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Technical Report

Investigation of the Requested Alternate Dynamometer Power Absorption for the Ford Mercury Marquis

by

Glenn D. Thompson
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Standards Development and Support Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Office of Air and Waste Management
U.S. Environmental Protection Agency

Abstract

Concern about the EPA fuel economy measurements has focused greater attention on the dynamometer and the dynamometer adjustment. Specifically the alternate procedures for determining the dynamometer power absorption to simulate the vehicle road experience affords an opportunity for both greater precision and possible abuse. Because of the possibility for abuse it was decided to occasionally check the appropriateness of the alternate dynamometer power absorptions requested by vehicle manufacturers.

The question of the representativeness of the requested dynamometer power absorption for the Mercury Marquis was first raised during the summer of 1977. This report collects and summarizes the pertinent available data which have been generated by the EPA Emission Control Technology Division, the EPA Certification Division, and by Ford Motor Company.

It is concluded that a dynamometer adjustment of 11.4 horsepower is representative of typical, recommended vehicle use. The dynamometer adjustment requested by Ford, 8.8 horsepower is certainly inappropriately low. Some of the discrepancy between the original requested power absorption and the EPA results occurred because of the increased tire pressures used by Ford during their road tests. These tire pressures are considered unrepresentative of anticipated consumer use of the vehicle because they are significantly higher than the tire pressures used by Ford dealers in preparation of the vehicles for consumer use. Even with the increased tire inflation pressures the recent tests indicate a dynamometer adjustment of 10.8 horsepower is necessary to simulate the road experience of the vehicle.

The EPA exhaust emission certification and fuel economy measurements of the Ford Mercury Marquis were unrepresentative because of the inappropriately low dynamometer adjustments used during these tests. The unrepresentative nature of these tests resulted in reduced NOx emission measurements for the vehicle and resulted in significantly increased vehicle fuel economy. If the vehicle were tested at the representative dynamometer power absorption, it is predicted that the NOx emissions would increase approximately 0.05 gm/mi. The predicted decrease in the urban fuel economy would be about 0.25 mi/gal, while the highway fuel economy would be expected to decrease about 1.5 mi/gal. The composite urban-highway fuel economy would be expected to decrease approximately 0.6 mi/gallon, or about 3 percent.

Purpose

The question of the representativeness of the test vehicle and the requested dynamometer power absorption for the Mercury Marquis was first raised during the summer of 1977. This report collects and summarizes the pertinant available data which have been generated by the EPA Emission Control Technology Division, the EPA Certification Division, and by Ford Motor Company.

Background

During the summer of 1977, ECTD personnel became aware of several requests for alternate dynamometer power absorption which appeared to be anomalously low. One of the most outstanding of these was the 8.8 horsepower requested by Ford Motor Company for the Mercury Marquis. This request was 34% below the 13.4 horsepower specified by the Federal Register, for testing a vehicle of the inertia weight category of the Marquis. The concern over the appropriateness of this requested dynamometer adjustment resulted in an ECTD test program which was conducted in July 1977. The report of this program concluded that the alternate dynamometer power adjustments requested for this vehicle did not appropriately reflect the road experience of the vehicle as reported by Ford. In addition, this report questioned the representativeness of the certification vehicle with respect to the production vehicle. The report of July 1977, which is attached as Appendix A, has been the basis for the additional investigations which have been conducted.

Discussion

This report first considers all of the available data, assuming the road data submitted by Ford is correct. The second section of the report challenges the road data, and the final section documents the effects the indicated descrepancies in dynamometer adjustment would probably have on the fuel economy and exhaust emissions of this vehicle.

A. Analysis of the Dynamometer Data assuming Validity of the Ford Road Data

In response to the questions raised by the first EPA report, Ford Motor Company conducted a series of road and dynamometer tests on three production Mercury Marquis. The results of these tests are given in Table 1 of Appendix B and are summarized in Table 1.

Table 1

Ford Production Marquis Tests
November 1977

Average Corrected Road Coastdown Times (sec)	Average Dynamometer Power Absorption (horsepower)
16.72	10.67

For comparison the data presented by Ford in their request for an alternate dynamometer power absorption is given in Table 2.

Table 2

Data Presented by Ford in Support of the
Requested Alternate Dynamometer Power Absorption

Corrected Road Coastdown Time (sec)	Dynamometer Power Absorption (horsepower)
16.98	8.8

In the request for the alternate dynamometer adjustment Ford reported a corrected road coastdown time 0.26 seconds or 1.5%, longer than the production vehicle coastdown time. This would indicate the production vehicles had slightly greater actual road load than the prototype vehicle. However, this degree of consistency of the Ford road data indicates the original road data is probably representative of the vehicle road experience for the test conditions used. In contrast, the difference between the requested dynamometer adjustment of 8.8 horsepower and the November 1977 test results of 10.7, was 1.9 horsepower, or 21 percent of the requested dynamometer adjustment. The early EPA results of 10.5 horsepower tend to corroborate the November results from Ford.

In October 1977, the 1978 model year vehicles became available in the rental car fleet. EPA subsequently rented a Ford Mercury Marquis, and performed road coastdowns on this vehicle at the Transportation Research Center of Ohio (TRC) test track. The vehicle was then brought to EPA for the dynamometer coastdown tests. The resulting test data are presented in Table 2 of Appendix B, and average values are plotted in Figure 1. Matching the original Ford road coastdowns time of 16.98 seconds with this vehicle required an average of 10.6 horsepower. Matching the road coastdown time obtained by Ford from the production vehicle, 16.7 seconds, required an average dynamometer power absorption of 10.9 horsepower. All of the test results, based on Ford road coastdown times, are summarized in Table 3.

All of the data show reasonable agreement, except the alterante dynamometer power absorption requested by Ford for the certification vehicle.

Table 3

Summary of Dynamometer Power Absorption Determination for the Mercury Marquis

Test Series	Average Dynamometer Power (horsepower)
Ford Certification Request	8.8
EPA Tests on the Certification Vehicle, July 1977 using the Ford corrected road coastdown time of 16.98 seconds.	10.5
Ford Tests on Production Vehicles, November 1977	10.7
EPA Tests on a 1978 Rental Vehicle, January 1978 using the Ford corrected road coastdown time of 16.98 seconds	10.6
EPA Tests on a 1978 Rental Vehicle January 1978, using the Ford production corrected road coastdown time of 16.7 seconds	10.9

Throughout this extended investigation, Ford indicated the differences between the original request and the subsequent tests were a result of the variations among dynamometers. Reasonable estimates of the dynamometer variability can be obtained from the multiple dynamometer tests which were conducted. The Ford confirmation tests of November 1977 consisted of six dynamometer coastdown tests on two different dynamometers. The two Ford dynamometers differed on the average by about one horsepower. Even including variations in the road test times, the twelve determined dynamometer adjustments were between 9.72 horsepower and 11.86 horsepower. In the case of the EPA production vehicle coastdowns, tests were conducted on all four of the EPA certification dynamometers which were available. At the original Ford road coastdown time of 16.98 seconds, the test results ranged only from 10.2 to 10.9 horsepower. Thus, there is no evidence dynamometer-to-dynamometer variations could cause the extremely low value for the dynamometer adjustment originally requested by Ford.

B. Comparison of the Submitted Ford Road Data with EPA Track Results

The major purpose of the road tests conducted by EPA on the rented production Mercury Marquis was to verify the road coastdown data submitted by Ford.

