EPA-AA-TAEB 75-12
Revised

Evaluation of The LaForce-Modified AMC Hornet

December 1974

Technology Assessment and Evaluation Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Environmental Protection Agency

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

SUBJECT: Corrections to EPA Report Number 75-12, "Evaluation of the LaForce Modified AMC Hornet."

DATE: January 3, 1975

FROM: H. Anthony Ashby, Project Manager
Technology Assessment and Evaluation Branch

H. A. Ashby

TO: Recipients of EPA Report No. 75-12

The enclosed pages, numbered 13c (Revised) and 36 (Revised) are to replace those respective pages in the subject report.

On page 13c the changes consist of 1) adding a column for the rotational speed of the electric dynamometer roll and 2) correcting a misprint on the engine speed of the LaForce car at 60 mph.

On page 36, 0-30, 0-40, and 0-50 mph acceleration times for the Rented '74 Hornet (Mfrs. Specs.) had been omitted from Table E-10, as had the 0-30 mph time for the Rented '74 Hornet (Economy Tuned).

Table 3

Maximum Power @ Rear Wheels, Electric Dynamometer

1) $HP = \frac{T \times N}{5250}$, where N = rpm of dyno roll
T = torque at dyno roll, ft - lbs
dyno roll diam. = 48"

	Vehicle Speed, mph	Engine Speed, rpm	Torque at Rear Wheels, ft - lbs	Calculated Horsepower at Rear Wheels	N, rpm
LaForce Car	50	3500	830	55.4	350
	55	3850	815	59.8	385
	60	*2850	600	48.0	420
EPA-rented	50	3050	1032	68.8	350
74 Hornet	55	3300	968	71.0	385
Mfrs. Spec	60	3500	893	71.5	420
EPA-rented	50	3025	1038	69.2	350
74 Hornet	55	3300	955	70.1	385
Econony-Tuned	60	3435	887	71.0	420

* Transmission in high gear.
All others in second gear.

Table E-10

Chassis Dynamometer Acceleration Tests

	Time, Seconds to Speed, mph			
	0-30	0-40	0-50	0-60
LaForce-Supplied 74 Hornet	5.0	8.1	11.8	16.4
LaForce Modified Car	5.4	9.1	13.0	17.6
Rented 74 Hornet (Mfrs. Specs.)	2.2	8.1	11.4	15.2
Rented 74 Hornet (Economy Tuned)	4.6	7.6	10.9	14.8

ERRATA REPORT NO. 75-12

February 1975

Several revisions have been made to Report No. 75-12 to correct typographical errors, to correct errors of omission, or to explain in more detail certain parts of the discussion of the results. Also, a General Motors Memorandum Report on the acceleration tests conducted at the GM Proving Ground has been included as Appendix J.

The revisions are listed below:

1. Page 10, end of third paragraph: Sentence was added to reference the GM acceleration test report in Appendix J.

2. Page 12, first paragraph: In the last sentence, "prior to" was changed to "after" to reflect the fact that the calibration parameter check was made after the tests, when the engines were fully warmed.

3. Page 13c, Table 3: A column of data "N, rpm" was added to include the dynamometer roll speed. Typographical error on the engine speed of the LaForce car at 60 mph was corrected: 3850 was changed to 2850. A note was added to explain that the transmission in the LaForce car upshifted to high gear.

4. Page 13d, Figure 3: % power loss at 60 mph removed, notes added to explain transmission upshifting.

5. Page 14, last paragraph: At the end of the last sentence, "better EGR system" was changed to "proportional EGR system" to eliminate confusion and vagueness. The 1974 Hornet does not have EGR.

6. Page 15, fourth paragraph: The discussion of performance test data was changed to reflect the inclusion of the GM Proving Ground data.

7. Page 15, seventh paragraph: The number of vehicle speeds was changed from "three" to "two" and the percent power difference was changed from "15 to 32%" to "15 to 20%" since only the power output at 50 and 55 mph is fully comparable. Two sentences added to explain transmission upshifting.

8. Page 15, last paragraph: Discussion expanded to include GM Proving Ground data.

9. Page 16: In Conclusions, section 2 was expanded to discuss the GM Proving Ground data.

10. Page 16: In Conclusions, section 3 was expanded to more fully discuss the fuel economy of the LaForce car and conventional cars.

11. Page 22, Table A-4: In the description of the Engine, the fuel requirement was changed to reflect the fact that the 1975 Hornet uses unleaded gasoline.

12. Page 24, Appendix C: The discussion of power calculations based on acceleration tests was revised for more accuracy and clarity.

13. Page 36, Table E-10: Times to intermediate speeds were added.

14. Page 42: Appendix J, GM report on acceleration tests, was added.

Background

The Environmental Protection Agency receives information about many systems which appear to offer potential for emission reduction or fuel economy improvement compared to conventional engines and vehicles. EPA's Emission Control Technology Division (ECTD) is interested in evaluating all such systems, because of the obvious benefits to the Nation from the identification of systems that can reduce emissions, improve economy, or both. EPA invites developers of such systems to provide to the EPA complete technical data on the system's principle of operation, together with available test data on the system. In those cases in which review by EPA technical staff suggests that the data available show promise, attempts are made to schedule tests at EPA's Motor Vehicle Emission Laboratory (MVEL) at Ann Arbor, Michigan. The results of all such test projects are set forth in a series of Technology Assessment and Evaluation Reports, of which this report is one.

The conclusions drawn from the EPA evaluation tests are necessarily of limited applicability. A complete evaluation of the effectiveness of an emission control system in achieving improvements on the many different types of vehicles that are in actual use requires a much larger sample of test vehicles than is economically feasible in the evaluation test projects conducted by EPA. For promising systems it is necessary that more extensive test programs be carried out.

The conclusions from the EPA evaluation tests can be considered to be quantitatively valid only for the specific test car used. However, it is reasonable to extrapolate the results from the EPA tests to other types of vehicles in a directional or qualitative manner, i.e., to suggest that similar results are likely to be achieved on other types of vehicles.

This evaluation of a LaForce engine is the third opportunity that personnel from EPA and its predecessor organizations in the U.S. Public Health Service have had to examine and report on a LaForce engine.

The first occasion was in 1965, when automotive engineers from the USPHS Division of Air Pollution (DAP) in Cincinnati, Ohio met with LaForce, Inc. personnel in Pittsburgh, Pennsylvania and examined an experimental carburetor and variable compression engine. Based on their examination of hardware and available information, DAP personnel recommended no further investigation or consideration of these inventions by USPHS, citing the impracticality of the designs, the crude state of their development, and the lack of substantiating test data.

In late 1971, a 1967 Ford Falcon with LaForce-modified carburetor, exhaust manifold, ignition timing and valve timing was evaluated in a test program conducted by EPA personnel at the Ann Arbor laboratory. The car achieved the exhaust emission levels required by the 1973 standards. Compared to other systems, however, the LaForce modifications were considered to be more extensive than necessary to attain the required emission levels. It was also felt that many features in the system were ineffective.

In late September 1974, EPA was approached by persons representing Ventur-E, Inc., who proposed that EPA evaluate and test at the Agency's Ann Arbor laboratory an engine modified and installed in a 1974 Hornet by Edward P. LaForce and Robert C. LaForce. EPA engineers concluded that the data submitted for review were not sufficient to justify an evaluation, since the data were limited to a fuel economy value and pollutant concentrations (not mass measurements) with the car running at a constant 30 mph on a chassis dynamometer with no load programmed into the dynamometer. Power output at the rear wheels was only that required to deflect the tires and to overcome the small amount of friction in the dynamometer rolls, a total of about 1 or 2 horsepower. Ordinarily the dynamometer would be programmed with 11.2 hp at 50 mph for the 1974 Hornet, the vehicle in which the LaForce engine was installed. EPA's response, in a letter dated October 3, 1974, was to urge Ventur-E to test the car by the 1975 Federal Test Procedure (75 FTP) and also to provide to EPA more information on the road tests that Ventur-E personnel were conducting for fuel economy. It was explained that EPA would conduct tests at MVEL if substantiated fuel economy data warranted it.

No data were forthcoming, but in late November members of the U.S. Senate Committee on Public Works requested the EPA Administrator to conduct a thorough evaluation of the LaForce engine at the Ann Arbor laboratory, and tests of the LaForce engine as installed in the 1974 Hornet were scheduled in response to that request.

On December 4, 1974, Ventur-E personnel delivered the LaForce modified car and a standard 1974 Hornet with the same general specifications to MVEL for the test program. In meetings the next day EPA personnel discussed the test program and Ventur-E personnel gave an informal discussion of the LaForce modifications. Checkout, preparation and familiarization with the test vehicles were conducted by EPA laboratory personnel with Ventur-E personnel present. Testing began on December 6, 1974 and was completed on December 12, 1974.

The following description of the LaForce engine and the claims made for it is based upon a Ventur-E press release dated November 14, 1974; the statement of Edward P. LaForce, President of Ventur-E, Inc., to the U.S. Senate Committee on Commerce on November 26, 1974; and the written notes of EPA personnel who were present at the meetings mentioned above between EPA and Ventur-E personnel on December 5, 1974.

In the LaForce intake system the fuel - air charge from a conventional carburetor is made to turn 180°, using "the centrifuge principle to separate heavy and light elements in gasoline. The volatile elements are delivered immediately through intake manifolds to the cylinders. The less volatile elements are cycled through heating chambers surrounding the exhaust manifolds and then delivered back to a separator and recycled until they are volatile enough for delivery to the cylinder."

A LaForce - designed camshaft "causes the inlet valves to close much later on the compression stroke than in conventional engines." The fuel - air charge in the cylinder is thus transferred from cylinder to cylinder, providing even mixture distribution in all cylinders. It is claimed that the delayed inlet valve closing also results in better performance at high engine speed. The hydraulic valve lifters in the stock engine have been replaced by solid lifters.

Cylinder bore and stroke, pistons, and crankshaft are unchanged from the stock engine.

The stock cylinder head has been milled, resulting in a smaller combustion chamber and an expansion ratio that is "two to three times greater in (the LaForce) engine than in conventional engines," which leads to higher efficiency. However because of the delayed inlet valve closing, conventional compression pressures are maintained.

The stock exhaust manifold has been divided into two separate parts to permit alternating of exhaust discharges between them, and modified to include the heating chambers for the intake system, and a dual exhaust system is employed.

The initial ignition timing was said to be advanced 4° over the stock timing, with the vacuum advance reduced significantly. The carburetor is essentially stock, but with a lower idle fuel flow rate and a richening of the main jets. The crankcase ventilation system is intact, although the evaporative control system has been removed. Neither the standard 1974 Hornet nor the LaForce - modified engine employs exhaust gas recirculation (EGR).

Among the claims made by Ventur-E for the engine are these:

1) "... tests ... show substantially increased power."

2) "Road tests also point to improved performance over comparable displacement engines."

3) "The LaForce engine, with its much higher efficiency, reduces pollutants to what appears to be a negligible level."*

4) "The explanation for the improved efficiency of the LaForce Engine is that we have discovered a way to achieve more complete combustion of gasoline than the method used by the conventional engine. Our research has shown that in the conventional engine only about 3/4 of every gallon of gasoline is involved in the effective combustion process. The remaining one quarter is wasted. Not only is it wasted, but it is a major contributor to our pollution problem. The LaForce engine effectively utilizes this normally unused quarter of a gallon. In addition, the engine utilizes the entire gallon more efficiently. The result is greater mileage out of each gallon of gas. The result, in addition, is decreased pollution."

Vehicle Description

Four cars were involved in the test program. The LaForce car was basically a 1974 American Motors Corporation (AMC) Hornet, equipped with a six-cylinder engine of 258 cubic inches displacement (CID) and automatic transmission. Ventur-E personnel stated that they had made extensive modifications to the induction and exhaust systems, cylinder head, camshaft, and valve train of the basic engine. This car was equipped with a rear axle having a gear ratio of 3.08:1.

Two standard, unmodified 1974 Hornets were also tested, the one furnished by Ventur-E, another rented by EPA from a dealer in the Ann Arbor - Detroit area. Both these cars were equipped with the 258 CID engine, automatic transmission, and rear axle having a gear ratio of 2.73:1.

