.1894E+02	0.1039E+01	0.3906E+03	11.707
5103	0.6807E+02	0.1113E+02	0.2431E+00	0.4382E+03	13.133
5203	0.9862E+02	0.3697E+01	0.4845E+00	0.4233E+03	12.686
5303	0.7524E+02	0.1011E+02	0.2600E+00	0.4310E+03	12.918
5403	0.1803E+03	-0.5978E+01	0.7847E+00	0.4387E+03	13.148
5503	0.2383E+03	-0.9662E+01	0.8128E+00	0.4283E+03	12.836
5601	0.1057E+03	0.3870E+01	0.4269E+00	0.4054E+03	12.151
5603	-0.3265E+01	0.1374E+02	0.2314E+00	0.4195E+03	12.574
5701	0.6606E+02	0.5913E+01	0.4750E+00	0.4355E+03	13.052
5802	0.4664E+02	0.5897E+01	0.4446E+00	0.4005E+03	12.004
6002	0.7936E+02	0.9278E+01	0.3783E+00	0.4757E+03	14.257
6102	-0.1149E+02	0.1626E+02	0.2086E+00	0.4562E+03	13.674
6202	-0.2716E+01	0.1308E+02	0.2446E+00	0.4118E+03	12.342
6302	0.9574E+02	-0.3209E+01	0.7182E+00	0.3828E+03	11.472
6402	-0.3389E+02	0.1254E+02	0.3583E+00	0.4254E+03	12.749
6502	0.1105E+02	0.7061E+01	0.5551E+00	0.4461E+03	13.372
6702	0.6191E+02	0.2287E+01	0.7385E+00	0.4819E+03	14.444
6802	0.1905E+03	-0.1098E+02	0.9875E+00	0.4385E+03	13.142
6909	0.1285E+02	0.9953E+01	0.3338E+00	0.4020E+03	12.050
8101	0.2102E+03	-0.1079E+02	0.7654E+00	0.3513E+03	10.530
8401	0.2126E+02	0.5518E+01	0.5472E+00	0.4179E+03	12.526
9101	0.9405E+02	0.3261E+01	0.4822E+00	0.4078E+03	12.223