The road test portion of the program was conducted by TRC personnel. The vehicle was first driven for about 250 miles for drive train component brake-in. The vehicle system was then allowed to equilibrate to

Average Vehicle Dynamometer Coastdown Time
versus
Dynamometer Power Absorption

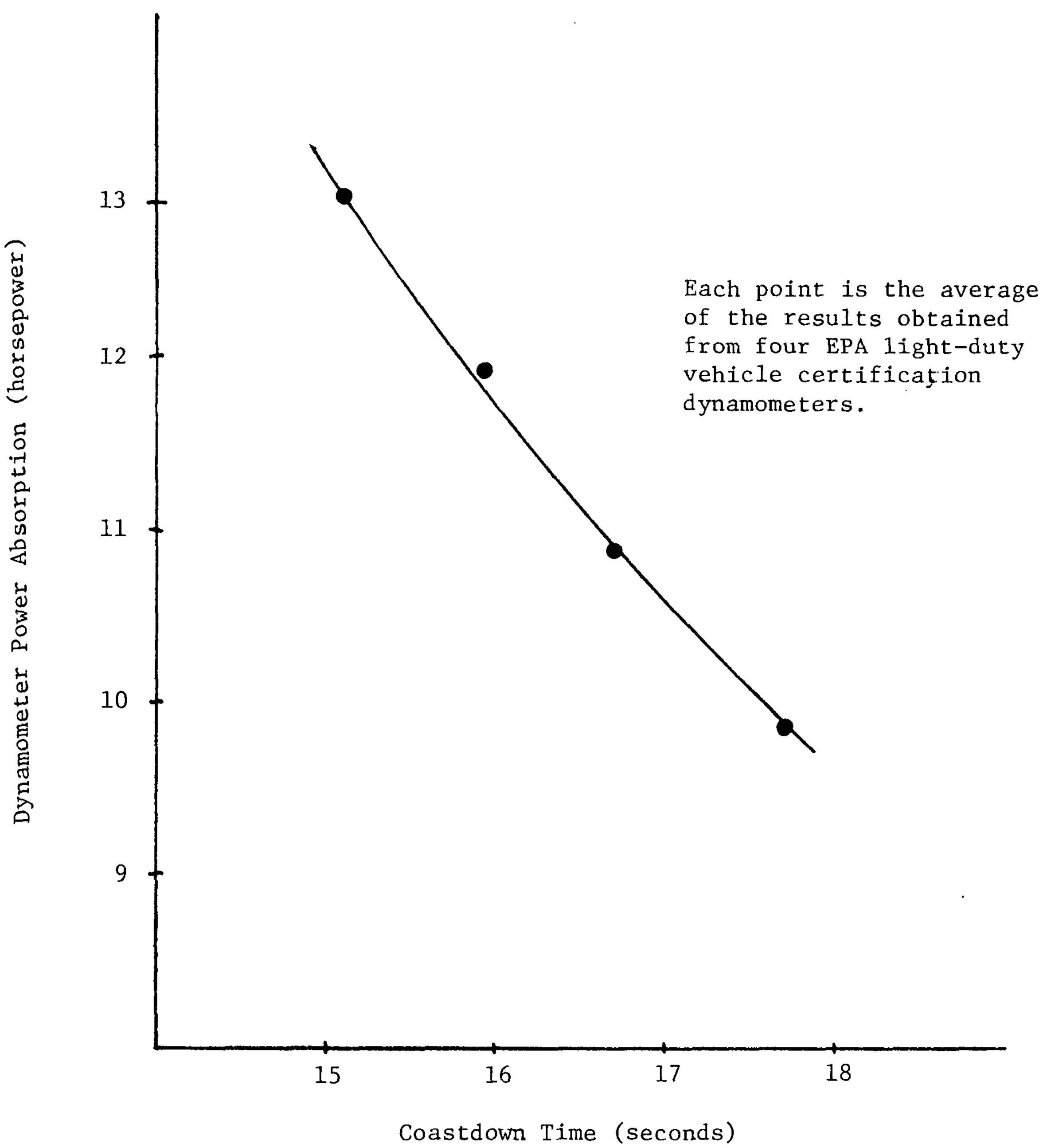

Figure 1

ambient temperatures over night. Prior to the vehicle warm-up for the coastdown tests the vehicle tires were adjusted to the recommended cold inflation pressures. The vehicle was then warmed up for approximately one half hour at 50 mph. Twenty coastdowns were subsequently conducted, ten in each direction of the TRC track. Ten of the coastdowns, five in each direction, were started at approximately 60 mph. The remainder were started at approximately 40 mph. It was necessary to divide the coastdowns into these two speed ranges because of the relatively short, 1 km, section of constant grade track available on the TRC skid pad.

The data analysis was conducted in the manner described in the data analysis section of the EPA Recommended Practice for Road Load Determination except that a $\Delta v/\Delta t$ approximation was used for the vehicle deceleration during the coastdown.

A two term model of the acceleration versus velocity was chosen, that is:

$$A = a_0 + a_2 v^2 \qquad (1)$$

where:

A = the calculated deceleration of the vehicle
v = the vehicle velocity
a_0 and a_2 are coefficients to be fitted by the regression analysis.

Additional terms were added to equation 1 to account for the directional dependent effects caused by track grade and wind. The grade effect was assumed to be independent of velocity while the wind effect was assumed to be linearity dependent on the vehicle velocity.

The a_0 term of the regression will contain a constant term introduced by the ambient wind. This correction to still air conditions was made using the measured value for the ambient wind. In addition, since the a_2 term represents the aerodynamic drag, an air density correction was applied to this term to correct to the standard ambient conditions given in the EPA recommended practice. The corrected coefficients which were obtained are:

$$a_0^* = 0.284 \text{ mi/hr-sec}$$
$$a_2^* = 0.000132 \text{ hr/mi-sec} \qquad (2)$$

The coefficients of equation 2 were used to calculate the total road force on the vehicle from the vehicle mass and the estimates of the rotational inertias of the rotating components of the vehicle. The 55 to 45 mph dynamometer coastdown time interval necessary to reproduce this force was then calculated by correcting for the differences between the total effective vehicle mass during the road coastdowns and the dynamometer simulated mass plus the rotational inertia of the drive train components. The final, dynamometer "target" coastdown time obtained from the EPA track measurements was:

$$\Delta T = 16.31 \text{ seconds} \qquad (3)$$

This coastdown time gave an average dynamometer adjustment of 11.4 horsepower based on the EPA dynamometer tests of December 1977, plotted in Figure 1. This value is significantly greater than the average dynamometer power absorbtion of 10.6 horsepower obtained from these data using the coastdown time of 16.98 seconds reported by Ford for the prototype vehicle. It is also greater than the dynamometer power absorption of 10.9 horsepower which was obtained from the EPA dynamometer data based on the coastdown time of 16.72 seconds reported by Ford for their production vehicle tests.

The test data were reveiwed to attempt to locate the reason for this discrepancy. An obvious difference observed between the Ford and EPA test conditions was the tire inflation pressures.

The Ford road tests were conducted at tire inflation pressures of 30 and 32 psi, front to rear respectively, while the EPA tests were conducted with inflation pressures of 26 and 28 psi. This difference in tire pressure would theoretically be expected to cause a change of about 0.5 horsepower in the vehicle road power. Since the differences between the Ford and EPA results from production vehicles were approximately this amount, these differences were attributed to the difference in the tire inflation pressure during the road tests.

TRC personnel had been instructed to conduct the road tests at the normal tire inflation pressures recommended by the manufacturer, therefore the basis for the test pressure difference was investigated. TRC personnel reported that the vehicle was prepared by the local Ford dealer who had inflated the tires to approximately 26-28 psi. In addition the consumer safety information contained in the vehicle glove box was based on the tire inflation pressure of 26-28 psi.

The vehicle owners manual did not specifically recommend any tire inflation pressures but referred the reader to the decal on the jamb of the passenger door. This decal recommended tire inflation pressures of 26-28 psi for best vehicle ride and 30-32 psi for maximum fuel economy.

Since either inflation pressure might be considered as recommended by the manufacturer, a brief telephone survey of local Ford dealers was conducted to ascertain which inflation pressure might be considered normal for the vehicle, at least as originally delivered to the customer. All dealers responded that the vehicles were normaly prepared for the consumer with tire inflation pressures of 26-28 psi or lower. It was therefore concluded that tire inflation pressures of 30-32 psi are not typical for this vehicle even at the time of dealer preparation. Consequently, the high tire inflation pressures cannot be considered typical for the normal use of this vehicle.

The dynamometer adjustment of 11.4 horsepower is therefore more representative of typical, recommended vehicle use than the power absorption values obtained from data collected at the evaluated tire pressures. The dynamometer adjustment requested by Ford, 8.8 horsepower is certainly inappropriately low.