The fourth car, also rented by EPA from a local dealer, was a 1975 Hornet with 258 CID engine, automatic transmission and 2.73 rear axle. The cars are described in detail in Tables A-1 through A-4 in Appendix A. Ignition timing and mixture settings are discussed below, under Test Procedures.

* Although this claim appears in Ventur-E press releases, no claims for emission reductions were made to EPA personnel by Ventur-E personnel in the meetings of December 5, 1974.

LaForce Engine Concept Analysis

Although EPA has received no information quantifying or documenting the modifications to the LaForce engine, EPA personnel judge that the three effective changes to the engine are, in order of decreasing importance, delaying the inlet valve closing, milling the cylinder head, and separating liquid fuel from the fuel-air mixture.

Contrary to common belief, it is the expansion ratio of an Otto cycle engine that determines its efficiency, not the compression ratio. In a conventional engine, both expansion ratio and compression ratio are equal and therefore expansion ratio increases (and consequently efficiency) are limited by pre-ignition and detonation problems that arise from the attendant higher compression ratio, and heat losses from the mixture near the end of the compression stroke. It has been found that an expansion ratio of about 12:1 is the highest that is practical for a conventional, spark ignited engine.

If a technique could be found to increase the expansion ratio without increasing the compression ratio then an increase in efficiency would result without the combustion problems mentioned above. Over the years several ideas and engine designs have been proposed, including variable compression ratios, variable stroke, variable valve timing and so on. All such approaches have been found to be bulky, complex, costly, with reduced power output, or otherwise impractical.

With its smaller combustion chamber and delayed inlet valve closing, the LaForce engine is the latest in this line to appear. The combination of a delayed inlet valve closing and a reduced clearance volume, achieved by milling the cylinder head, has resulted in an increased expansion ratio with apparently little or no increase in compression ratio. If the compression ratio remains the same as in the standard Hornet engine, no increase in nitrogen oxides (NO_x) emissions would be expected.

Because part of the fuel-air charge is pushed back out of the cylinder on the compression stroke, the LaForce engine would be expected to have less power potential than the standard Hornet engine.

The effects of milling the head and delaying the inlet valve closing may be better understood by referring to Figure 1 and Figure 2 which illustrate the events that occur during the compression stroke in the standard engine and in the LaForce engine. The AMC combustion chamber is known to have a wedge shape and is suitably depicted.

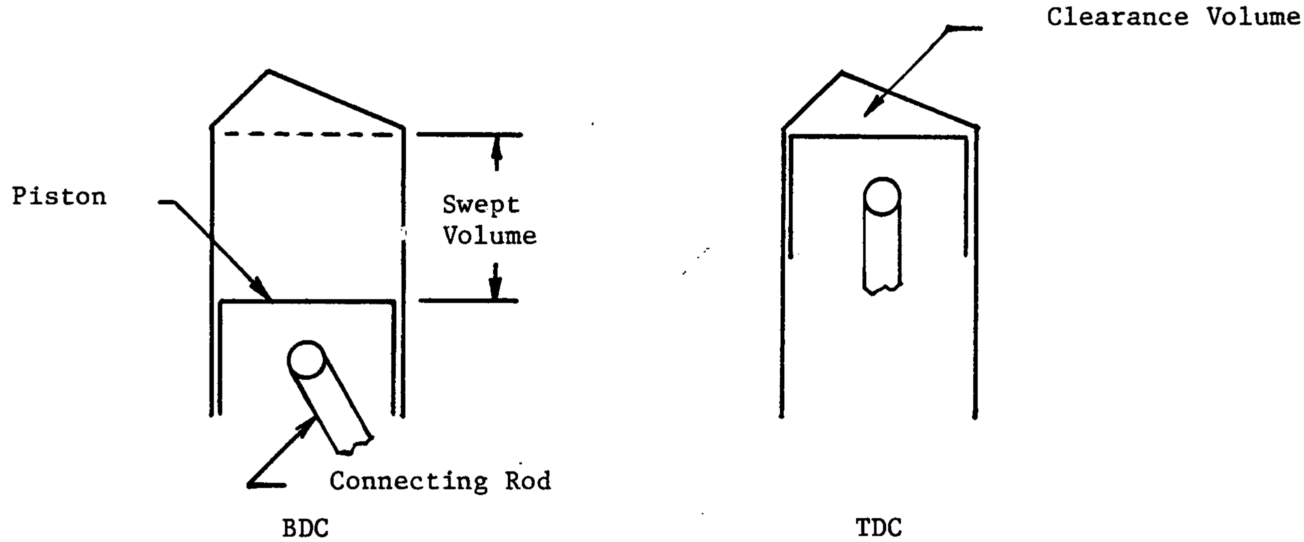

Figure 1. Standard Engine

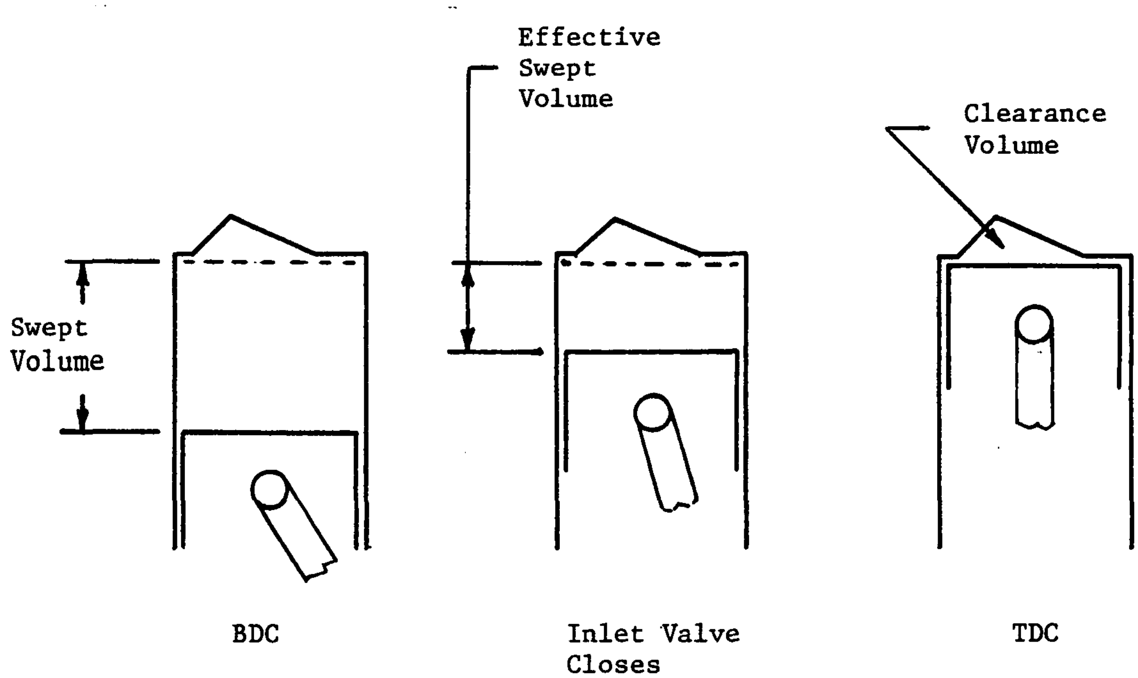

Figure 2. LaForce Engine

In the standard engine (Figure 1) the inlet valve closes near bottom dead center (BDC). As the crankshaft rotates, the connecting rod pushes the piston up, compressing the fuel air charge. Near top dead center (TDC) the spark plug ignites the mixture and the piston starts downward on its expansion, or power-producing, stroke. In the standard engine the expansion ratio and the compression ratio are both 8:1. Swept Volume is the volume displaced by the piston as it moves from BDC to TDC. Clearance Volume is the volume above the piston at TDC. In a standard engine the relationship between compression ratio (C.R.) and expansion ratio (E.R.) is thus:

C.R. = E.R. = (Clearance Volume + Swept Volume) ÷ (Clearance Volume)

C.R. = E.R. = 8:1

In the LaForce engine (Figure 2) the clearance volume is smaller due to the milling of the head and the swept volume remains the same (no change in stroke or crankshaft was made), but the inlet valve closes at a later time during the compression stroke than in the standard engine. The volume between the point when the valve closes and TDC can be referred to as Effective Swept Volume. Because of the delayed valve closing the Effective Swept Volume is smaller, but since the Clearance Volume is also smaller the compression ratio remains the same.

C.R. = (Clearance Volume + Effective Swept Volume) ÷ (Clearance Volume)

C.R. = 8:1

Due to the smaller Clearance Volume, expansion ratio is higher, with the Ventur-E personnel claiming an expansion ratio 2 to 3 times greater than in the standard engine. If one assumes the lower value to be correct, the relationship between expansion ratio and volume is:

E.R. = (Clearance Volume + Swept Volume) ÷ (Clearance Volume)

E.R. = 16:1

The available power is proportional to the volume of the fuel-air charge remaining in the cylinder when the inlet valve closes, for both the standard engine and the LaForce engine. To obtain the increased expansion ratio the LaForce engine intakes only half as much volume as the standard. Thus the effect of delayed valve closing on power output can be approximately quantified as follows:

$$\text{Power Ratio} = \frac{\text{Power, LaForce Engine}}{\text{Power, Stock Engine}}$$

$$= \frac{\text{Intake Charge, LaForce Engine}}{\text{Intake Charge, Stock Engine}}$$

$$= \frac{\text{(Clearance Volume + Effective Swept Volume)}}{\text{(Clearance Volume + Swept Volume)}} = \frac{8}{16} = \frac{1}{2}$$

If, indeed, the LaForce engine has an expansion ratio 2 times that of the standard engine, then its theoretical power output would be expected to be one half that of the standard engine. The actual power output of the LaForce engine was measured in the test program, as described on page 20 of this report, and was about 20% lower than the standard engine. This suggests that the expansion ratio is less than 2:1 in comparison to a standard engine.

Figures 1 and 2, though dimensionally exaggerated, represent the changes made to the shape of the combustion chamber merely by milling the head. There is now a flat surface, which, with the piston at TDC, creates a large "squish" area that is not present in the standard engine. Squish areas cause quenching of the flame during combustion, which results in increased hydrocarbon (HC) emissions. The LaForce car thus might be expected to have higher HC emissions than the stock cars.

The effect of the LaForce intake manifold is to separate larger liquid fuel droplets from the stream of air, vaporized fuel and entrained droplets flowing from the carburetor. This should result in a more homogeneous mixture, good cylinder-to-cylinder distribution, and the ability to run with a leaner air-fuel ratio. One drawback of the LaForce manifold, as EPA's engineers understand it, is a possible lack of air-fuel ratio control due to the sudden addition of fuel vapor from the heaters during transient operation. This richening, if it occurs, would result in higher carbon monoxide (CO) emissions.

The concept of removing the larger fuel droplets from the fuel air mixture delivered by the carburetor, and vaporizing them with exhaust system heat, is not a new one. "Quick heat" or "Early Fuel Evaporation (EFE)" manifolds have been developed by several auto manufacturers, and some 1975 models already use such devices. The EFE system consists of a modified intake manifold and exhaust system plumbing arrangement which creates high temperatures at the floor of the intake manifold to vaporize the fuel that is unable to remain entrained in the fuel-air mixture as it changes direction between the carburetor and the intake ports. While most EFE - type systems utilize exhaust heat to vaporize the fuel, a system under development by Chrysler uses electric resistance to heat the intake manifold floor.

Other independent developers have also demonstrated mixture improvement systems which EPA has evaluated in the past. Quoting from EPA report number 72-20 (April 1972) on intake system modifications made by Mr. Robert Edde, "The main feature of the system was a special intake manifold which had been designed to remove liquid fuel from the intake charge. This was accomplished by using a gap which could be crossed only by fuel in the vapor state, suspended in the air charge or clinging to the upper walls of the intake manifold." As with the EFE concept and the LaForce concept the object is to vaporize liquid fuel after it is brought into contact with a heat exchanger of some type.

The intake systems developed by Edde, GM, Chrysler and others have all demonstrated emissions as low as the 1975 Federal Standards when installed on conventional engines without catalysts.