TABLE 3
TWIN SMALL ROLL DYNAMOMETER POWER ABSORPTION ESTIMATES
FOR VEHICLES WITH RADIAL TIRES

ID	F0 (NT)	F1 (KG/SEC)	F2 (KG/M)	F@50 (NT)	HP@50 (HP)
101	0.5961E+02	0.1414E+01	0.5860E+00	0.3839E+03	11.507
201	0.1614E+03	-0.1040E+02	0.9936E+00	0.4253E+03	12.746
301	-0.2327E+02	0.8876E+01	0.2000E+00	0.2750E+03	8.243
401	0.8863E+02	-0.4969E+01	0.6926E+00	0.3235E+03	9.697
502	0.8553E+02	-0.5252E+01	0.7195E+00	0.3276E+03	9.817
601	0.1756E+03	-0.1207E+02	0.9457E+00	0.3783E+03	11.340
804	-0.4747E+02	0.1464E+02	0.1032E+00	0.3314E+03	9.933
901	0.1724E+02	0.4515E+01	0.6562E+00	0.4459E+03	13.365
1001	0.4774E+02	0.2625E+01	0.4068E+00	0.3096E+03	9.280
1102	0.3281E+02	0.5216E+01	0.4610E+00	0.3797E+03	11.379
1201	-0.4175E+02	0.1318E+02	0.3270E+00	0.4162E+03	12.475
1301	-0.1257E+02	0.8975E+01	0.3936E+00	0.3846E+03	11.528
1401	-0.1984E+02	0.1184E+02	0.2255E+00	0.3574E+03	10.711
1501	-0.1846E+02	0.7160E+01	0.3596E+00	0.3212E+03	9.627
1601	0.7333E+02	-0.3808E+01	0.4953E+00	0.2356E+03	7.062
1702	0.1301E+02	0.3076E+01	0.4373E+00	0.3002E+03	8.996
1802	0.3457E+02	0.3445E+01	0.4544E+00	0.3385E+03	10.147
1901	0.7912E+02	-0.4224E+01	0.5647E+00	0.2668E+03	7.995
2102	0.4788E+02	-0.6730E+00	0.5188E+00	0.2920E+03	8.751
2203	0.1517E+03	-0.6778E+01	0.7477E+00	0.3737E+03	11.202
2301	-0.7248E+01	0.6477E+01	0.5262E+00	0.3974E+03	11.910
2401	0.3278E+02	0.4406E+01	0.6615E+00	0.4617E+03	13.838
2502	0.1963E+03	0.3310E+01	0.5077E+00	0.5239E+03	15.702
2602	0.5375E+02	0.3099E+01	0.3366E+00	0.2912E+03	8.725
2706	0.1340E+01	0.4767E+01	0.3499E+00	0.2827E+03	8.472
2802	0.5872E+02	0.1062E+01	0.4602E+00	0.3123E+03	9.361
2906	0.9889E+02	-0.6976E+01	0.6477E+00	0.2665E+03	7.988
3011	0.1594E+03	-0.6169E+01	0.6943E+00	0.3683E+03	11.039
3102	0.1473E+02	0.5061E+01	0.3735E+00	0.3144E+03	9.424
3212	0.1295E+03	-0.1108E+02	0.7864E+00	0.2746E+03	8.231
3304	0.6325E+01	0.3905E+01	0.3760E+00	0.2814E+03	8.435
3402	-0.5651E+02	0.1382E+02	0.1693E+00	0.3370E+03	10.109
3505	0.1055E+03	-0.1047E+01	0.5202E+00	0.3419E+03	10.24[illegible]
3613	0.3142E+01	0.8338E+01	0.2122E+00	0.2955E+03	8.857
3908	0.6141E+02	-0.1287E+01	0.6015E+00	0.3331E+03	9.984
4014	0.9543E+02	-0.3597E+01	0.6859E+00	0.3577E+03	10.720
4102	0.5200E+02	0.6834E+01	0.4874E+00	0.4482E+03	13.433
4202	-0.5724E+02	0.1814E+02	0.1744E+00	0.4352E+03	13.045
4302	0.4928E+03	-0.3974E+02	0.1658E+01	0.4329E+03	12.975
4402	0.5926E+02	-0.1486E+01	0.6670E+00	0.3592E+03	10.76[illegible]

TABLE 3 (CONTINUED)
TWIN SMALL ROLL DYNAMOMETER POWER ABSORPTION ESTIMATES
FOR VEHICLES WITH RADIAL TIRES

ID	F0 (NT)	F1 (KG/SEC)	F2 (KG/M)	F@50 (NT)	HP@50 (HP)
4507	-0.1193E+02	0.7797E+01	0.2515E+00	0.2880E+03	8.631
4607	0.2209E+02	0.2361E+01	0.3359E+00	0.2426E+03	7.273
4701	0.8817E+02	-0.2181E+01	0.6013E+00	0.3398E+03	10.184
4801	0.5423E+02	-0.2535E+01	0.7274E+00	0.3609E+03	10.817
4903	-0.2160E+02	0.1088E+02	0.1701E+00	0.3065E+03	9.185
5001	0.2728E+03	-0.1913E+02	0.1039E+01	0.3642E+03	10.915
5103	0.4212E+02	0.1055E+02	0.2431E+00	0.3994E+03	11.972
5203	0.7191E+02	0.3683E+01	0.4845E+00	0.3962E+03	11.876
5303	0.4619E+02	0.9681E+01	0.2600E+00	0.3924E+03	11.762
5403	0.1426E+03	-0.6241E+01	0.7847E+00	0.3951E+03	11.841
5503	0.2105E+03	-0.9938E+01	0.8128E+00	0.3944E+03	11.822
5601	0.8358E+02	0.3676E+01	0.4264E+00	0.3790E+03	11.359
5603	-0.2999E+02	0.1350E+02	0.2314E+00	0.3874E+03	11.616
5701	0.2092E+02	0.5547E+01	0.4750E+00	0.3822E+03	11.454
5802	0.2062E+02	0.5750E+01	0.4446E+00	0.3712E+03	11.126
6002	0.5095E+02	0.9232E+01	0.3783E+00	0.4463E+03	13.375
6102	-0.4376E+02	0.1612E+02	0.2086E+00	0.4208E+03	12.612
6202	-0.3876E+02	0.1294E+02	0.2446E+00	0.3726E+03	11.168
6302	0.6972E+02	-0.3356E+01	0.7182E+00	0.3535E+03	10.594
6402	-0.6875E+02	0.1239E+02	0.3583E+00	0.3871E+03	11.603
6502	-0.1947E+02	0.6926E+01	0.5551E+00	0.4126E+03	12.367
6702	0.4439E+02	0.2241E+01	0.7355E+00	0.4634E+03	13.888
6802	0.1688E+03	-0.1115E+02	0.9875E+00	0.4129E+03	12.377
6909	-0.4329E+01	0.9895E+01	0.3338E+00	0.3836E+03	11.496
8101	0.1883E+03	-0.1099E+02	0.7654E+00	0.3250E+03	9.741
8401	-0.2707E+01	0.5436E+01	0.5472E+00	0.3921E+03	11.753
9101	0.7218E+02	0.3061E+01	0.4822E+00	0.3815E+03	11.433