C. The Emission and Fuel Economy Effects of the Dynamometer Adjustment

In December 1977 the Certification Division conducted exhaust emissions and fuel economy measurements as a function of dynamometer power absorption. The vehicle used was a Ford LTD which was tested at the appropriate weight category to represent the Mercury Marquis. This vehicle was used because it is a full sized Ford vehicle, as is the Marquis, and it was available at the EPA laboratory. The data from the Certification Division tests are given in Appendix C. Regression analyses of these data conclude that the vehicle fuel economy significantly decreases with increasing dynamometer power absorption, the NOx emissions increase with increasing dynamometer power absorption, and the HC and CO emissions tend to decrease with increasing power absorption. The regression statistics indicate there is little confidence that the slopes of the HC and CO regression lines are different from zero. Therefore the statistically significant effects are the increase in NOx emissions and the degradation of the vehicle fuel economy with increasing dynamometer power absorption. The fuel economy and NOx emissions data, together with the regression lines are plotted in Figures 2 and 3.

The plots of the data demonstrate the strong dependence of the vehicle fuel economy on the dynamometer power absorption. The statistical confidence in the effects of the dynamometer power absorption on the vehicle fuel economy was, as expected, very high. The confidence in the prediction of the effects on NOx emissions, was however, somewhat weaker. The statistical uncertainty in the effects on NOx emissions was primarily caused by the, possibly outlier, datum from the test at the lowest dynamometer power absorption.

The regression lines can be used to predict the effect on NOx emissions and fuel economy if vehicles had been tested at the higher, more representative, dynamometer power absorptions. When predicting this effect it should be noted that Mercury Marquis were not selected as EPA exhaust emissions certification vehicles. Because of the extreme low road load requested for these vehicles the test vehicles selected to represent the Mercury engine family categories were Ford LTDs. If the more representative power absorption of 11.4 horsepower had been requested for the Marquis, these vehicles would presumably have been selected. The alternate dynamometer adjustment requested for the LTD was 9.5 horsepower. The discrepancy in the dynamometer adjustment for the vehicle during the applicable emissions tests was therefore 9.5 horsepower versus 11.4 for vehicles without air conditioning and 10.5 versus 12.5 horsepower for air conditioned vehicles. The predicted increase in NOx emissions would be approximately 0.05 gm/mi for both of the two cases.

Including the predicted NOx increase of 0.05 gm/mi most of the certification vehicles tested to represent the Mercury Marquis would still have met the NOx standard. There was, however, one which would have equaled the 2.0 gm/mi standard but would have been certified because of round-off