Test Program

A. Test Procedures

In order to respond fully to the Senate Public Works Committee request of November 25, 1974, for an evaluation of the LaForce vehicle, a broad range of emissions, fuel economy and performance tests was carried out. These tests were conducted during the program:

1. 1975 Federal Test Procedure (75 FTP)

This procedure, described more thoroughly in Appendix B (and in complete detail in Reference 1), is the procedure used in the certification tests of new cars beginning with the 1975 model year. It is also the procedure EPA has been using since 1971 to evaluate prototype engines and emission control systems. The 1975 FTP provides the most representative characterization available of exhaust emissions and urban fuel economy. During the test the vehicle is driven on a chassis dynamometer over a stop-and-go driving schedule having an average speed of about 20 mph. Through the use of flywheels and a water brake, the loads that the vehicle would actually see on the road are simulated. The vehicle's exhaust is collected, diluted and thoroughly mixed with filtered make-up air, to a known constant volume flow, using a positive displacement air pump. (This procedure is known as Constant Volume Sampling - CVS).

A continuous sample of the diluted exhaust-air stream is collected and pumped into impermeable, chemically inert Tedlar sample bags (evacuated at the start of the test) during the test period. At the end of the test period the samples are analyzed for concentrations of HC, CO, NOx and CO_2 (carbon dioxide). The sample probe is a quarter-inch diameter stainless steel tube, placed diametrically across the duct, having a number of equally spaced holes which face upstream. Previous studies involving cars powered by various gasoline - fueled conventional engines, stratified charge engines and rotary engines, and using heated and non-heated FID instrumentation, have confirmed that 1) the exhaust-air stream at the sample point is homogeneous and 2) the sample collected is representative.

2. <u>EPA Highway Cycle (HWC)</u>

This test, which employs the same dynamometer and sampling procedure as the 1975 FTP, provides exhaust emissions and fuel economy information for non-urban conditions. The driving schedule has a length of about 10.2 miles and an average speed of 48.6 mph. The highway driving schedule is described in detail in Reference 2.

3. <u>Steady State Tests</u>

These tests, again employing the chassis dynamometer and CVS system, are routinely conducted at MVEL on prototype systems to help give insight into the operational differences and exhaust emission and fuel economy variations among vehicles. Speeds between 0 and 60 mph are investigated. Steady state data must be interpreted cautiously, because the vehicle is being exercised in an unrepresentative manner. Many vehicle operation surveys conducted by EPA and others have clearly shown that true steady state operation rarely occurs in customer use.

4. <u>Acceleration Tests on Chassis Dynamometer</u>

Wide open throttle (WOT) acceleration from 0 to 60 mph were conducted on the chassis dynamometer to help assess the relative performance and power output of all test cars except the 1975 standard Hornet. Neither emissions nor fuel economy were measured during these tests, only the 0 to 60 mph time in seconds.

5. Acceleration Tests on Test Track

At the request of EPA, General Motors Corporation consented to run acceleration tests, on the two cars supplied by Ventur-E, at the GM Proving Ground near Milford, Michigan. The tests, conducted by personnel from GM's Product Evaluation group, consisted of 1) a standing start, WOT acceleration to one quarter mile, 2) a 30 to 70 mph WOT acceleration simulating the acceleration of a car on an expressway entrance ramp, and 3) the U.S. Department of Transportation (National Highway Traffic Safety Administration) low speed and 4) high speed passing maneuvers. The former is a 20 to 35 mph WOT acceleration, the latter a 50 to 80 mph WOT acceleration.

In tests 1) and 2) the cars were run at a weight of 3500 pounds, which included the driver, test gear and an observer. In 3) and 4) the cars were tested at the gross vehicle weight of 4176 pounds, which included the driver, test gear, two observers and bags of lead shot.

For reasons of insurance coverage, test track safety, and experience with the test track layout and test procedures, if was understood beforehand that the drivers in all tests would be GM personnel. A fifth wheel, attached to the rear bumper of each car, furnished signals to the on-board data acquisition system which computed and printed out speed, time and distance. The GM report on these tests is included as Appendix J.

6. Maximum Power Tests on Electric Chassis Dynamometer

The LaForce-modified Hornet and the EPA-rented 1974 Hornet were subjected to tests on a large roll (48" diameter) electric chassis dynamometer. At three different vehicle speeds - 50, 55 and 60 mph - the maximum power output at the rear wheels was determined.

B. Test Fuels

Leaded Indolene 30 gasoline, one of the standard test fuels used by EPA, was used in the first two series of emissions tests (1975 FTP, Highway Cycle, Steady States) on the LaForce car, the LaForce - supplied 1974 Hornet, and the EPA-rented 1974 Hornet. At the request of Ventur-E representatives a leaded pump gasoline (Mobil Regular) was used in subsequent tests in all three cars.

The reason given by Ventur-E personnel for this request was that their entire engine/intake system was developed using normal pump gasoline. Their claim was that Indolene is sufficiently different from pump gasoline in its mixture of hydrocarbon components that the full effect of the LaForce intake system may not be realized if Indolene is used, resulting in higher emissions and degraded performance.

By EPA specification (Reference 1) Indolene is a relatively non-volatile, summer-grade fuel with a Reid Vapor Pressure (RVP) of about 9 pounds. In contrast the Mobil Regular purchased at a local service station was a winter-grade, relatively volatile fuel of 11.3 pounds RVP. A copy of the EPA distillation report is included in Appendix F. The rented 1975 Hornet was run on non-leaded Indolene in both series of tests run on it.

C. Fuel Economy Calculations

EPA normally computes fuel economy from chassis dynamometer CVS tests using the carbon - balance method. Explained in References 3 and 4, it makes use of HC, CO and CO_2 mass emissions data and the assumptions that 1) all carbon in the exhaust is in the form of either HC, CO or CO_2, and 2) all carbon in the exhaust came from the fuel. This method is accurate, repeatable, and simple since those three emissions are always measured. However, in response to requests made by Ventur-E representatives, fuel economy was also determined by a gravimetric method, in which the weight of the fuel used during a test was measured. Because of the relatively crude apparatus employed by EPA for this method, it is less accurate, with greater test-to-test variability. The combination of vapor locks in the plumbing, the loss of fuel vapors escaping from the weigh can and evaporative losses in the vehicle's fuel system during a test causes fuel economy determined by the gravimetric method to be less reliable than that determined by the carbon balance method.

Gravimetric fuel economy was measured in all chassis dynamometer tests on the LaForce car and the LaForce - supplied 1974 Hornet, and on most chassis dynamometer tests run on the EPA - rented 1974 Hornet.

D. Tuning and Adjustment of Test Cars

Consistent with procedures followed in other EPA device evaluation test programs, Ventur-E personnel were invited to tune both their cars to their desired timing, idle speed and idle CO settings at the beginning of the test program.

EPA engine diagnostic equipment and laboratory personnel were made available for this initial tuneup.

No adjustments were allowed to be made on the LaForce modified car after the initial settings by LaForce. This practice is consistent with EPA policy in the conduct of tests of this type, the purpose of which is to evaluate as fully as possible the validity of claims being made for a particular development. Because there can be test-to-test variability, EPA's general practice is to run a series of at least three complete tests, and to use the average of the results of the several tests as the best estimate of the performance of the vehicle under test. Obviously, it is necessary to avoid changing the calibrations of the test vehicle while these repeat tests are being made, for to make such changes would invalidate the objective of avoiding skewed results which can be caused by random test variability. In fact, calibration parameters on the LaForce car were checked after each test to assure that no malfunction or calibration shift had occurred.

Changes were made to timing and carburetor parameters on the EPA-rented 1974 Hornet, however, after the first two series of tests (1975 FTP, Highway Cycle, Steady States). The reason for this was to allow a comparison of the LaForce car with the stock car and also with the stock car adjusted for better economy. Starting with the same car, two different approaches to improve fuel economy were taken: the LaForce modifications and the EPA adjustments, and a comparison of the results allows an assessment of the LaForce engine in the proper context: the fuel economy improvements possible with two different modifications to the same basic engine.

The rented Hornet was selected as the best vehicle for comparison purposes for these reasons:

1. It was not supplied by Ventur-E, Inc. and therefore EPA was relatively free to make adjustments.

2. Nearly all of the recommended break-in mileage had been accumulated on it, while the Ventur-E supplied standard car had less than half that mileage.

The Ventur-E supplied standard Hornet and the rented 1975 Hornet were not subjected to as many comparison tests because they were not considered fully comparable, inasmuch as they were not fully broken-in. Had they been fully broken-in their fuel economy would probably have been one to two miles higher.

The rented standard 1974 Hornet was tested in two different configurations: 1) adjusted to manufacturer's specifications and 2) recalibrated for better fuel economy, to better determine the fuel economy potential of the standard engine.

E. Proposal to Isolate Effects of LaForce Modifications

Part way into the test program it was proposed to Ventur-E representatives by EPA that a study be undertaken to determine how much each of two basic LaForce modifications, the intake system and the valve timing change, contributed to the total. This would be accomplished by removing the intake and exhaust systems from the modified car and installing them on the standard 74 Hornet furnished by Ventur-E. Also, the standard intake and exhaust systems would be mounted on the modified engine. It was felt that this cross-switch of components would allow EPA personnel to determine the effect of the intake system alone and of the valve timing changes alone. It was proposed that the cross-switch would be performed by EPA laboratory personnel, in the MVEL, under the direction of Ventur-E personnel.

While Ventur-E personnel were willing to permit the cross-switch experiment, EPA personnel accepted the persuasive arguments that Ventur-E had been making against the experiment: that the cross-switch would take at least two days to accomplish, that several more days might be spent in trying to make both engines run optimally, and finally that the amount of useful information likely to be derived did not justify the effort required. Hence, the cross-switch tests were not conducted by EPA.

Results and Discussion

As shown in the first three columns of Table 1, exhaust emission levels of the LaForce - modified car were generally higher than the emissions of the stock vehicles. Specifically, HC emissions from the LaForce car were 72% higher than those from the economy-tuned 1974 Hornet, and CO emissions were 265% higher. The higher HC and CO emissions indicate that the LaForce engine had less complete combustion of the fuel than the standard vehicles. The lower exhaust temperatures measured at the tailpipe (see Table 2) could be an indication of lower exhaust temperatures at the engine. This would contribute to the higher HC and CO emissions of the LaForce car by reducing post-cylinder oxidation reactions.

All fuel economy data reported herein were calculated by the carbon-balance method.* The fuel economy of the LaForce car was significantly higher than the Ventur-E furnished and EPA -rented standard versions of the Hornet. However, recalibration of the EPA - rented standard Hornet narrowed the composite fuel economy difference to 8%. (Composite fuel economy is explained in Appendix G)

The comparison in Table 1 of data from the rented 1974 Hornet (3) and data on the 1975 Hornet (4) acquired during the 1975 certification program, indicates the trend in emissions and fuel economy resulting from AMC's current optimization programs. The 1975 Hornet is simultaneously demonstrating 8% better composite fuel economy than the 1974 Hornet and substantially lower emissions. The NOx emissions

* See Appendix H for comparison of gravimetric fuel economy and carbon-balance fuel economy.

Table 1

Summary of LaForce Evaluation Program

	'75 FTP Emissions			Fuel Economy				Performance: Acceleration Time, Seconds	
	HC	CO	NOx	City MPG	Hiway MPG	Composite MPG	Composite MPG for equal Performance	0-60 Dyno	0-60 Track
1. LaForce Engine Hornet	2.87	22.6	3.3	20.6	27.3	23.2	23.2	17.6	19.9
2. Stock 1974 Hornet economy tuned	1.67	6.2	4.8	18.8	25.6	21.4	22.8*	14.8	--
3. Stock 1974 Hornet manufacturers specs.	1.17	19.9	2.8	15.3	23.8	18.2	--	15.2	--
4. 1975 Hornet certification car	.90	6.3	2.6	16.7	24.7	19.6	--	--	--
5. 1975 Hornet (not broken in)	1.67	16.8	3.1	16.2	21.6	18.3	--	--	--
6. 1974 Hornet supplied by LaForce (not broken in)	.68	5.3	3.5	14.8	23.2	17.7	--	16.4	18.1

1974 Standards	3.0	28	3.1
1975 Standards	1.5	15	3.1
1977 Standards	.41	3.4	2.0

* based on EPA regression analysis Ref. SAE paper 730790.