TABLE 4
SINGLE LARGE ROLL DYNAMOMETER POWER ABSORPTION ESTIMATES

ID	F0 (NT)	F1 (KG/SEC)	F2 (KG/M)	F@50 (NT)	HP@50 (HP)
101	0.1387E+03	0.1781E+01	0.5860E+00	0.4712E+03	14.123
201	0.2484E+03	-0.1013E+02	0.9936E+00	0.5184E+03	15.539
301	0.6252E+02	0.9245E+01	0.2000E+00	0.3691E+03	11.061
401	0.1690E+03	-0.4689E+01	0.6926E+00	0.4102E+03	12.294
502	0.1418E+03	-0.4911E+01	0.7195E+00	0.3915E+03	11.733
601	0.2218E+03	-0.1203E+02	0.9457E+00	0.4254E+03	12.749
804	0.1907E+02	0.1495E+02	0.1032E+00	0.4047E+03	12.128
901	0.8861E+02	0.4310E+01	0.6562E+00	0.5127E+03	15.367
1001	0.1084E+03	0.2750E+01	0.4068E+00	0.3731E+03	11.183
1102	0.6853E+02	0.5832E+01	0.4610E+00	0.4292E+03	12.863
1201	0.1460E+02	0.1359E+02	0.3270E+00	0.4818E+03	14.439
1301	0.5499E+02	0.9040E+01	0.3936E+00	0.4536E+03	13.597
1401	0.4093E+02	0.1190E+02	0.2255E+00	0.4196E+03	12.575
1501	0.6542E+02	0.7702E+01	0.3596E+00	0.4172E+03	12.504
1601	0.1361E+03	-0.3345E+01	0.4953E+00	0.3087E+03	9.253
1702	0.5865E+02	0.3426E+01	0.4373E+00	0.3537E+03	10.600
1802	0.8140E+02	0.3728E+01	0.4544E+00	0.3917E+03	11.740
1901	0.1360E+03	-0.3911E+01	0.5647E+00	0.3306E+03	9.910
2102	0.9406E+02	-0.2950E+00	0.5188E+00	0.3466E+03	10.389
2203	0.1607E+03	-0.5076E+01	0.7477E+00	0.4207E+03	12.611
2301	0.6382E+02	0.6487E+01	0.5202E+00	0.4687E+03	14.046
2401	0.8628E+02	0.5042E+01	0.6615E+00	0.5294E+03	15.867
2502	0.2510E+03	0.3091E+01	0.5077E+00	0.5736E+03	17.193
2602	0.6032E+02	0.3141E+01	0.3366E+00	0.2987E+03	8.951
2706	0.4960E+02	0.4927E+01	0.3499E+00	0.3345E+03	10.026
2802	0.1354E+03	0.1282E+01	0.4602E+00	0.3939E+03	11.807
2906	0.1191E+03	-0.6635E+01	0.6477E+00	0.2944E+03	8.822
3011	0.1682E+03	-0.6041E+01	0.6943E+00	0.3800E+03	11.390
3102	0.7703E+02	0.5343E+01	0.3735E+00	0.3830E+03	11.480
3212	0.1578E+03	-0.1089E+02	0.7864E+00	0.3073E+03	9.210
3304	0.7287E+02	0.4193E+01	0.3760E+00	0.3544E+03	10.622
3402	0.1923E+02	0.1394E+02	0.1693E+00	0.4154E+03	12.451
3505	0.1157E+03	-0.1010E+01	0.5202E+00	0.3530E+03	10.580
3613	0.1092E+02	0.8363E+01	0.2122E+00	0.3038E+03	9.106
3908	0.9622E+02	-0.1072E+01	0.6015E+00	0.3727E+03	11.171
4014	0.1226E+03	-0.3608E+01	0.6859E+00	0.3846E+03	11.527
4102	0.1052E+03	0.6173E+01	0.4874E+00	0.4866E+03	14.586
4202	0.3691E+02	0.1864E+02	0.1744E+00	0.5405E+03	16.201
4302	0.5825E+03	-0.3968E+02	0.1658E+01	0.5238E+03	15.700
4402	0.1644E+03	-0.1534E+01	0.6670E+00	0.4633E+03	13.886