Vehicle Fuel Economy
versus
Dynamometer Power Absorption

TEST VEHICLE: Ford LTD 8A1-351W-F-64
INERTIA WEIGHT CATEGORY: 5000 pounds

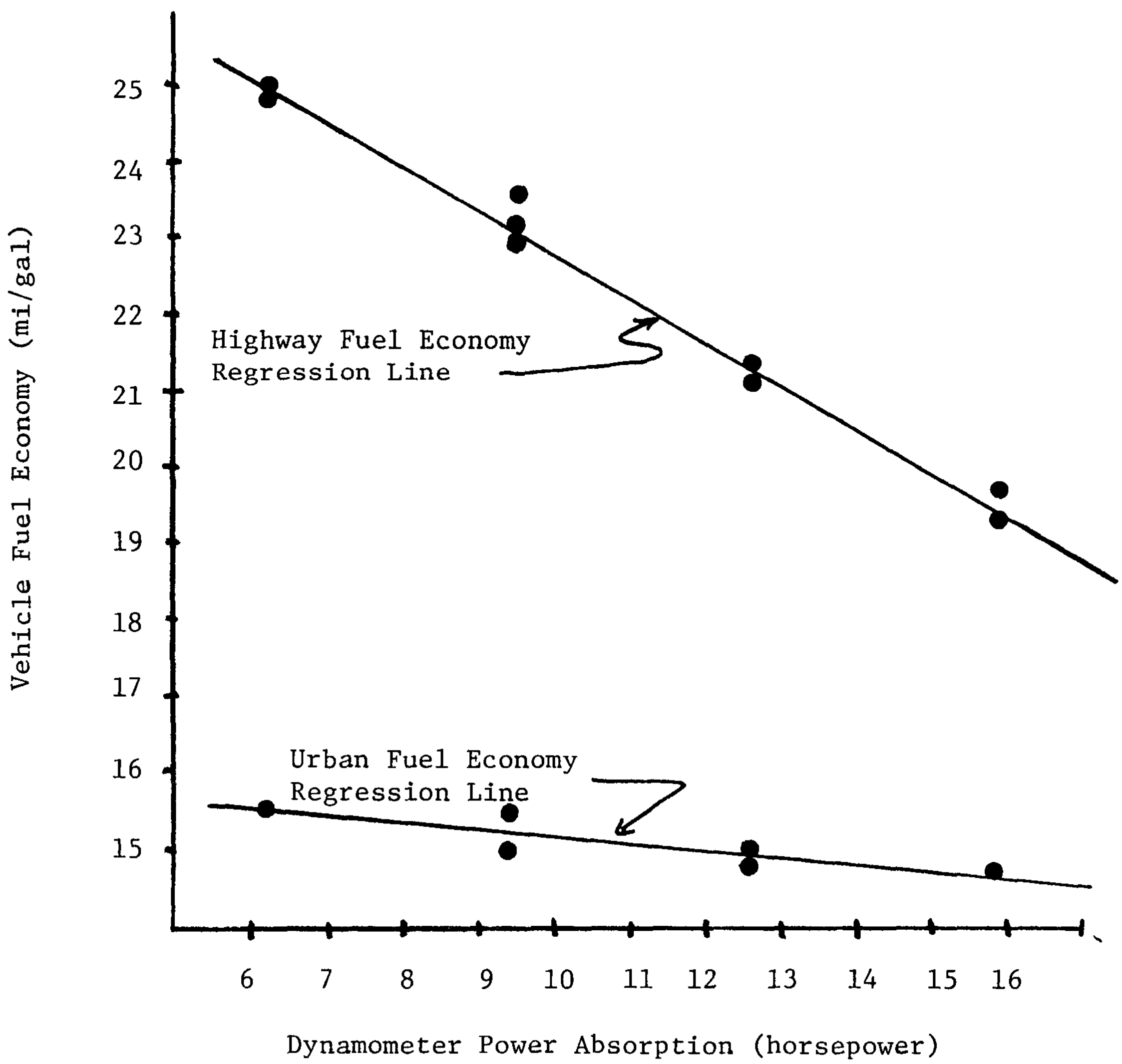

Figure 2

Nitrogen Oxide Emissions
versus
Dynamometer Power Absorption

TEST VEHICLE: Ford LTD 8A1-351W-F-64
INERTIA WEIGHT CATEGORY: 5000 pounds

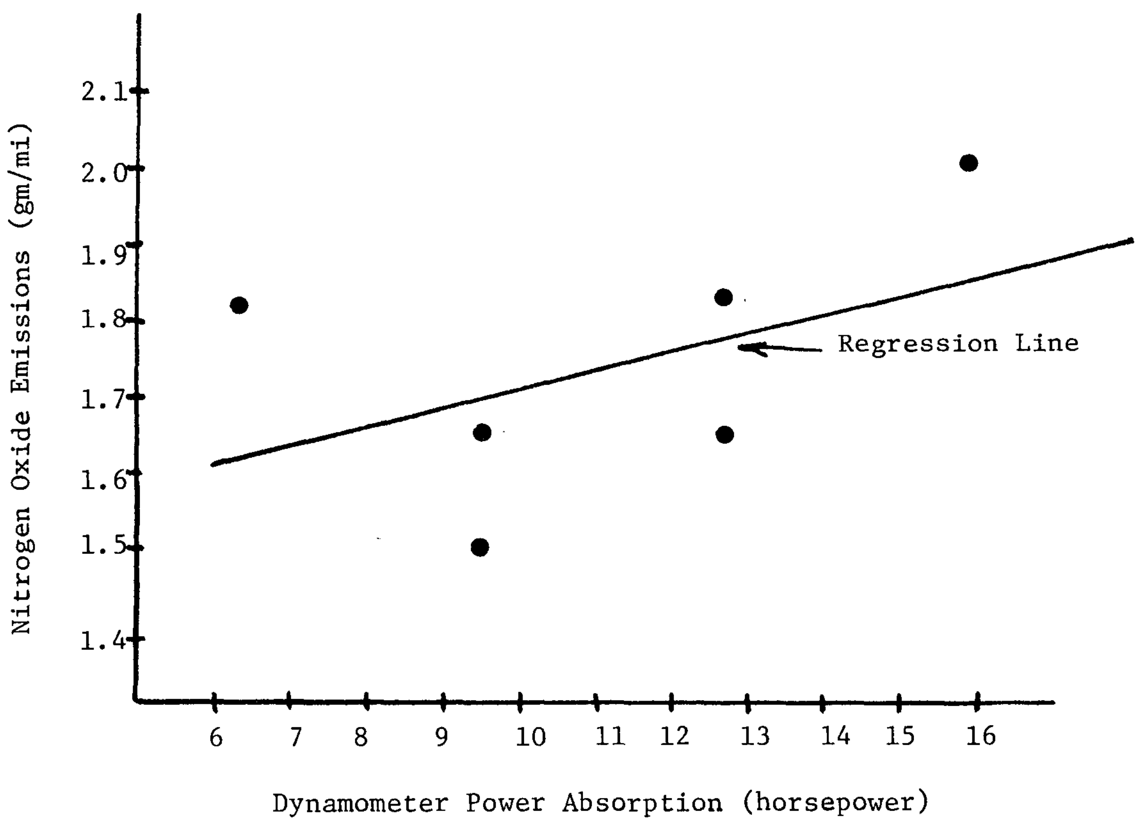

Figure 3

tolerances.[1] It should be noted that this analysis strongly depends on the slope of the NOx versus dynamometer power absorption regression, shown in Figure 3. If, for example, the datum at the lowest dynamometer power absorption were judged to be an outlier and deleted, the slope of the regression would increase and failure of these vehicles with high NOx emissions would probably be predicted. Considering this sensitivity of the regression and the normal test variability, the success or failure of this particular vehicle, if tested at a representative dynamometer power absorption cannot be accurately predicted.

The Mercury Marquis was tested as a fuel economy vehicle. Therefore, in this case the horsepower discrepancy between the dynamometer power absorption during the test and a representative value was 8.8 versus 11.4 horsepower for vehicles without air conditioning and 9.7 versus 12.5 horsepower for vehicle equipped with air conditioners. The predicted decrease in fuel economy would be 0.24 and 0.26 mi/gallon respectively for the urban cycle. The predicted highway fuel economy decrease would be 1.5 and 1.6 mi/gallon respectively. The composite urban-highway fuel economy would be expected to decrease approximately 0.6 mi/gallon, or about 3 percent for vehicle both with and without air conditioning. Based on current sales predictions, such a decrease in the fuel economy of this vehicle would be expected to lower the Ford Corporate Average Fuel Economy for 1978.[2]

Conclusions

It is concluded that the EPA tests of the Ford Mercury Marquis were unrepresentative because:

1. The dynamometer adjustment requested by Ford was inappropriate for the road data submitted by Ford;

2. The road data submitted by Ford is unrepresentative of anticipated consumer use of the vehicle because the tire pressures used during these road tests were significantly higher than the tire pressures used during the dealer preparation of the vehicle for consumer use.

It is further concluded that the unrepresentative nature of these tests resulted in reduction of the NOx emissions measurements for these vehicles. Most of the vehicles tested to represent the Mercury Marquis would still be expected to meet the exhaust emission standards if these vehicles were tested at the higher, more representative dynamometer power absorption. One test vehicle was, however, sufficiently close to the 2.0 gm/mi NOx standard that the success or failure of this particular vehicle cannot be accurately predicted.

The unrepresentative nature of the EPA fuel economy tests resulted in a significant increase in the vehicle fuel economy for the Mercury Marquis. This increase could effect the 1978 Ford Corporate Average Fuel Economy.

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[1] C. Larson, discussion, February 1977.

[2] J.D. Murrell, discussion, February 1977.

APPENDIX A

EPA Report of July 1977

Abstract:

Concern about the EPA fuel economy measurements has focused greater attention on the dynamometer and the dynamometer adjustment. Specifically the alternate procedures for determining the dynamometer adjustment to simulate the vehicle road experience affords an opportunity for both greater precision and possible abuse. Because of the possibility for abuse it was decided to occasionally check the coast down time of the test vehicle on the dynamometer, when the dynamometer is adjusted to the requested power setting, versus the road coast down times reported for the vehicle by the manufacturer. While this procedure assumes the validity of the submitted road coast down data, it does provide an easy and convenient check that the dynamometer experience of the test vehicle is similar to the reported road experience.

The Ford Mercury Marquis was selected for such a "quick check" since the alternate dynamometer adjustment requested by the manufacturer, 8.8 horsepower, was considered unusually low. This requested alternate power adjustment is 4.6 horsepower below the 13.4 horsepower specified by the current Federal Register table and 4.2 horsepower below the results of EPA measurements on a 1975 Mercury Marquis. This report concludes that the requested dynamometer power adjustement of 8.8 horsepower, when used in conjunction with the certification test vehicle, does <u>not</u> accurately reflect the road experience of the Mercury Marquis, as reported by Ford.

Background:

Concern about the EPA fuel economy measurements has focused greater attention on the dynamometer and the dynamometer adjustment. Specifically the alternate procedures for determining the dynamometer adjustment to simulate the vehicle road experience affords an opportunity for both greater precision and possible abuse. Because of the possibility for abuse it was decided to occasionally check the coast down times of the certification test vehicle on the dynamometer, with the dynamometer adjusted to the requested power setting, versus the road coast down times reported for the vehicle by the manufacturer. While this procedure assumes the validity of the submitted road coast down data, it does provide an easy and convenient check that the dynamometer experience of the test vehicle is similar to the reported road experience. It insures that vehicle components such as tires and drive train lubricants are effectively the same on the EPA test vehicle as on the vehicle which was road tested by the manufacturer.

Discussion:

The Ford Mercury Marquis was selected for such a "quick check" since the alternate dynamometer adjustment requested by the manufacturer, 8.8 horsepower, was considered unusually low. This requested alternate power adjustment is 4.6 horsepower below the 13.4 horsepower specified for this 5000 pound vehicle in the current Federal Register table. This large difference seemed particularly questionable since there is no obvious reason, such as exceptional aerodynamics, to expect this large a discrepancy for a conventional front engine, rear axle drive vehicle.

EPA measurements on a 1975 Mercury Marquis estimated the appropriate dynamometer adjustment to be 13.0 horsepower. In response to requests for reference frontal area information, Ford submitted the same area data, 26 square feet, for both the 1975 and the 1978 model. It is therefore concluded that no significant reduction in the size of the Mercury Marquis has occurred between 1975 and 1978. Using the submitted frontal area data, the proposed road load equation for 1979 model year predicts a dynamometer adjustment of 13.0 horsepower for this vehicle.

It was originally intended to coast the Mercury Marquis from 55 to 45 mph immediately following the highway fuel economy test. In this manner the highway schedule would be used as the vehicle warm-up, and the actual test horsepower adjustment would be confirmed versus the road measurements. Unfortunately this could not be arranged because of scheduling problems. At the time the test could be scheduled, the vehicle was placed on the dynamometer and warmed up for approximately 30 minutes. Coast downs, from 55 mph to 45 mph were then performed for four horsepower settings. The total dynamometer absorbed power, the indicated dynamometer absorbed power and the coast down times are given in Table 1.

Table 1

Dynamometer No. 1, 7/9/77

Total Dynamometer Power at 50 mph (horsepower)	Indicated Dynamometer Power at 50 mph (horsepower)	Coast Down Time Interval (sec)
8.8	6.2	19.2
8.8	6.1	19.4
9.8	7.0	18.5
9.8	7.0	18.5
10.8	8.0	17.5
10.8	8.0	17.6
11.8	9.0	16.7
11.8	9.0	16.8

The coast down times are plotted against total dynamometer power at 50 mph in Figure 1. A "reasonable" fit line is also drawn in Figure 1. Ford reported a road coast down time of 15.8 seconds for the road test. After correction to standard ambient conditions and adjustment to the dynamometer simulated inertia weight Ford calculated the target dynamometer coast down time to be 16.98 seconds. The dynamometer power adjustment corresponding to this dynamometer coast down time was reported to be 8.8 horsepower. A verticle line corresponding to 17 seconds is shown on Figure 1. This line intersects the curve at 11.5 horsepower.