TABLE 2
TEMPERATURE COMPARISON

Temperatures taken on LaForce car and LaForce-supplied standard car at tailpipe. Temperatures mentioned here are highest for the particular test phase or cycle. A reading of 500+ denotes that the temperature went off scale.

	Temperature, °F	
Cycle	LaForce	Standard Car
	(avg. of 2 pipes)	
Bag 1 of 1975 FTP	160	450
Bag 2 of 1975 FTP	155	455
Bag 3 of 1975 FTP	165	439
Hiway	320	500+ for entire test
Idle	140 (still hot from Hiway cycle)	215 constant
15 Steady State	125	228 constant
30 Steady State	142	380 steep upward trend
40 Steady State	195 upward trend	437 constant
50 Steady State	265 upward trend	500+
60 Steady State	350 upward trend	500+

Table 3

Maximum Power @ Rear Wheels, Electric Dynamometer

1) $HP = \frac{T \times N}{5250}$, where N = rpm of dyno roll
T = torque at dyno roll, ft - lbs
dyno roll diam. = 48"

	Vehicle Speed, mph	Engine Speed, rpm	Torque at Rear Wheels, ft - lbs	Calculated Horsepower at Rear Wheels	N, rpm
LaForce Car	50	3500	830	55.4	350
	55	3850	815	59.8	385
	60	*2850	600	48.0	420
EPA-rented	50	3050	1032	68.8	350
74 Hornet	55	3300	968	71.0	385
Mfrs. Spec	60	3500	893	71.5	420
EPA-rented	50	3025	1038	69.2	350
74 Hornet	55	3300	955	70.1	385
Econony-Tuned	60	3435	887	71.0	420

* Transmission in high gear.
All others in second gear.

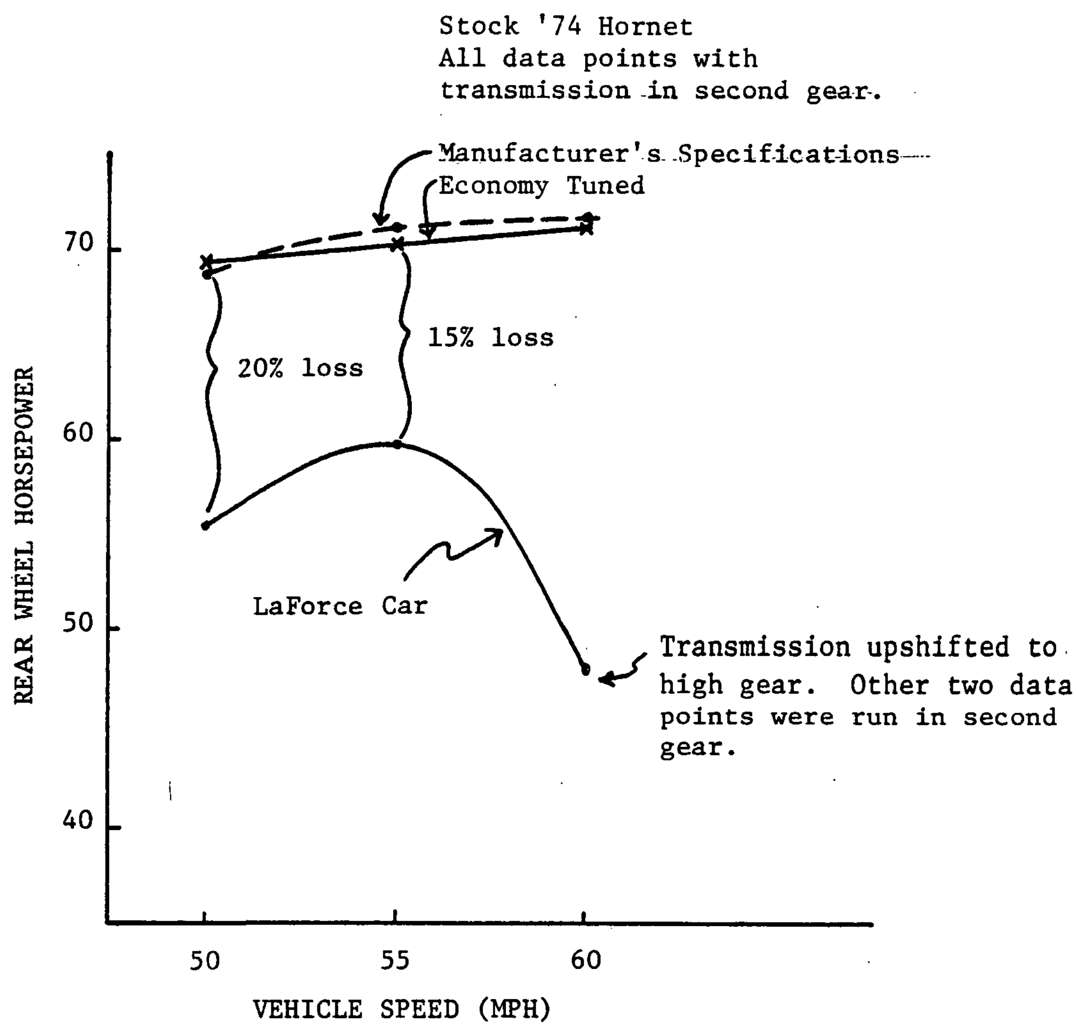

Figure 3. REAR WHEEL HORSEPOWER
LAFORCE VS. STANDARD VEHICLE

from the 1974 Hornet, as recalibrated by EPA for fuel economy (2) were higher than before recalibration, but the use of proportional EGR would be expected to reduce NOx without adversely affecting economy. With the use of improved emission control techniques such as catalytic converters and proportional EGR systems, future versions of the AMC Hornet would be capable of duplicating the fuel economy of the LaForce car with an even greater advantage in emission control than is evident from these tests.

On an equal performance basis (Reference 2) the fuel economy of the 1974 Hornet as recalibrated by EPA was essentially equivalent to the LaForce vehicle. As explained in the "Vehicle Description" section of the report the intake valve timing modifications made by LaForce would be expected to reduce the maximum power output of the engine. The 0 to 60 mph acceleration times shown in the last two columns of Table 1 indicate a 20% power loss for the LaForce engine compared to the economy-tuned 1974 Hornet (2), and about a 17% power loss compared to the stock 1974 Hornet at manufacturer's specifications (3). Appendix C shows the computation of this power difference. A nominal 20% power loss is also apparent from the full load steady state tests run on the electric chassis dynamometer. The results of these tests are tabulated in Table 3 and shown in Figure 3. Appendix D explains the calculations necessary to correct the economy of the standard Hornet to the performance level of the LaForce car. Note that the difference in axle ratio was also considered in the calculations. As shown in the seventh column of Table 1, on an equal performance basis the difference in composite fuel economy between the LaForce car and the economy-tuned 1974 Hornet is less than 2%.

Differences in economy between the two standard 1974 Hornets (3) and (6) and between the two 1975 Hornets (4) and (5) are at least partially attributable to the differences in mileage accumulated on each vehicle. In both cases the car with poorer fuel economy had accumulated fewer miles. The AMC six-cylinder engine is known to require a substantial break-in period (approximately 5000 miles) during which time the fuel economy can be expected to improve by 1-2 mpg.

Differences in fuel economy between the "economy tuned" Hornet (2) and the stock configuration of the car (3) were due primarily to increased vacuum spark advance and increased initial spark advance. The 1974 Hornet relies on spark retard for NOx control possibly because of the low production cost associated with that control approach; it could deliver better fuel economy with acceptable emissions if a proportional EGR system were used.

Table 4 *

Steady State Fuel Economy

Vehicle	gal/hr. Idle	MPG 15 mph	30 mph	40 mph	50 mph	60 mph
LaForce Engine Hornet	.36	27.0	37.2	34.7	29.8	24.7
Stock '74 Hornet economy tuned	.56	26.7	32.1	30.6	28.0	23.6
Stock '74 Hornet manufacturer's specs.	.60	23.3	24.6	28.9	26.3	22.7
1975 Hornet (not broken in)	.57	23.3	28.1	26.8	22.9	20.0
1974 Hornet supplied by LaForce (not broken in)	.56	21.0	22.9	28.1	25.4	21.8

*All the above tests were run at the road load specified for the vehicles under test. See reference 1.

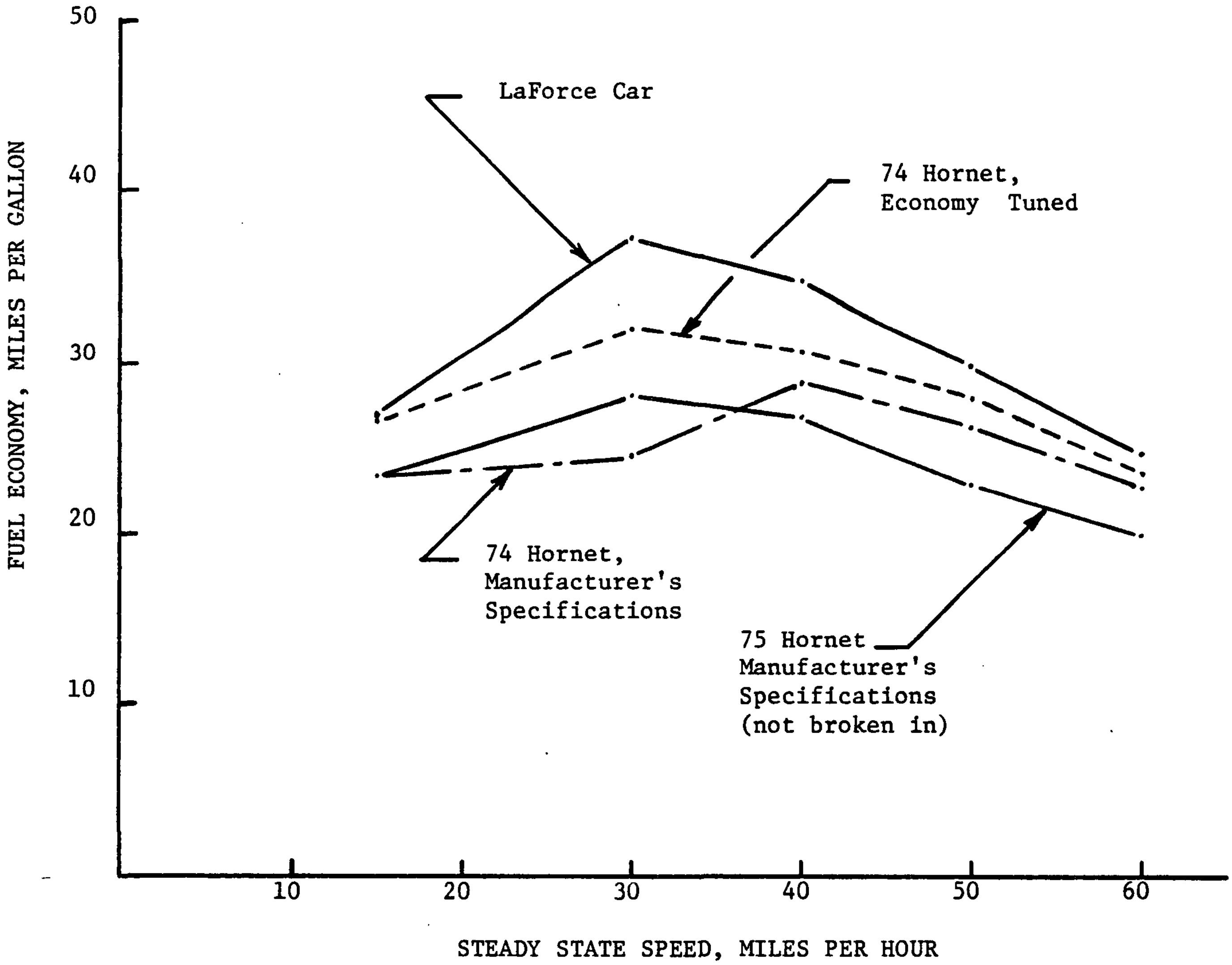

Figure 4. FUEL ECONOMY VERSUS SPEED

The modulation of spark timing used by AMC results in the greatest fuel economy loss during low speed cruises. The earlier tests reported by LaForce, such as the test at the Dover Downs race track, compared fuel economy during low speed cruises, and the fuel economy advantage of the LaForce car over the standard Hornet was at its greatest at these low speeds. This driving mode (30 mph cruise) coupled with the fact that the comparison car used by LaForce was not fully broken-in, in the judgement of EPA, causes the difference in fuel economy claimed by Ventur-E to be somewhat exaggerated.