TABLE 4 (CONTINUED)
SINGLE LARGE ROLL DYNAMOMETER POWER ABSORPTION ESTIMATES

ID	F0 (NT)	F1 (KG/SEC)	F2 (KG/M)	F@50 (NT)	HP@50 (HP)
4507	0.2457E+02	0.7695E+01	0.2515E+00	0.3222E+03	9.656
4607	0.6428E+02	0.2394E+01	0.3359E+00	0.2856E+03	8.559
4701	0.1264E+03	-0.1743E+01	0.6013E+00	0.3877E+03	11.621
4801	0.1112E+03	-0.2356E+01	0.7274E+00	0.4220E+03	12.647
4903	0.5525E+02	0.1126E+02	0.1701E+00	0.3919E+03	11.746
5001	0.3266E+03	-0.1895E+02	0.1039E+01	0.4221E+03	12.652
5103	0.7951E+02	0.1210E+02	0.2431E+00	0.4714E+03	14.129
5203	0.1629E+03	0.3594E+01	0.4845E+00	0.4852E+03	14.542
5303	0.1137E+03	0.9719E+01	0.2600E+00	0.4608E+03	13.812
5403	0.2030E+03	-0.5799E+01	0.7847E+00	0.4654E+03	13.948
5503	0.2974E+03	-0.9280E+01	0.8128E+00	0.4960E+03	14.866
5601	0.1374E+03	0.3860E+01	0.4259E+00	0.4369E+03	13.096
5603	0.4170E+02	0.1410E+02	0.2314E+00	0.4724E+03	14.158
5701	0.1120E+03	0.6042E+01	0.4750E+00	0.4844E+03	14.517
5802	0.9090E+02	0.6171E+01	0.4446E+00	0.4509E+03	13.515
6002	0.1270E+03	0.8986E+01	0.3783E+00	0.5168E+03	15.490
6102	0.3573E+02	0.1626E+02	0.2086E+00	0.5034E+03	15.087
6202	0.7184E+02	0.1297E+02	0.2446E+00	0.4839E+03	14.503
6302	0.1400E+03	-0.2935E+01	0.7182E+00	0.4332E+03	12.983
6402	0.1428E+02	0.1276E+02	0.3583E+00	0.4784E+03	14.337
6502	0.6898E+02	0.7041E+01	0.5551E+00	0.5036E+03	15.095
6702	0.1012E+03	0.2358E+01	0.7385E+00	0.5228E+03	15.670
6802	0.2276E+03	-0.1104E+02	0.9875E+00	0.4742E+03	14.212
6909	0.3735E+02	0.1021E+02	0.3338E+00	0.4323E+03	12.958
8101	0.2415E+03	-0.1087E+02	0.7654E+00	0.3810E+03	11.420
8401	0.5022E+02	0.5897E+01	0.5472E+00	0.4554E+03	13.648
9101	0.1254E+03	0.3185E+01	0.4822E+00	0.4375E+03	13.112