The Ford representative was asked by Certification Division personnel for his explanation of this 2.7 horsepower difference. The response attributed the difference to variations in the vehicle warm-up procedure on the dynamometer. The EPA procedure recommends 30 minutes warm-up at 50 mph while the Ford procedure calls for 30 minutes warm-up with the speeds slowly varying between 70 mph and 40 mph. While it seemed very unlikely this minor variation in warm-up procedure would cause a 2.7 horsepower difference, it was decided to re-run the dynamometer coast downs on the vehicle utilizing the Ford method of preconditioning.

The results of these coast downs are given in Table 2 and are plotted in Figure 2. In this instance the dynamometer adjustment corresponding to a 17 second coast down is 9.9 horsepower.

DYNAMOMETER NO. 1

7/9/77

VEHICLE FUEL TANK NEARLY EMPTY

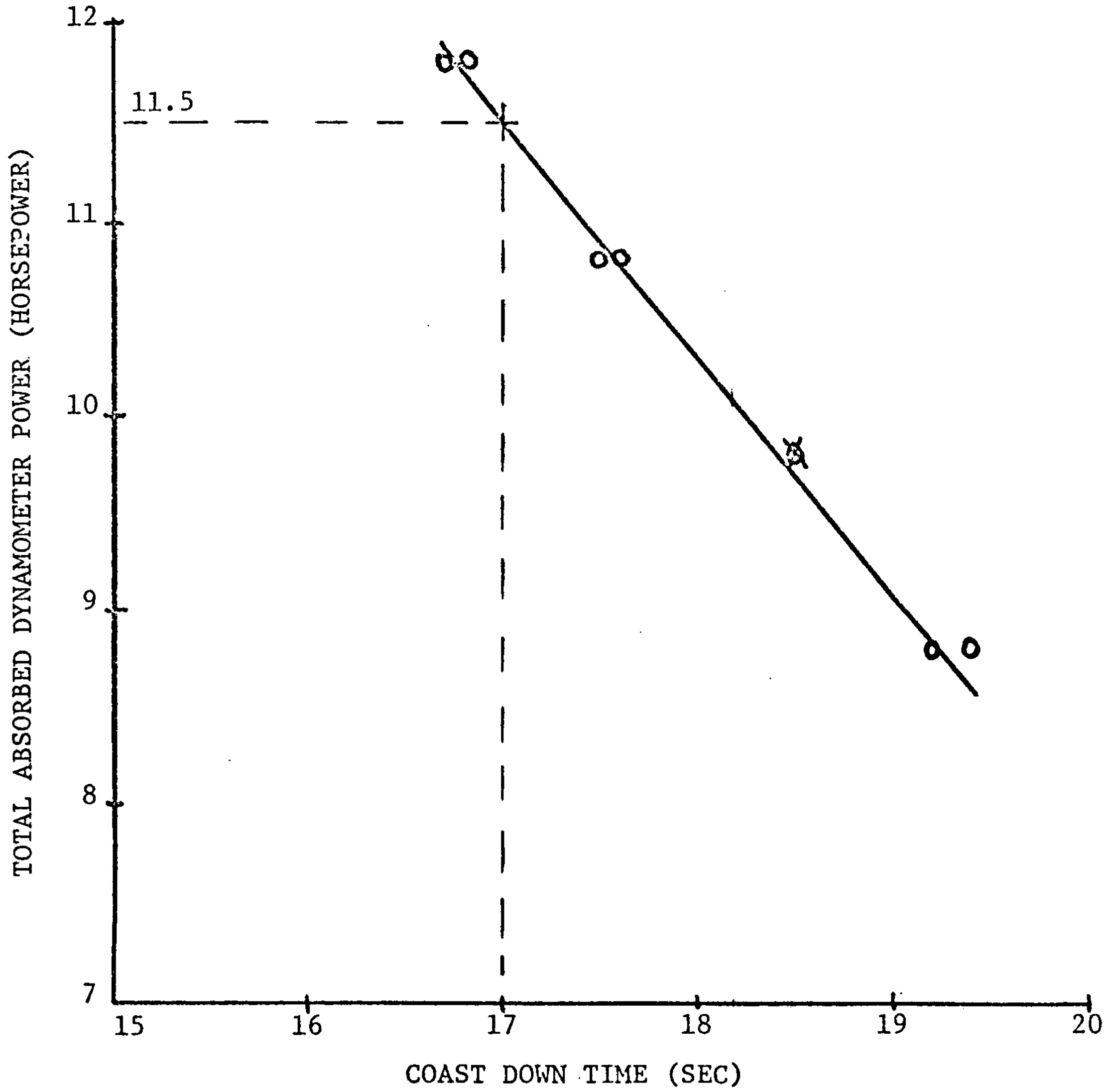

FIGURE 1

DYNAMOMETER NO. 6

7/16/77

VEHICLE FUEL TANK FULL

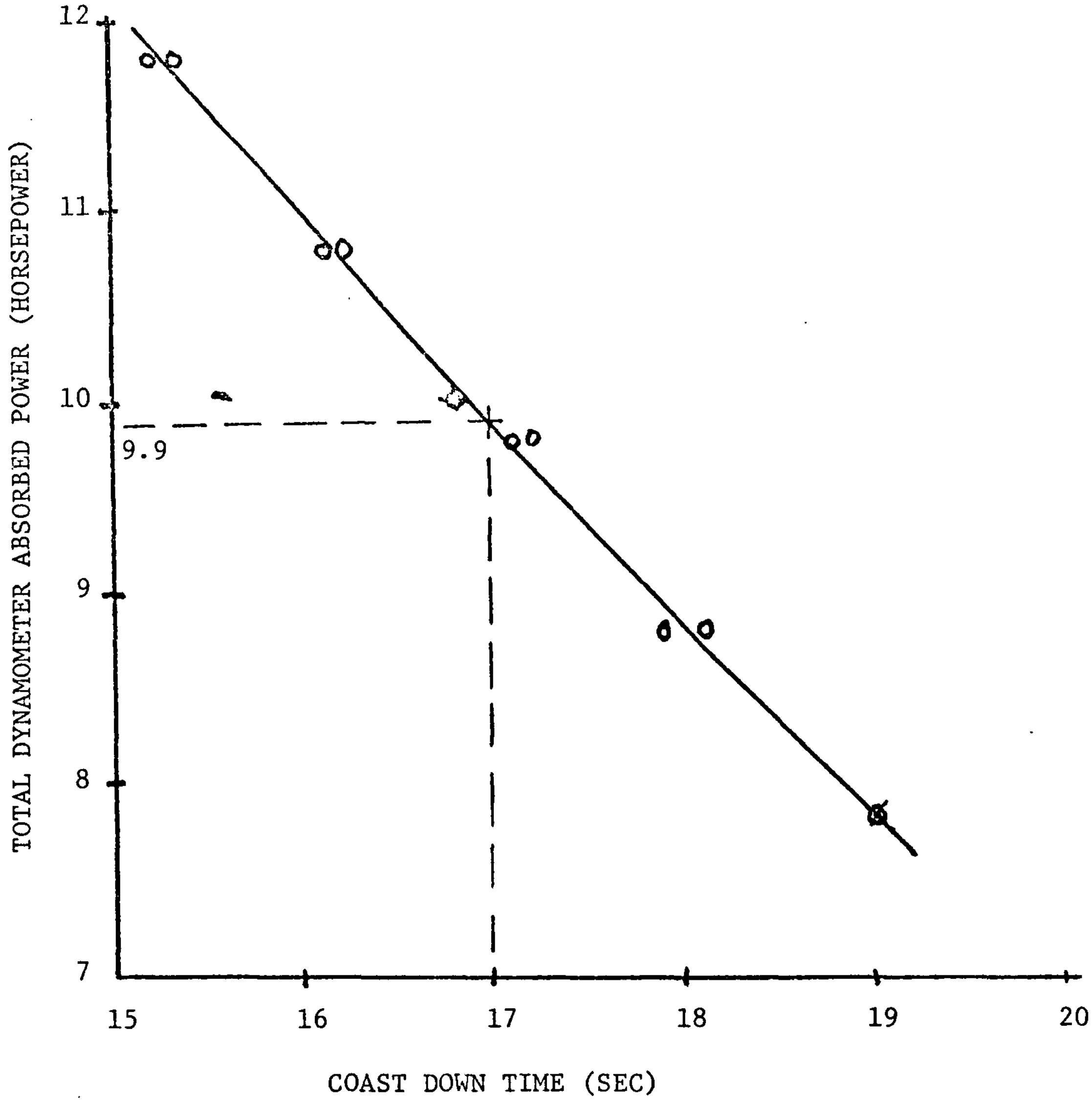

FIGURE 2

Table 2

Dynamometer No. 6, 7/16/77

Total Dynamometer Power at 50 mph (horsepower)	Indicated Dynamometer Power at 50 mph (horsepower)	Coast Down Time Interval (sec)
7.8	5.4	19.0
7.8	5.4	19.0
8.8	6.4	17.9
8.8	6.4	18.1
9.8	7.3	17.2
9.8	7.3	17.1
10.8	8.3	16.2
10.8	8.3	16.1
11.8	9.3	15.2
11.8	9.3	15.3
10.0	7.5	16.8
10.0	7.5	16.8