The steady state economy data measured by EPA are summarized in Table 4 and plotted in Figure 4. The most significant difference between the LaForce car and the EPA economy-tuned Hornet occurred at idle. This difference could be due in part to the effects of the valve timing modifications made by LaForce.

Detailed emissions, fuel economy and performance data for all tests can be found in Appendix E. Tables E-1 and E-2 indicate that a slight decrease in HC and CO emissions from the LaForce car, accompanied by a slight increase in NOx emissions, occurred when the more volatile pump gasoline was used, as would be expected. The difference in fuel economy is considered insignificant. The same effects are seen in the steady state data.

Chassis dynamometer acceleration test data are shown in Table E-10. It can be seen that the LaForce modified car was slower in all acceleration modes up to 60 mph. The General Motors Memorandum Report on the acceleration tests conducted at the GM Proving Ground test track is included as Appendix J. The data in Table I of that report show the LaForce modified car to be slower in 0 to 60 mph and 30 to 70 mph tests, but faster in 50 to 80 mph tests.

All vehicles involved in the program were free of any driveability problems.

The claims made for the LaForce engine, listed earlier in this report, may now be compared with the results of the EPA evaluation program.

1) In maximum - power tests made at two different vehicle speeds on an electric chassis dynamometer, the LaForce car delivered 15 to 20% less power than the economy-tuned standard car. Before reaching the 60 mph point the LaForce car upshifted to high gear due to its high axle ratio and engine speed. Thus the maximum power determined at 60 mph is not directly comparable to that generated by the stock car, which remained in second gear in both manufacturer's specification and economy-tuned conditions.

2) Chassis dynamometer tests showed that the LaForce car was slower than the standard car in acceleration, requiring about 10% more time to reach 60 mph from a standing start. Tests on the GM Proving Ground track confirmed the chassis dynamometer results (See Appendix J), as the LaForce car was about 10% slower in a 0 to 60 mph acceleration. In a rolling start 30 to 70 mph acceleration the LaForce car was about 5% slower. However the 50 to 80 mph data show the LaForce car to be slightly faster. The acceleration data indicate that the power penalty due to late inlet valve closing diminishes at higher engine speeds.

3) Pollutants from the LaForce car are not "negligible," as claimed by Ventur-E. The car does not quite meet 1974 standards, and to meet the current (1975) standards considerable reduction of HC and CO emissions would be required. HC emissions would have to be reduced about 50%; CO emissions would have to be reduced about 35%, and a slight reduction in NOx emissions would be required to meet 75 standards.

4) The slightly improved efficiency (with accompanying lower power output) is the result of the delayed inlet valve closing and its effect on expansion ratio. The HC and CO emissions data show that the LaForce engine <u>does not</u> achieve more complete combustion of gasoline than the standard engine.

In EPA's judgement, the HC and CO reductions required to meet 1975 standards might be achieved with a catalytic converter, although there may not be sufficient heat in the exhaust gases to allow a converter to work efficiently. Other approaches to lower HC might include a redesigned combustion chamber or spark retard, although the latter would lead to a loss in fuel economy. The required CO reduction might be achieved with better air-fuel ratio control in the intake system. NOx emission reductions could be achieved through spark retard, but preferably through use of a well designed EGR system.

If Ventur-E pursues its present course in achieving fuel economy improvements through valve timing changes and attempts to increase expansion ratio, it is EPA's judgement that some fuel economy improvements may continue to be gained, but at the expense of power output. HC and CO emissions will also continue to rise, precluding its sale in the United States.

<u>Conclusions</u>

1. The LaForce engine powered vehicle failed to meet the levels of the current (1975 Federal) emission standards on all three regulated pollutants. Compared to the 1977 standards, the exhaust emissions of the LaForce car were approximately 600% too high in unburned hydrocarbons, 565% too high in carbon monoxide, and 65% too high in oxides of nitrogen.

2. The full load steady state tests conducted on the electric chassis dynamometer indicated that the modifications made to the standard engine by LaForce resulted in a power loss of about 20% compared to the EPA standard car in economy tune. Data from acceleration tests at the GM Proving Ground indicated that the power loss was greatest at low engine speeds.

3. In our tests the LaForce modified car delivered about 35% better fuel economy than the stock 1974 Hornet (manufacturer's specifications) over the 1975 FTP, which represents urban driving. However, on an equal performance basis the fuel economy of the LaForce car would not be significantly different from the economy available with conventional engines. The 8.4% advantage in composite fuel economy that the LaForce car showed over the economy-tuned stock 1974 Hornet (see Table 1) could be eliminated by re-sizing the engine of the stock car to match the slower acceleration of the LaForce car.

References

1. Environmental Protection Agency, "New Motor Vehicles and New Motor Vehicle Engines". Federal Register, Volume 37, No. 221, Part II, November 15, 1972, pages 24, 250 - 24, 320.

2. Thomas C. Austin, Karl H. Hellman, and C. Don Paulsell, "Passenger Car Fuel Economy During Non-Urban Driving", Paper No. 740592, Society of Automotive Engineers.

3. Thomas C. Austin and Karl H. Hellman, "Passenger Car Fuel Economy - Trends and Influencing Factors", Paper No. 730790, Society of Automotive Engineers.

4. Environmental Protection Agency, "Control of Air Pollution from New Motor Vehicles and Engines - Federal Certification Test Results for 1974 Model Year". Federal Register, Volume 38, No. 212, Part II, November 5, 1973, page 30494.

Appendix A

Vehicle Descriptions

The cars described in the following tables were similar in these respects: weight, transmission type, basic engine, and chassis.

The LaForce - modified car differed from the other three in axle ratio, 3.08:1 compared to 2.73:1 for the other three cars. Had the LaForce car also been equipped with a 2.73 rear axle, it is expected that its fuel economy would be slightly better and its acceleration times slightly worse. The effect on emissions is impossible to estimate.

The LaForce - supplied standard 74 Hornet and the EPA - rented 75 Hornet were both considered to be not broken-in because of low mileage accumulation at the start of the test program.

Manufacturer's specifications for initial timing and idle CO concentration are as follows:

'74 Hornet: $3^{\circ} \pm 2\ 1/2^{\circ}$ BTDC @ 700 rpm/Dr
1 - 1.5% CO

'75 Hornet: $3^{\circ} \pm 2^{\circ}$ BTDC @ 550 rpm/Dr
1% CO

TABLE A-1

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1974 AMC Hornet, LaForce modified vehicle
Source: Ventur-E, Inc.

<u>Engine</u>

type	4 cycle, OHV, In-Line 6, Wedge head, Otto Cycle
bore x stroke	3.75 x 3.90 in. (95.2 x 99.1 mm)
displacement	258 CID (4229 cc)
compression ratio	8.0:1
max. power @ rpm	89 hp (66.4 kW) @ 3500 rpm (estimated)
fuel metering	1V fixed orifice carburetor
fuel requirement	91 RON leaded
exhaust system	dual

<u>Drive Train</u>

transmission type	3 speed automatic
final drive ratio	3.08:1

<u>Chassis</u>

type	Unitized, front engine, rear wheel drive
tire size	C78 x 14
curb weight	3050 lbs (1383 kg)
inertia weight	3500 lbs (1588 kg)
passenger capacity	5

<u>Emission Control System</u>

engine modifications	

<u>Initial Test Conditions</u>

Odometer reading	8295 miles
Ignition timing	7^{o} BTDC
Idle CO concentration	0.15%

TABLE A-2

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1974 AMC Hornet
Source: Ventur-E, Inc.

Engine	
type	4 cycle, OHV, In-Line 6, Wedge head, Otto cycle
bore x stroke	3.75 x 3.90 in. (95.2 x 99.1 mm)
displacement	258 CID (4229 cc)
compression ratio	8.0:1
max. power @ rpm	110 hp (82 kW) @ 3500 rpm
fuel metering	1V fixed orifice carburetor
fuel requirement	91 RON leaded
exhaust system	single
Drive Train	
transmission type	3 speed automatic
final drive ratio	2.73:1
Chassis	
type	Unitized, front engine, rear wheel drive
tire size	6.95 x 14
curb weight	2950 lbs (1338 kg)
inertia weight	3500 lbs (1588 kg)
passenger capacity	5
Emission Control System	
engine modifications	
Initial Test Conditions	
Odometer reading	1995 miles
Ignition timing	5^{o} BTDC
Idle CO concentration	0.1%

TABLE A-3

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1974 AMC Hornet
Source: EPA - supplied, rented from local dealer

Engine

type	4 cycle, OHV, In-Line 6, Wedge head, Otto cycle
bore x stroke	3.75 x 3.90 in. (95.2 x 99.1 mm)
displacement	258 CID (4229 cc)
compression ratio	8.0:1
max. power @ rpm	110 hp (82 kW) @ 3500 rpm
fuel metering	1V fixed orifice carburetor
fuel requirement	91 RON leaded
exhaust system	single

Drive Train

transmission type	3 speed automatic
final drive ratio	2.73:1

Chassis

type	Unitized, front engine, rear wheel drive
tire size	6.95 x 14
curb weight	2950 lbs. (1338 kg)
inertia weight	3500 lbs. (1588 kg)
passenger capacity	5

Emission Control System

engine modifications	

Initial Test Conditions

Odometer reading	4730 miles
Ignition timing	5° BTDC
Idle CO concentration	1.0%

TABLE A-4

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1975 AMC Hornet
Source: EPA - supplied, rented from local dealer

Engine

type	4 cycle, OHV, In-Line 6, Wedge head, Otto Cycle
bore x stroke	3.75 x 3.90 in. (95.2 x 99.1 mm)
displacement	258 CID (4229 cc)
compression ratio	8.0:1
max. power @ rpm	110 hp (82 kW) @ 3500 rpm
fuel metering	1V carburetor, fixed orifice
fuel requirement	91 RON unleaded
exhaust system	single

Drive Train

transmission type	3 speed automatic
final drive ratio	2.73:1

Chassis

type	Unitized, front engine, rear wheel drive
tire size	6.95 x 14
curb weight	2925 lbs. (1327 kg)
inertia weight	3500 lbs. (1588 kg)
passenger capacity	5

Emission Control System

engine modifications	

Initial Test Conditions

Odometer reading	468 miles
Ignition timing	3° BTDC
Idle CO concentration	0.2%

Appendix B

1975 Federal Exhaust Emission Test Procedure

The Federal procedure for emission testing of light duty vehicles involves operating the vehicle on a chassis dynamometer to simulate an 11.1 mile commuting trip in an urban area. Through the use of flywheels and a water brake, the vehicle's actual load on a level road is simulated. The driving schedule is primarily made up of stop and go driving and includes some operation at speeds up to 57 mph. The average vehicle speed is approximately 20 mph. The 1975 FTP captures the emissions generated during a "cold start" (12-hour soak @ 68°F to 86°F before start-up), and includes a "hot start" after a ten minute shut-down following the first 7.5 miles of driving.

All the vehicle's exhaust is collected and drawn through a constant volume sampler (CVS), which dilutes the exhaust to a known constant volume with make-up or dilution air. A continuous sample of the diluted exhaust is pumped into sample bags during the test.

Analysis of the diluted exhaust collected in the sample bags is used to determine the mass of vehicle emissions per mile of operation (grams per mile). A flame ionization detector (FID) is used to measure unburned hydrocarbon (HC) concentrations. Non-dispersive infrared (NDIR) analyzers are used to measure carbon monoxide (CO) and carbon dioxide (CO_2). A chemiluminescence (CL) analyzer is used to determine oxides of nitrogen (NOx).

These procedures are used for all motor vehicles designed primarily for transportation of property and rated at 6,000 pounds GVW or less, or designed primarily for transportation of persons and having a capacity of twelve persons or less.