APPENDIX C

EFFECTS OF VEHICLE TYPE AND VEHICLE PROTUBERANCES

Table 1

Fastback Vehicle Selection

Vehicle Identification Number	Description		Inclined Rear Surface Angle (Degrees)	Inclined Rear Surface Area+ (Percentage of Reference Area)
301	Pontiac	Firebird	20	37
502	Ford	Pinto	27	
1601	Chevrolet	Monza	19	37
1702	Ford	Mustang Mach I	20*	36
1901	Buick	Skyhawk	19	37
2102	Mercury	Capri II	26	
2602	Mercury	Capri	30	
2706	Toyota	Corolla	21	
2906	Toyota	Celica	16	27
3102	Ford	Mustang Mach I	20*	36
4507	Datsun	280Z 2 + 2	22	
4607	Datsun	B210	16	30

Vehicles Meeting Fastback Criteria

Vehicle Identification Number	Description	
301	Pontiac	Firebird
1601	Chevrolet	Monza
1702	Ford	Mustang Mach I
1901	Buick	Skyhawk
2906	Toyota	Celica
3102	Ford	Mustang Mach I
4607	Datsun	B210

* Data supplied by Ford Motor Company

\+ Area measurements were made on only those vehicles with an inclined rear surface angle of 20 degrees or less.

TABLE 2
CALCULATED VEHICLE DRAG COEFFICIENTS

ID	VALUE*	C D
101	2	0.5889
201	2	0.6776
301	1	0.4932
401	2	0.5484
502	2	0.6269
601	2	0.6027
804	2	0.6461
901	2	0.6784
1001	2	0.6246
1102	2	0.6237
1201	2	0.6631
1301	2	0.6128
1401	2	0.6058
1501	2	0.5445
1601	1	0.4677
1702	1	0.5715
1802	2	0.6444
1901	1	0.5296
2102	2	0.5735
2203	2	0.6425
2301	2	0.6096
2401	2	0.7024
2502	2	0.7509
2602	2	0.5689
2706	2	0.5703
2802	2	0.5367
2906	1	0.5589
3011	2	0.6614
3102	1	0.5985
3212	2	0.5570
3304	2	0.4963
3402	2	0.5792
3505	2	0.6346
3613	2	0.6464
3908	2	0.6798
4014	2	0.7631
4102	2	0.7110
4202	2	0.6676
4302	2	0.6181
4402	2	0.5334

TABLE 2(CONTINUED)
CALCULATED VEHICLE DRAG COEFFICIENTS

ID	VALUE *	C D
4507	2	0.6061
4607	1	0.5230
4701	2	0.5414
4801	2	0.5750
4903	2	0.5292
5001	2	0.5802
5103	2	0.6867
5203	2	0.6033
5303	2	0.6816
5403	2	0.6793
5503	2	0.6025
5601	2	0.6038
5603	2	0.5865
5701	2	0.5863
5802	2	0.6097
6002	2	0.7080
6102	2	0.6248
6202	2	0.5787
6302	2	0.5806
6402	2	0.5746
6502	2	0.5983
6702	2	0.6720
6802	2	0.6334
6909	2	0.6452
8101	2	0.7014
8401	2	0.6090
9101	2	0.8234

* Value = 1 for Fastback Vehicles
= 2 for Non-Fastback Vehicles

Table 3

Estimated Protuberance Effects

Vehicle Identification Number	Model Year	Manufacturer	Model Name	Body Style	Estimated Protuberance Power
804	1974	Am. Motors	Gremlin	Sedan	0.4
901	1975	Chevrolet	Impala	Stationwagon	0.4
2401	1975	Buick	Estate	Stationwagon	0.4
6702	1975	Ford	Gran Torino	Stationwagon	1.0

Vehicle 6702 was equipped with a roof rack and air deflector. The other vehicles in the table were equipped with a roof rack only. The remaining vehicles in the test fleet were not equipped with roof racks.