Since this power adjustment is significantly different from the previous results of 11.5 horsepower, efforts were made to resolve this 1.7 horsepower discrepancy. Three parameters were identified which had changed between the two measurements; the warm-up procedure, the test dynamometer and the quantity of fuel in the vehicle tank. It was considered improbable that either the warm-up procedure or the difference in the quanity of fuel in the vehicle tank could have this large an effect. Therefore it was decided to investigate the possible effect caused by the change in the test dynamometer. The first step was to verify the previous results on the first dynamometer. However in this case the fuel tank was filled to capacity and the Ford warm-up procedure was used. These data are presented in Table 3 and plotted in Figure 3.

Table 3

Dynamometer No. 1, 7/16/77

Total Dynamometer Power at 50 mph (horsepower)	Indicated Dynamometer Power at 50 mph (horsepower)	Coast Down Time Interval (sec)
11.5	8.7	16.6
11.5	8.7	16.6
10.8	8.0	17.2
10.8	8.0	17.4

DYNAMOMETER NO. 1

7/16/77

VEHICLE FUEL TANK FULL

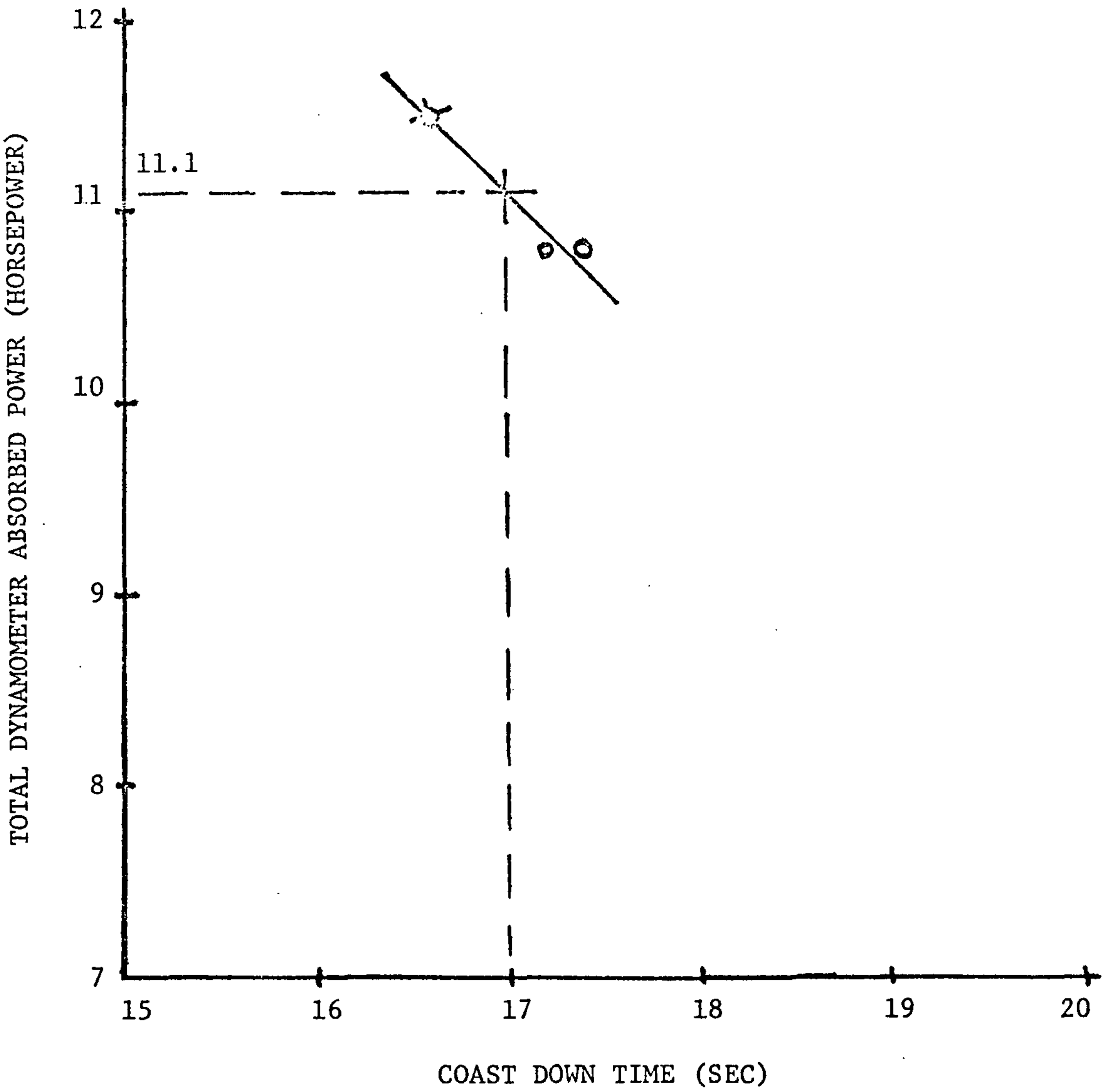

FIGURE 3

The dynamometer adjustment obtained was 11.1 horsepower. While similar to the previous results, there is a difference of 0.4 horsepower. The most recent tests were conducted with a full tank of fuel, while the first coast downs were conducted with a nearly empty fuel tank. Checking the fuel records showed approximately 20 gallons, or about 100 pounds of fuel, were added to the vehicle between tests. Tire power consumption is very nearly proportional to the vertical load on the tires, therefore this increase in load would increase tire losses and therefore reduce the dynamometer power adjustment necessary to achieve the same coast down time interval. The rear axle load on the vehicle was measured to be 2040 pounds with a full tank of fuel. Consequently the tire losses would be expected to be 5.3 percent greater with the full tank of fuel than with an empty fuel tank. The submitted Ford data gives a computed total corrected road power of 18.23 horsepower. Therefore, if the dynamometer adjustment necessary to reproduce the same coast down time was 11.5 total dynamometer horsepower, 6.7 horsepower was being dissipated in the vehicle tires. After the vehicle fuel tank was filled, the tire power dissipation would be about 5.3 percent greater, or 0.34 additional horsepower. Therefore to maintain the same total horsepower, the expected dynamometer adjustment would be 11.16 horsepower.

The dynamometer adjustments, after correction for differences in the rear axle loads, are in very good agreement. The difference, 0.06 horsepower may be attributed to the differences in the vehicle warm-up procedure or may simply be the limits of the test precision. In either case it is not considered significant. This indicates the different preconditioning methods did not produce the 2.7 horsepower difference as suggested by Ford.

The difference between tests two and three, 1.2 horspoewer is considered significant. This difference was attributed to the differences between the dynamometers. It was hypothesized that one of the two dynamometers might yield an anomalous result, while all other EPA dynamometers might be in good agreement. To test this hypothesis the measurements were repeated on certification dynamometer No. 3. This dynamometer gave an intermediate value of 10.5 horsepower for the same coast down time. The data from these measurements are presented in Table 4 and are plotted in Figure 4.