Appendix C

In an acceleration to 60 mph from a standing start the work output, W, of a vehicle is equal to the change in its kinetic energy between zero and 60 mph (neglecting friction and aerodynamic drag).

$$W = \Delta KE = \frac{1}{2} m (v_f^2 - v_o^2)$$

Where $v_f = 60$ mph

$v_o = 0$ mph

then

$$W = \frac{1}{2} m v_f^2$$

For vehicles (1 and 2) of the same mass and final velocity,

$$W_1 = W_2$$

Work may be expressed as the product of the average power over a time interval times that time interval.

$$W = P \text{ avg.} \times t$$

If friction horsepower and drive train losses are ignored, the product of average power output times time to reach 60 mph is equal for both vehicles.

$$P_1 \text{ avg.} \times t_1 = P_2 \text{ avg.} \times t_2 \qquad (1)$$

where: P_1 avg. is the average power output of the standard Hornet engine

t_1 is the time required for the standard Hornet to accererate to 60 mph

P_2 avg. is the average power output of the LaForce engine

t_2 is the time required for the LaForce vehicle to reach 60 mph if it had the same axle ratio as used in the standard Hornet.

Correcting the 0-60 time for the LaForce vehicle (t_2) for the 10% difference in axle ratio (from 3.08:1 to 2.73:1) increases the 0-60 acceleration time by about 3% according to Huebner .[1]

$$t_2 = 1.03 \times 17.6 = 18.3 \text{ sec.} \qquad (2)$$

Substituting the values from equation (2) and Table 1 (page 13a) into equation (1):

$$P_{1\ avg.} \times (14.8\ sec) = P_{2\ avg.} \times (18.3\ sec)$$

$$\frac{P_{2\ avg.}}{P_{1\ avg.}} = \frac{14.8}{18.3} = .809$$

This indicates that the average power output of the LaForce engine was about 81% of that of the standard Hornet engine, in other words a power loss of 19%.

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[1] G.J. Huebner Jr. and D.J. Gasser, "General Factors Affecting Vehicle Fuel Consumption", SAE paper 730517, 1973.

Appendix D

Constant Performance Correction Factor Calculation From SAE paper 730790:

$$MPG = A + B \left(\frac{1}{IW}\right) + C \left(\frac{HP}{IW}\right) + D \left(\frac{HP}{CID}\right) + E\,(AR) + F\,(HP) + G\,(CID) \qquad (1)$$

where: A = 5.6678
B = 48,702
C = -204.32
D = 3.2784
E = -.66387
F = .03012
G = -.00909
IW = inertia weight
HP = rated horsepower
CID = engine displacement
AR = axle ratio

substituting the values for the standard '74 Hornet

$$MPG = 13.71 \qquad (2)$$

Substituting the values for a modified Hornet with a 3.08 axle and an 89 hp, 209 CID engine (same specific power):

$$MPG = 14.58 \qquad (3)$$

The ratio of (3) over (2) is the correction factor to be applied to the actual test results of the standard Hornet:

$$\frac{14.58}{13.71} = 1.064 = \text{correction factor}$$

Appendix E

Emission, Fuel Economy, and Performance Results

The following pages present the detailed data generated on the test cars in the EPA test program. The results are listed for each individual test, and averages are calculated when multiple tests were run.

On Tables E-1 to E-9 the third test listed for the LaForce supplied 1974 standard Hornet and for the LaForce modified car was run, in each case, using Mobil Regular leaded gasoline obtained from a local retail station (see page 10 of test report). On the rented 1974 Hornet the tests in which the cars were adjusted to the LaForce standard car specifications and as well as the tests that were run with the car in 'fuel economy tuned' condition were run on the same Mobil Regular gasoline. All other tests were run on Indolene leaded test gasoline, except that the 1975 car was run on the Indolene unleaded gasoline, for that car was certified using unleaded gasoline. All performance tests were run on Mobil Regular leaded gasoline.

Table E-1

1975 FTP

		Mass Emissions Grams Per Mile		City Fuel Economy	
		HC	CO	NOx	mpg
LaForce-Supplied 74 Hornet		.67	5.39	3.49	14.5
		.68	5.42	3.52	14.7
		.70	5.07		15.4
	avg.	.68	5.29	3.50	14.8
LaForce Modified Car		3.05	25.6	3.22	20.3
		2.89	21.8	3.29	20.8
		2.69	20.3	3.40	20.8
	avg.	2.87	22.57	3.30	20.6
Rented 74 Hornet - (Mfrs. Specs.)		1.16	19.5	2.72	15.3
		1.18	20.4	2.92	15.4
	avg.	1.17	19.9	2.82	15.3
Rented 74 Hornet - (.2% CO, 10^{o} BTDC)*		1.22	6.43	4.14	17.1
Rented 74 Hornet - (Economy Tuned)		1.68	5.85	4.89	18.6
		1.66	6.53	4.76	18.9
	avg.	1.67	6.19	4.82	18.8
Rented 75 Hornet		1.83	18.8	2.94	15.6
		1.55	14.9	3.25	16.8
	avg.	1.67	16.8	3.10	16.2

* Adjusted approximately to specifications of the LaForce Modified Car.

Table E-2

Federal Highway Cycle

		Mass Emissions Grams Per Mile			Highway Fuel Economy
		HC	CO	NOx	mpg
LaForce-Supplied 74 Hornet		.43	2.22	4.61	23.1
		.47	2.28	5.35	22.6
		.48	2.45	5.34	23.9
	avg.	.46	2.32	5.10	23.2
LaForce Modified Car		2.29	6.50	4.58	27.3
		2.30	6.99	4.74	26.9
		1.96	5.39	5.20	27.8
	avg.	2.18	6.29	4.84	27.3
Rented 74 Hornet (Mfrs. Specs.)		.52	3.68	3.66	24.3
		.58	3.90	4.34	23.4
	avg.	.55	3.79	4.00	23.8
Rented 74 Hornet (.2% CO, 10^{o} BTDC) *		.73	2.51	6.99	24.7
Rented 74 Hornet - (Economy Tuned)		.76	2.57	5.35	25.4
		.71	2.58	5.73	25.9
	avg.	.74	2.58	5.55	25.6
Rented 75 Hornet		.67	5.63	2.51	21.2
		.80	9.76	2.58	22.1
	avg.	.74	7.69	2.54	21.6

* Adjusted approximately to specifications of the LaForce Modified Car.

Table E-3

Steady State - Idle

		Mass Emissions Grams Per Minute			Fuel Consumption
		HC	CO	NOx	gph
LaForce-Supplied 74 Hornet		.186	.328	.064	.574
		.176	.332	.052	.558
		.138	.340	.056	.540
	avg.	.166	.334	.058	.558
LaForce Modified Car		.296	.604	.044	.339
		.364	2.154	.056	.360
		.248	.278	.064	.365
	avg.	.302	1.012	.054	.355
Rented 74 Hornet - (Mfrs. Specs.)		.376	9.12	.050	.594
		.394	8.64	.058	.609
	avg.	.384	8.88	.054	.603
Rented 74 Hornet - (.2% CO, 10° BTDC)*		.316	2.488	.082	.558
Rented 74 Hornet - (Economy Tuned)		.390	1.122	.148	.556
		.404	2.036	.148	.563
	avg.	.396	1.580	.148	.561
Rented 75 Hornet		.232	.974	.198	.561
		.298	3.820	.206	.585
	avg.	.264	2.396	.202	.574

* Adjusted approximately to specifications of the LaForce Modified Car.

Table E-4

Steady State - 15 mph

		Mass Emissions Grams Per Mile			Fuel Economy
		HC	CO	NOx	mpg
LaForce-Supplied 74 Hornet		.41	1.96	.68	19.2
		.44	1.85	.53	21.5
		.50	2.59	.54	22.5
	avg.	.45	2.13	.58	21.0
LaForce Modified Car		1.10	2.08	.51	27.3
		1.12	2.07	.50	27.8
		1.06	2.02	.38	25.9
	avg.	1.09	2.06	.46	27.0
Rented 74 Hornet (Mfrs. Specs.)		1.41	23.12	.34	23.4
		1.41	20.64	.31	23.3
	avg.	1.41	21.88	.32	23.3
Rented 74 Hornet (.2% CO, 10^{o} BTDC)*		1.34	14.28	.32	24.9
Rented 74 Hornet (Economy Tuned)		1.53	2.82	.48	26.7
		1.46	3.62	.50	26.7
	avg.	1.50	3.22	.49	26.7
Rented 75 Hornet		1.00	2.52	1.54	21.8
		1.00	4.07	1.14	25.0
	avg.	1.00	3.30	1.34	23.3

* Adjusted approximately to specifications of the LaForce Modified Car.

Table E-5

Steady State - 30 mph

		Mass Emissions Grams Per Mile			Fuel Economy
		HC	CO	NOx	mpg
LaForce-Supplied 74 Hornet		.11	1.45	1.13	21.7
		.12	1.44	.96	23.0
		.09	1.31	.89	24.1
	avg.	.11	1.40	.99	22.9
LaForce Modified Car		1.13	1.72	1.33	37.6
		1.09	1.64	1.33	37.3
		.86	1.62	1.44	36.7
	avg.	1.03	1.66	1.37	37.2
Rented 74 Hornet (Mfrs. Specs.)		.13	1.35	.73	24.6
		.16	1.40	.71	24.7
	avg.	.14	1.38	.72	24.6
Rented 74 Hornet (.2% CO, 10° BTDC)*		.28	1.51	.78	27.5
Rented 74 Hornet (Economy Tuned)		.79	1.43	1.33	31.5
		.72	1.41	1.22	32.8
	avg.	.76	1.42	1.28	32.1
Rented 75 Hornet		.73	2.16	2.91	26.2
		.66	1.90	2.31	30.2
	avg.	.70	2.03	2.61	28.1

* Adjusted approximately to specifications of the LaForce Modified Car.

Table E-6

Steady State - 40 mph

		Mass Emissions Grams Per Mile			Fuel Economy
		HC	CO	NOx	mpg
LaForce-Supplied 74 Hornet		.40	1.75	2.12	27.1
		.46	1.76	2.09	28.0
		.38	1.78	1.95	29.4
	avg.	.41	1.76	2.05	28.1
LaForce Modified Car		1.55	2.08	2.73	35.0
		1.55	1.81	2.82	34.7
		1.29	1.57	2.93	34.4
	avg.	1.46	1.82	2.83	34.7
Rented 74 Hornet (Mfrs. Specs.)		.53	1.72	1.70	28.8
		.56	1.70	1.71	29.0
	avg.	.54	1.71	1.70	28.9
Rented 74 Hornet (.2% CO, 10° BTDC)*		.64	1.74	2.47	29.9
Rented 74 Hornet (Economy Tuned)		.68	1.70	2.48	30.6
		.65	1.70	2.33	30.7
	avg.	.66	1.70	2.40	30.6
Rented 75 Hornet		.92	7.59	3.37	25.7
		.86	7.39	3.09	28.1
	avg.	.87	7.49	3.23	26.8

* Adjusted approximately to specifications of the LaForce Modified Car.

Table E-7

Steady State - 50 mph

		Mass Emissions Grams Per Mile			Fuel Economy
		HC	CO	NOx	mpg
LaForce-Supplied 74 Hornet		.38	2.01	4.01	24.8
		.45	2.04	4.35	25.4
		.46	1.98	4.33	25.9
	avg.	.43	2.01	4.23	25.4
LaForce Modified Car		1.84	4.09	4.25	29.6
		1.87	4.25	4.31	29.5
		1.59	2.73	4.51	30.5
	avg.	1.77	3.69	4.36	29.8
Rented 74 Hornet (Mfrs. Specs.)		.48	2.11	3.32	26.2
		.55	2.06	3.47	26.4
	avg.	.52	2.08	3.40	26.3
Rented 74 Hornet (.2% CO, 10^{o} BTDC)*		.67	1.99	5.53	26.4
Rented 74 Hornet (Economy Tuned)		.63	1.99	5.22	27.4
		.59	1.94	4.70	28.6
	avg.	.61	1.96	4.46	28.0
Rented 75 Hornet		.83	5.28	1.65	22.1
		.92	8.40	1.28	23.7
	avg.	.88	6.84	1.46	22.9

* Adjusted approximately to specifications of the LaForce Modified Car.