TABLE 4
PREDICTED DYNAMOMETER POWER ABSORPTION

ID	AREA (FT)	TYPE *	HP@50 (HP)	PP@50 (HP)
101	24.20	2.00	11.507	12.061
201	23.30	2.00	12.746	11.612
301	20.70	1.00	8.243	8.933
401	21.90	2.00	9.697	10.915
502	19.40	2.00	9.817	9.669
601	23.30	2.00	11.340	11.612
804	19.04	3.00	9.933	9.889
901	24.40	3.00	13.365	12.560
1001	18.40	2.00	9.280	9.170
1102	22.60	2.00	11.379	11.263
1201	23.30	2.00	12.475	11.612
1301	23.30	2.00	11.528	11.612
1401	21.90	2.00	10.711	10.915
1501	21.90	2.00	9.627	10.915
1601	18.70	1.00	7.062	8.070
1702	19.50	1.00	8.998	8.415
1802	19.50	2.00	10.147	9.718
1901	18.70	1.00	7.996	8.070
2102	18.90	2.00	8.751	9.419
2203	21.59	2.00	11.202	10.760
2301	24.20	2.00	11.910	12.061
2401	24.40	3.00	13.838	12.560
2502	25.90	2.00	15.702	12.908
2602	19.00	2.00	8.726	9.469
2706	18.40	2.00	8.472	9.170
2802	21.60	2.00	9.361	10.765
2906	17.70	1.00	7.988	7.638
3011	20.67	2.00	11.039	10.302
3102	19.50	1.00	9.424	8.415
3212	18.30	2.00	8.231	9.120
3304	21.05	2.00	8.435	10.491
3402	21.60	2.00	10.100	10.765
3505	20.00	2.00	10.249	9.968
3613	16.97	2.00	8.857	8.458
3908	18.19	2.00	9.984	9.066
4014	17.40	2.00	10.720	8.672
4102	23.40	2.00	13.433	11.662
4202	24.20	2.00	13.045	12.061
4302	26.00	2.00	12.975	12.958
4402	25.00	2.00	10.766	12.459

TABLE 4 (CONTINUED)
PREDICTED DYNAMOMETER POWER ABSORPTION

ID	AREA (FT)	TYPE*	HP@50 (HP)	PP@50 (HP)
4507	17.64	2.00	8.631	8.791
4607	17.22	1.00	7.273	7.431
4701	23.30	2.00	10.184	11.612
4801	23.30	2.00	10.817	11.612
4903	21.50	2.00	9.185	10.715
5001	23.30	2.00	10.915	11.612
5103	21.59	2.00	11.972	10.760
5203	24.38	2.00	11.876	12.151
5303	21.37	2.00	11.762	10.650
5403	21.59	2.00	11.841	10.760
5503	24.30	2.00	11.822	12.111
5601	23.30	2.00	11.359	11.612
5603	24.52	2.00	11.610	12.220
5701	24.20	2.00	11.454	12.061
5802	22.60	2.00	11.126	11.263
6002	23.40	2.00	13.375	11.662
6102	25.00	2.00	12.612	12.459
6202	23.90	2.00	11.168	11.911
6302	22.60	2.00	10.594	11.263
6402	25.00	2.00	11.603	12.459
6502	25.60	2.00	12.367	12.759
6702	25.60	3.00	13.888	13.759
6802	24.20	2.00	12.377	12.061
6909	22.07	2.00	11.496	10.999
8101	17.20	2.00	9.741	8.572
8401	23.90	2.00	11.753	11.911
9101	17.20	2.00	11.433	8.572

* Type = 1 Designates a Fastback Vehicle
Type = 2 Designates a Non-Fastback Vehicle
Type = 3 Designates a Non-Fastback Vehicle Equipped with a Roof Rack