Table 4

Dynamometer No. 3, 7/18/77

Total Dynamometer Power at 50 mph (horsepower)	Indicated Dynamometer Power at 50 mph (horsepower)	Coast Down Time Interval (sec)
11.1	8.5	16.4
11.1	8.5	16.3
10.3	7.8	17.3
10.3	7.8	17.2

DYNAMOMETER NO. 3

7/16/77

VEHICLE FUEL TANK FULL

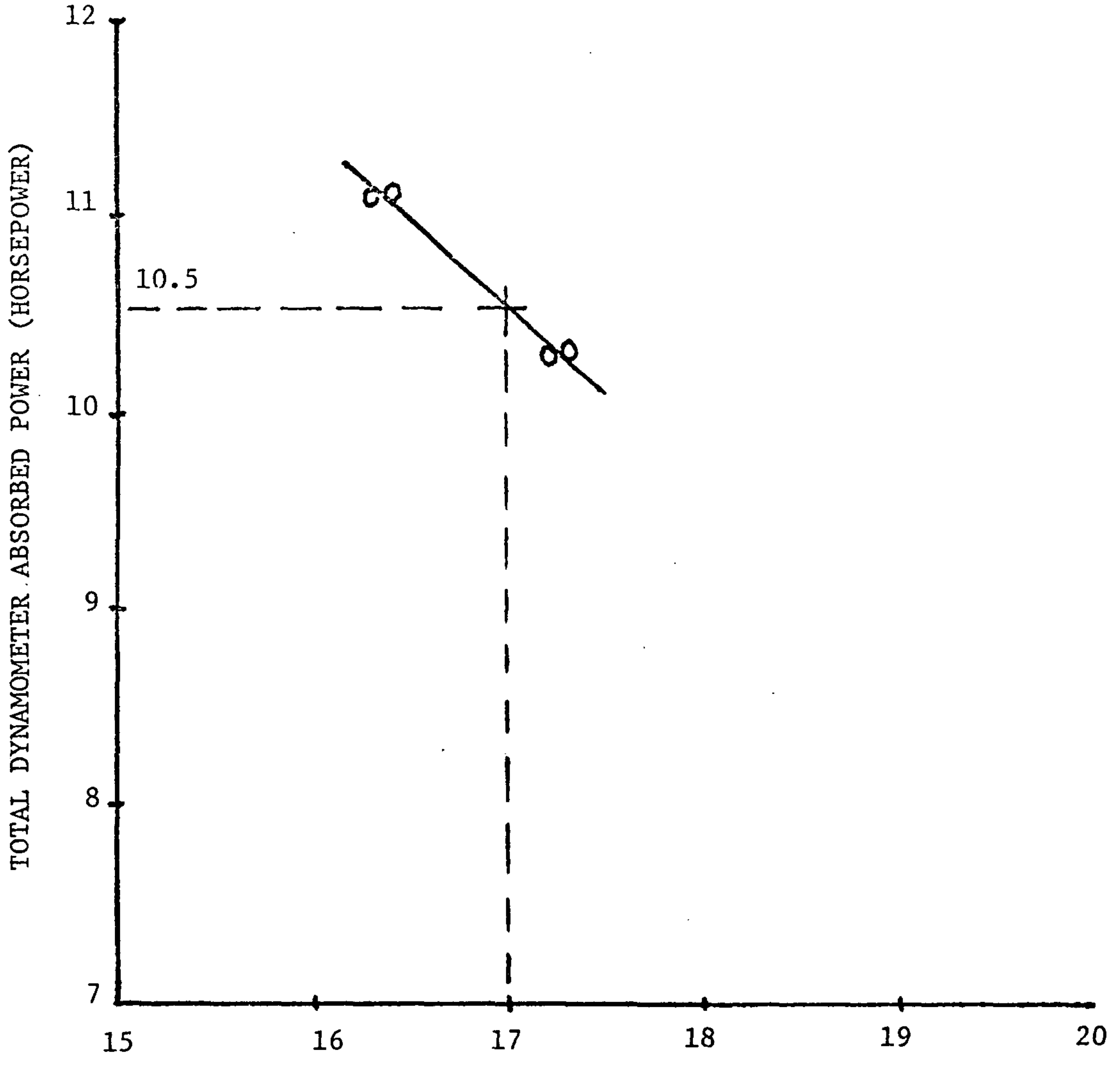

FIGURE 4

The results of the test series are summarized in Figure 5 where all measurements, conducted under similar vehicle conditions are plotted. These measurements were conducted with the same test personnel, the same instrumentation, the vehicle fuel tank was filled prior to each test and the vehicle warm-up was the same in each instance. The dynamometer is the only parameter known to vary between the tests. The range of the observed variations, 1.2 horsepower, is within the range of dynamometer variations reported in the recent EPA Technical Support Report "Comparison of Dynamometer Power Absorption Characteristics and Vehicle Road Load Measurements." It is, however, unknown if this variation is the extreme of the variations which might be observed since only dynamometers No. 1, No. 3 and No. 6 were used.

The mean of the three EPA measurements conducted under similar conditions is 10.5 horsepower. These measurements were conducted with a full tank of fuel; however, EPA certification and fuel economy measurements are conducted with the fuel tank 40 percent filled. Using the weight method previously described, correcting to the situation of a 40 percent full fuel tank, the estimated mean dynamometer power is 10.7 horsepower. The difference between this result and the Ford result of 8.8 horsepower is definitely significant. If a dynamometer adjustment of 8.8 horsepower is used for the certification vehicle, this will not represent the road experience of the vehicle tested by Ford. It is also very unlikely that a dynamometer adjustment of 8.8 horsepower would represent the road experience of the certification vehicle.

It may be informative to speculate how Ford may have obtained a dynamometer adjustment of 8.8 horsepower for their test vehicles. The problem, in addition to the dynamometer to dynamometer variations is the question of vehicle selection. The Ford test vehicle had reported axle loads, when dynamometer tested, of 2722 and 2281 pounds front to rear respectively. The axle loads measured at EPA for the Certification vehicle were 2760 and 2040 respectively, with a full fuel tank. There is the possibility of a difference in driver weights, and in the possibility for scale inaccuracies, however the front/rear weight distributions are 54.4/45.6 for the Ford vehicle, but 57.5/42.5 for the certification vehicle.

It appears that about 250 pounds of ballast were added to the trunk of the Ford test vehicle in addition to a full fuel tank. The rear axle load on the vehicle tested by Ford was about 300 pounds greater than would be anticipated for the rear axle load of the certification vehicle with a 40 percent full fuel tank. This would cause abnormally high tire power dissipation and result in a reduction of the necessary dynamometer power adjustment to match the road coast down time. In support of this speculation, the data submitted by Ford includes an operator note that one test sequence was aborted because of tire failure. Using the previous method for estimating the changes in the tire power dissipation with changes in axle load, a 300 pound increase in the axle load would decrease the dynamometer adjustment by about one horsepower. If such a