Table E-8

Steady State - 60 mph

		Mass Emissions Grams Per Mile			Fuel Economy
		HC	CO	NOx	mpg
LaForce-Supplied 74 Hornet		.29	2.41	6.00	21.4
		.29	2.39	6.27	21.7
		.32	2.09	6.96	22.4
	avg.	.30	2.30	6.41	21.8
LaForce Modified Car		2.20	6.76	5.66	24.6
		2.17	7.48	5.92	24.6
		1.81	5.14	6.13	25.0
	avg.	2.06	6.46	5.90	24.7
Rented 74 Hornet (Mfrs. Specs.)		.37	2.59	5.07	22.8
		.43	2.55	5.45	22.7
	avg.	.40	2.57	5.26	22.7
Rented 74 Hornet (.2% CO, 10° BTDC)*		.54	2.43	8.38	22.9
Rented 74 Hornet (Economy Tuned)		.56	2.41	8.01	23.2
		.52	2.41	7.44	24.1
	avg.	.54	2.41	7.72	23.6
Rented 75 Hornet		.47	4.27	3.40	19.4
		.63	6.60	3.32	20.7
	avg.	.55	5.43	3.36	20.0

* Adjusted approximately to specifications of the LaForce Modified Car.

Table E-9

Steady State - 30 mph No Load

		Mass Emissions Grams Per Mile			Fuel Economy
		HC	CO	NOx	mpg
LaForce-Supplied 74 Hornet		.09	1.24	.70	25.6
		.09	1.23	.68	26.0
		.20	3.59	.60	27.0
	avg.	.13	2.02	.66	26.2
LaForce Modified Car		1.16	2.25	.87	41.6
		.97	1.97	.84	42.2
		.78	1.67	.78	40.5
	avg.	.97	1.96	.83	41.4
Rented 74 Hornet (Mfrs. Specs.)		.15	1.30	.55	28.0
		.14	1.28	.52	28.2
	avg.	.14	1.29	.54	28.1
Rented 74 Hornet (.2% CO, 10° BTDC) *		.68	7.58	.49	31.4
Rented 74 Hornet (Economy Tuned)		.76	1.74	.70	36.6
		.63	1.23	.66	37.5
	avg.	.70	1.48	.68	37.0
Rented 75 Hornet		.43	1.32	1.53	30.4
		.66	3.97	1.64	33.3
	avg.	.54	2.64	1.58	31.8

* Adjusted approximately to specifications of the LaForce Modified Car.

Table E-10

Chassis Dynamometer Acceleration Tests

	Time, Seconds to Speed, mph			
	0-30	0-40	0-50	0-60
LaForce-Supplied 74 Hornet	5.0	8.1	11.8	16.4
LaForce Modified Car	5.4	9.1	13.0	17.6
Rented 74 Hornet (Mfrs. Specs.)	2.2	8.1	11.4	15.2
Rented 74 Hornet (Economy Tuned)	4.6	7.6	10.9	14.8

Table E-11

GM Proving Ground Acceleration Tests

	Time in Seconds, to Speed, mph, and Distance	
	LaForce-Supplied 74 Hornet	LaForce Modified Car
0-30 mph	5.7	7.0
0-60 mph	18.1	19.9
0-1/8 mile	14.1	15.3
0-1/4 mile	21.7	23.0
30 to 70 mph	21.5	22.5

Appendix F

PETROLEUM DISTILLATION

SAMPLE IDENTIFICATION Mobil Bruce Michaels

TEST NUMBER

DATE TAKEN 12-11-74

DATE ANALYZED 12-12-74

BAROMETRIC PRESSURE 734 mm

DEGREES F			DEGREES F		
IBP	80°	82°	70 ML	272	275
10 ML	109	111°	80 ML	312	315
20 ML	134	136	90 ML	369	372
30 ML	162	164	END POINT	388	391
40 ML	187	190	DRY POINT		
50 ML	210	213			
60 ML	238	241	FINAL VOLUME	97	ML

REID VAPOR PRESSURE 11.3 POUNDS

IBP	82	°F
10% POINT	111	°F
50% POINT	213	°F
90% POINT	369	°F
EP	396	°F

Appendix G

Composite Fuel Economy Calculation

City cycle and Highway cycle fuel economy values can be "mileage weighted" together to produce a "composite" fuel economy value that reflects the relative amounts of automobile travel in urban and non-urban areas. The fractions of automobile distances (mileage) travelled in urban and non-urban areas are known to be .55 and .45, respectively. Thus the formula used to "mileage - weight" city and highway fuel economy values is:

$$\text{mpg composite} = \frac{1}{\dfrac{.55}{\text{mpg city}} + \dfrac{.45}{\text{mpg highway}}}$$

Appendix H

Comparison of Carbon Balance and Gravimetric Fuel Economy

In this table the Carbon Balance Fuel Economy is taken as the standard. Gravimetric Fuel Economy is compared to Carbon Balance in terms of percent difference. A negative percentage means Gravimetric Fuel Economy is lower (poorer) than Carbon Balance; a positive percentage means Gravimetric Fuel Economy is higher (better) than Carbon Balance.

1. 75 FTP

LaForce Car	LaForce-Supplied 74 Hornet	Rented 74 Hornet
-9	-9	-15
Invalid Data	-4	- 6
-3	-3	No Data
		No Data

2. Highway Cycle

LaForce Car	LaForce-Supplied 74 Hornet	Rented 74 Hornet
-6	-4	-3
-6	-3	-4
-6	-1	0
		No Data
		No Data

3. Steady State Tests

	LaForce Car	LaForce-Supplied 74 Hornet	Rented 74 Hornet
15 mph	-12	+1	-6
	-10	-7	0
	0	+7	+4
			-12
			No Data
30 mph	-13	-4	Invalid Data
	-13	-2	-4
	-11	-3	+4
			-5
			No Data

Appendix H Continued

	LaForce Car	LaForce-Supplied 74 Hornet	Rented 74 Hornet
40 mph	-13	-6	+12
	-12	-5	-4
	-15	-7	+4
			-5
			No Data
50 mph	-4	-3	-3
	-7	-4	-4
	-8	-1	+2
			-5
			No Data
60 mph	Invalid Data	Invalid Data	-1
	-3	-1	Invalid Data
	-4	0	+13
			0
			No Data
30 mph No Load	No Data	-2	0
	-10	+12	+14
	Invalid Data	+10	-3
			-1
			No Data

See page 11 for discussion of the above data.

Appendix J

General Motors Corporation

Memorandum Report

"Acceleration Performance Tests"

MEMORANDUM REPORT

ACCELERATION PERFORMANCE TESTS

LaForce Modified Hornet Versus Production Hornet

Abstract

General Motors management, at the request of the Environmental Protection Agency (EPA), requested Product Evaluations to conduct acceleration performance tests on two vehicles being evaluated by the EPA. Both vehicles were owned by Ventur-E, Inc. of Vermont and were AMC Hornets equipped with 1974 six cylinder engines and automatic transmissions. One vehicle was reported to be standard production, while the other was equipped with an engine modified by Edward and Robert LaForce of Ventur-E, Inc. Zero speed and constant speed rolling start wide open throttle accelerations were conducted along with the Consumer Information Acceleration and Passing Ability tests (49 CFR 575.106). A lighter test weight was used for the zero speed starts and a 30-70 mph merging maneuver than for the passing tests which were conducted at gross vehicle weight rating.

Personnel from the EPA, Ventur-E, Inc., and the Proving Ground were present during testing. Test procedures were discussed and agreed upon by all involved prior to the road testing. Robert LaForce and members of his staff observed the testing from the side of the straightaway. Proving Ground testers drove both vehicles. An observer from Ventur-E rode in the LaForce modified car and an observer from the EPA rode in the LaForce supplied production car.

Test Objective

The objective of the acceleration tests was to determine the actual road performance of the LaForce modified vehicle relative to that of a production counterpart vehicle.

Results

The numerical results of the road test accelerations are given in Table I on the following page. These results are the average of at least six test runs for each of the test conditions. The passing test performance data was adjusted for transmission downshift delay due to a difference in driver starting procedure between the two vehicles. This adjustment allows the data to be comparable. To accomplish this, a third Hornet was tested separately from these tests. The adjustment technique is discussed in more detail in the "Discussion" and Appendix A.

TABLE I

	Production Hornet	LaForce Modified Hornet
Engine	258 CID, Production	258 CID, Modified
Transmission	Automatic, Production	Automatic, Production
Axle Ratio	2.73:1 Production	3.08:1 Production, Optional
Tire Size	6.95-14	C78-14
Inflation Pressure (Hot)	27F, 27R	27F, 27R
Test Fuel	Am. Reg. Leaded, 94 RON	Am. Reg. Leaded, 94 RON
Odometer	2290	8590

Performance - Zero Starts and Merging Maneuver

Test Weight (Lbs)	3496	3494
0-30 MPH, Secs. @ Ft.	5.7 @ 130	7.0 @ 157
0-60 MPH, Secs. @ Ft.	18.1 @ 992	19.9 @ 1040
0-1/8 Mi., Secs. @ MPH	14.1 @ 52.7	15.3 @ 50.7
0-1/4 Mi., Secs. @ MPH	21.7 @ 65.1	23.0 @ 63.8
30-70 MPH, Secs. @ Ft.	21.5 @ 1684	22.5 @ 1749

Consumer Information Acceleration and Passing Ability Tests (49 CFR 575.106)

Test Weight (Lbs)	4176	4181
Performance	(Adjusted)*	(Actual)
Low Speed (20-35 MPH)		
Secs. @ Ft.	4.6 @ 188	4.5 @ 182
High Speed (50-80 MPH)		
Secs. @ Ft.	35.8 @ 3613	32.6 @ 3296
Passing Performance (Calculated)		
Low Speed (20-35 MPH)		
Secs. @ Ft.	9.0 @ 416	9.2 @ 420
High Speed (50-80 MPH)		
Secs. @ Ft.	16.7 @ 1494	15.8 @ 1432

Test Date	12-10-74	
Time of Day	1:30 p.m. - 3:30 p.m.	
Test Track	N-S Straightaway	
Road Surface	Dry	
Temperature	37°F	
Barometric Pressure (Dry)	28.92	
Vapor Pressure	0.15	
Relative Humidity	70%	
Wind, Direction @ MPH	SSW @ 5	
Instrumentation	AMS No. 1	AMS No. 3
Calibration Date	12-9-74	12-9-74

*Data adjusted for transmission down-shift time to allow comparable results--see DISCUSSION for explanation.

DISCUSSION

1. TEST PROCEDURES

1.1 Test Facility

The acceleration performance tests were conducted on the North-South Straightaway at the General Motors Milford Proving Ground. This road surface has a zero grade and is straight for 2.6 miles. The ambient conditions at the time of the tests are indicated in Table I.

1.2 Test Instrumentation

The test vehicles were instrumented with the Acceleration Measurement System, units no. 1 and 3. This instrumentation consists of a fifth wheel with a distance transducer and a DC tach generator for speed measurement, a data acquisition instrumentation package including a digital printer, and a DC-AC inverter for powering the instrument. The system provides a digital printout every 0.2 seconds of vehicle speed, distance, and time from start of test. In addition, a precision analog speedometer is provided for driver monitoring.

System inaccuracies, exclusive of fifth wheel, are:

a) Speed ± 0.25% at constant speed. Due to the filtered response of the speed input, accuracy is reduced to ± 0.25% - 1.0 mph at 0.5 g acceleration.

b) Distance ± 0.1% ± 1 foot

c) Time ± 0.1% ± 0.1 second

This system, when used with the Proving Ground fifth wheels, provides an overall system error of typically one percent for the speed and distance printout. Time error is independent of the fifth wheel and remains unchanged.

1.3 Vehicle Preparation

The test vehicles were tested as received from the EPA. No engine adjustments or tune-ups were made by Proving Ground personnel.

Tire pressures were adjusted to 27 psig (front and rear) to compensate for hot tires and a manufacturer's recommended cold inflation pressures of 24 F, 24 R for loads up to maximum.