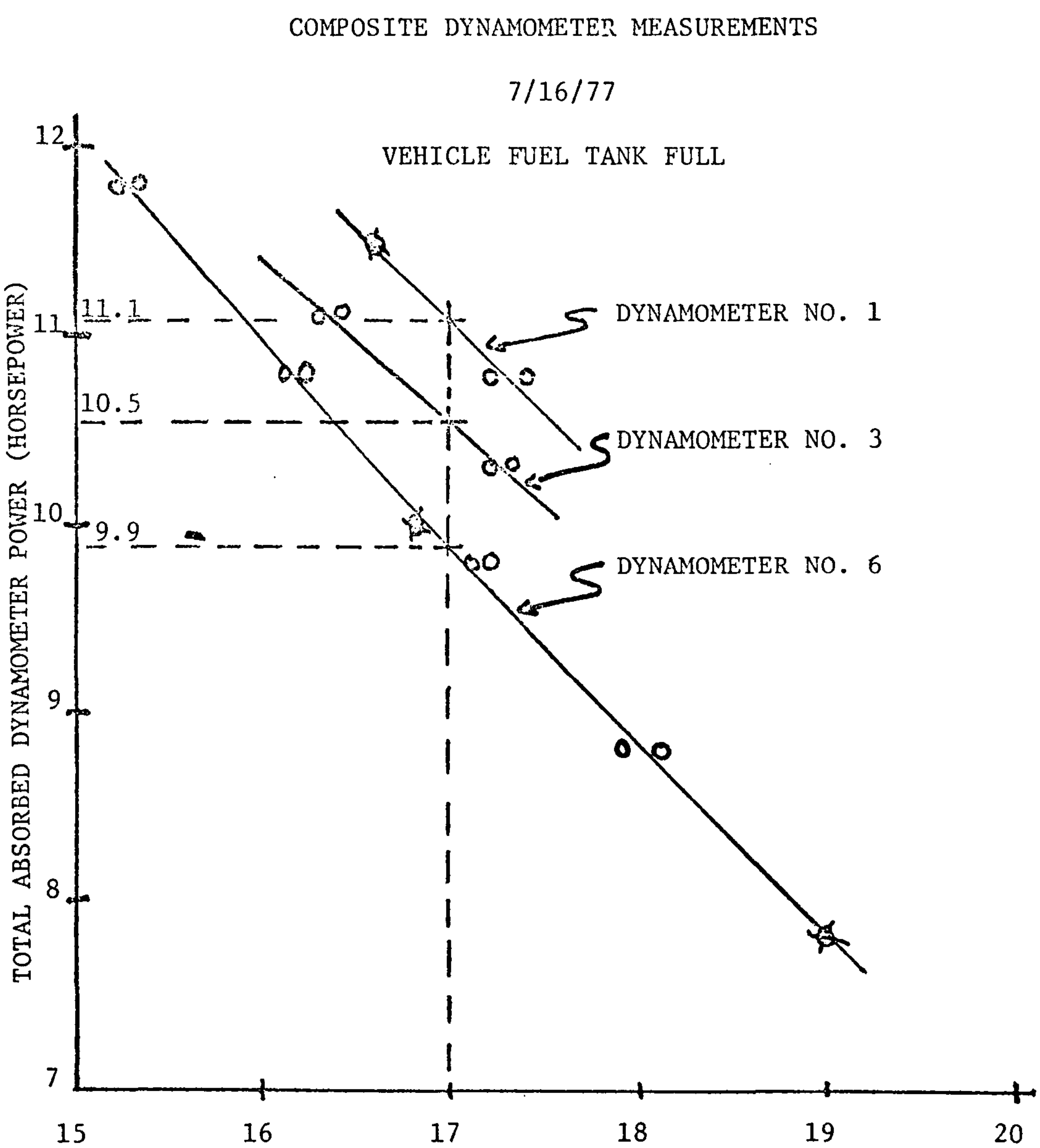
COMPOSITE DYNAMOMETER MEASUREMENTS
7/16/77
VEHICLE FUEL TANK FULL
TOTAL ABSORBED DYNAMOMETER POWER (HORSEPOWER)
12
11
11.1
10.5
10
9.9
9
8
7
15
16
17
18
19
20
DYNAMOMETER NO. 1
DYNAMOMETER NO. 3
DYNAMOMETER NO. 6

FIGURE 5

vehicle was coast down tested on a dynamometer which gave low power absorption results, such as EPA dynamometer No. 6, a dynamometer adjustment of about 8.8 horsepower could be expected.

The original EPA recommended practice for road load determination did recommend ballasting the vehicle to match the dynamometer simulated inertia weight. The current, revised version, does not recommend ballasting, and requires the front/rear axle weight distribution of the test vehicles to agree within ± 2% to the certification vehicle. It is assumed that Ford is well aware of the effects which result from changes in rear axle loads since the Ford coast down procedure calls for the dynamometer tests to be conducted with vehicle engine operating from an auxiliary fuel tank.

Conclusions:

1) A dynamometer adjustment of 8.8 horsepower, as requested by Ford, does not result in an accurate dynamometer simulation of the road experience of the vehicle tested by Ford when the certification vehicle is operated on the dynamometer.

2) The vehicle road tested by Ford was significantly different from the vehicle provided for certification testing.

Recommendations:

1) It is recommended that the vehicle discrepancy be resolved. That is, which vehicle best represents the vehicle Ford intends to sell? The road experience of the intended sales vehicle should be determined, then the dynamometer adjustment necessary to simulate the road experience of the intended sales vehicle should be used for certification and fuel economy testing. The weight and weight distribution of the certification vehicle should be adjusted, if necessary, to simulate the intended sales vehicle.

2) The requested alternate dynamometer adjustments of other Ford vehicles should be examined more thoroughly. These vehicles should be tested if any anomolies seem apparent.

3) The apparent 1.2 horsepower difference between dynamometers needs to be resolved. Some of this variation may be attributed to the differences in dynamometer calibration while some may be caused by parameters not currently considered in this dynamometer calibration process. Dynamometer to dynamometer calibration differences are currently believed to have a range of about 0.6 horsepower. Examples of parameters which are not currently considered are the vehicle restraint, the differences in dynamometer rear roll bearings and changes in roll bearing friction when under vehicle supporting loads. In any case, it should be noted that the range of the dynamometer adjustment specified in the current Federal Register is only 6.2 horsepower. If there are dynamometer to dynamometer differences of 1.2 horsepower in the simulation of

the vehicle road load, this is almost 20% of the range of this parameter. The simulation of the vehicle road load is possibly the most important parameter, with respect to composite fuel economy, in the EPA simulation of the vehicle road experience. Clearly such a large random effect in this parameter is undesirable.

APPENDIX B

Table B-1

Ford Submitted Data for Confirmation of
Alternate Dynamometer Power Absorption Request
November, 1977

VEHICLE: 1978 Mercury 4-Door Sedans
INERTIA WEIGHT CLASS: 5000 pounds
ROAD TIRE PRESSURE: Front-30 psi; Rear-32 psi
DYNO TIRE PRESSURE: Rear-45 psi

Vehicle Number	Corrected Coastdown Time (sec)	Dynamometer Cell Number	Total Dynamometer Power (horsepower)
313-T-823	16.79	2	9.88
313-T-823	17.09	2	9.85
313-T-825	16.98 (70-20)	2	9.72
313-T-825	17.04	2	10.06
313-T-826	16.43 (70-20)	2	10.24
313-T-826	16.00 (70-20)	2	10.95
313-T-823	16.79	6	11.10
313-T-823	17.09	6	11.09
313-T-825	16.98 (70-20)	6	11.04
313-T-825	17.04	6	11.05
313-T-826	16.43 (70-20)	6	11.22
313-T-826	16.00 (70-20)	6	11.86
AVERAGE	16.72		10.67

Table B-2

EPA Dynamometer Coastdown Data

Mercury Marquis (TRC Rental Vehicle)

Nominal Actual Power (Hp)	Mean Coastdown Time (sec) Dyno #1	Dyno #2	Dyno #3	Dyno #4	Average Coastdown Time for All Dynos (seconds)
12.95	15.25	15.42	14.66	--	15.11
11.95	15.93	16.28	15.61	15.87	15.92
10.90	16.93	16.98	16.22	16.61	16.69
9.85	17.76	17.98	17.31	17.70	17.69
7.75	20.17	20.37	19.49	19.81	19.96
6.75	21.58	21.73	20.96	21.14	21.35

APPENDIX C

Effects of Dynamometer Power Absorption

Table C-1

Vehicle Emissions and Urban Fuel Economy
versus
Dynamometer Power Absorption

Dynamometer Power Absorption (Hp)	Hydrocarbons (gm/mi)	Carbon Monoxide (gm/mi)	Nitrogen Oxides (gm/mi)	Carbon Dioxide (gm/mi)	Urban Fuel Economy (mi/gal)
6.3	0.75	10.5	1.85	552	15.5
9.5	0.82	12.0	1.65	552	15.5
9.5	0.90	13.7	1.50	566	15.0
12.7	0.73	11.0	1.83	579	14.8
12.7	0.75	11.0	1.65	577	14.9
15.9	0.81	11.1	2.00	583	14.7

TEST VEHICLE: Ford LTD 8A1-351W-F-64
INERTIA WEIGHT CATEGORY: 5000 pounds

Table C-2

Highway Fuel Economy
versus
Dynamometer Power Absorption

Dynamometer Power Absorpton (Hp)	Highway Fuel Economy (mi/gal)
6.3	24.8
6.3	25.0
9.5	23.7
9.5	23.0
9.5	23.2
12.7	21.1
12.7	21.4
12.7	21.1
15.9	19.7
15.9	19.3

TEST VEHICLE: Ford LTD 8A1-351W-F-64
INERTIA WEIGHT CATEGORY: 5000 pounds