The vehicles were ballasted to obtain a 3500 pound total weight for the zero starts and 30-70 mph merging maneuver accelerations. This test weight was specified by the EPA and was equivalent to the inertia weight class for the vehicles when tested by the EPA.

For the Consumer Information Acceleration and Passing Ability test, both test vehicles were ballasted to obtain the gross vehicle weight rating (GVWR) as specified on the vehicles' door weight label. This weight condition (4176 lbs) would be similar to that required of Federal Motor Vehicle Consumer Information Regulation 49 CFR 575.106.

The vehicles were warmed up by driving about 18 miles at approximately 70 mph. Both vehicles were tested at the same time.

1.4 Standing Start and Merging Maneuver Acceleration Performance

For these tests, all vehicle power accessories were turned off. The test vehicles were started in "drive" range and the automatic transmission was allowed to shift at its normal shift points. Vehicle speed, time, and distance recording began at the instant the driver's foot moved the accelerator pedal to accelerate the vehicle. Accelerations were limited to 1/4 mile at the request of Ventur-E personnel due to questionable reliability of the camshaft in the LaForce modified vehicle.

1.5 Consumer Information Acceleration and Passing Ability Tests

These tests were run according to Federal Motor Vehicle Consumer Information Regulation 49 CFR 575.106 without regard to certain ambient restrictions. The vehicles were tested at the gross vehicle weight rating (GVWR) indicated on the vehicle door label. The tests were also conducted with all electrical power equipment on including windshield wipers, headlights, radio, blower fan maximum, etc., to provide a maximum drain on the electrical system and engine.

1.5.1 Start of Test Shifting Procedure

For the passing acceleration tests, test vehicles with automatic transmissions are normally downshifted manually before the start of test into the range which it would normally downshift to automatically at wide open throttle (WOT). Immediately after the vehicle begins accelerating, the selector is returned to drive and the vehicle is allowed to upshift normally. This eliminates the variability of the downshift time and improves the repeatability of test runs. Elimination of the downshift usually improves the performance results slightly. The LaForce modified Hornet was driven in this manner; however, the production Hornet was driven in "drive" range. The shifting procedure to be used for these comparison tests was not clarified for the drivers before the start of test, and the passing acceleration test was conducted differently for each vehicle. This point was discovered after the road tests had been completed and the vehicles were no longer available for retest. In order to allow comparable results for the two vehicles, the production Hornet data has been corrected. This was accomplished by renting a 1974 Hornet with the same power train as the production Hornet and conducting performance tests on this vehicle to determine the effects of transmission downshift delays on its performance. These effects were then assumed to be the same for the LaForce production Hornet and appropriate corrections were made. The data correction techniques are discussed in Appendix A. The results of the passing performance tests on the rental Hornet are indicated in Appendix B.

APPENDIX A

DETERMINATION OF TRANSMISSION SHIFT EFFECTS ON VEHICLE PASSING PERFORMANCE

Low and high speed passing tests were conducted on a rented 1974 Hornet to determine a correction necessary for the LaForce production Hornet passing performance data. It was necessary to correct the data due to differences in starting procedure used for the LaForce production and modified vehicles.

Data analysis of the rental Hornet's acceleration curves, on a point by point basis, revealed that the effect of automatically versus manually downshifting the transmission at the start of test was to cause a delay in the start of acceleration. This automatic downshift delay amounted to approximately 0.2 seconds and 15 feet for the high speed passing tests and 0.3 seconds and 8 feet for the low speed passing tests. The WOT acceleration of the vehicle at any speed, other than near the starting speed, was the same irregardless of the starting technique. These adjustments agree well with differences due to the downshift delay observed in the overall performance of the rental Hornet. Figures 1 and 2 on the following pages show the initial portion of the acceleration curve and the delays due to shifting procedure. The data points shown on the curves are the average of eight runs.

The performance data for the LaForce production Hornet was adjusted by subtracting the downshift delays observed for the rental Hornet from the actual performance curves for the LaForce production Hornet. The passing performance data for the LaForce production Hornet were then recomputed using these adjusted curves.

Figure 1
RENTAL HORNET DOWNSHIFT DELAYS
20-35 MPH ACCELERATIONS

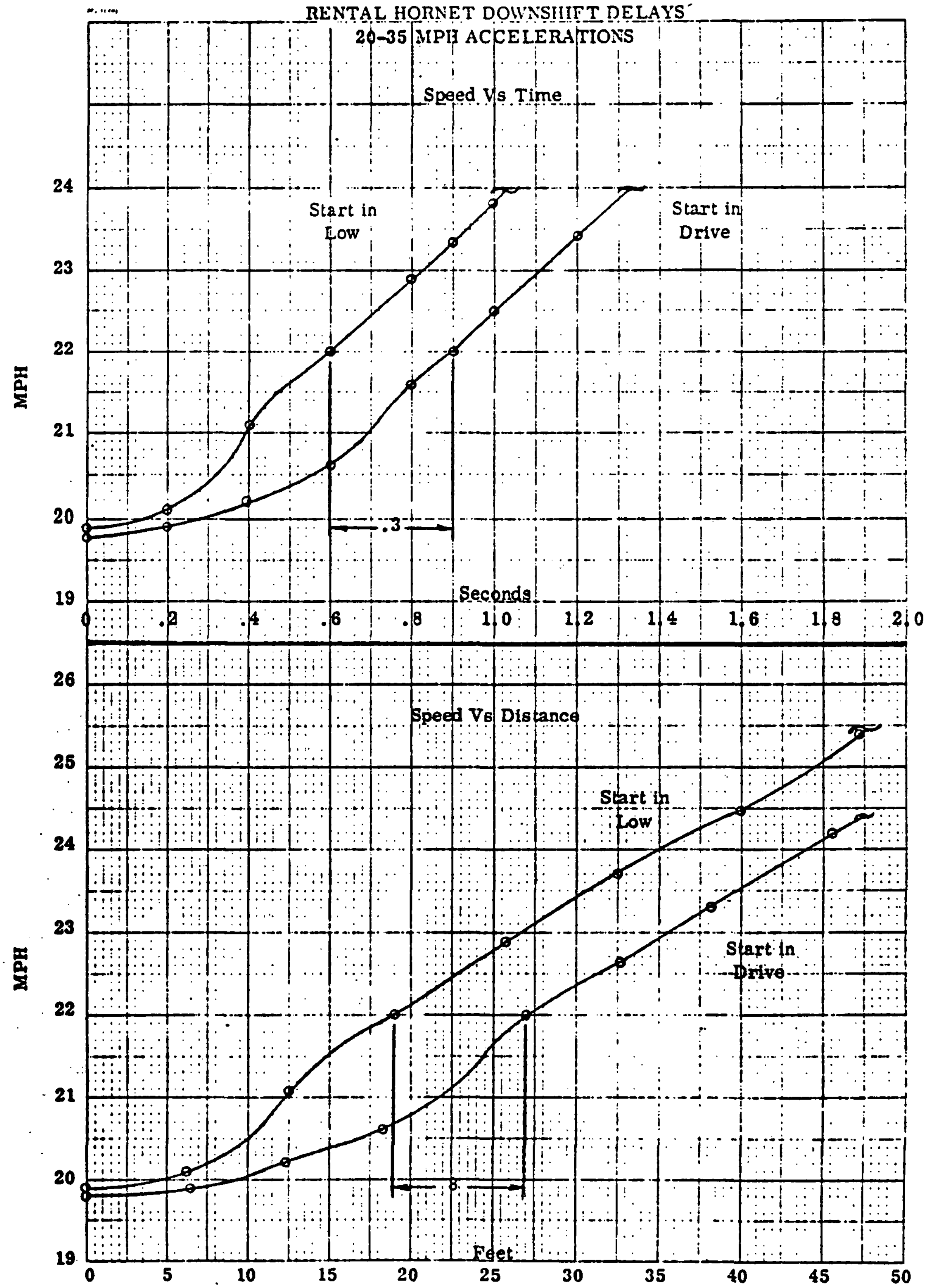
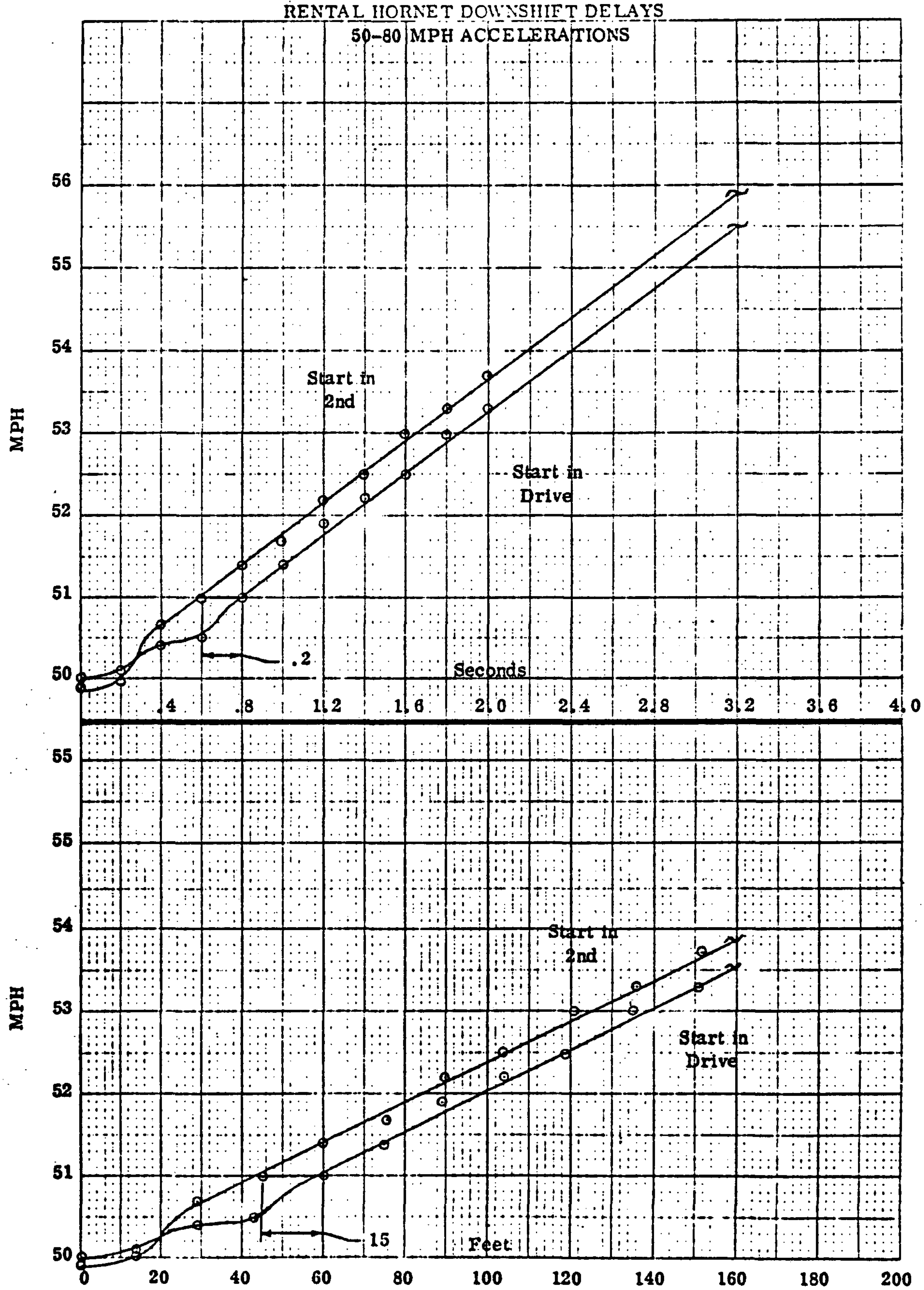


Figure 2
RENTAL HORNET DOWNSHIFT DELAYS
50-80 MPH ACCELERATIONS



APPENDIX B

RENTAL HORNET

Serial No.	A4A067A770606
Engine	258 CID
Transmission	Automatic
Axle Ratio	2.73:1
Tire Size	C78-14
Inflation Pressure (Cold)	24F, 24R
Test Fuel	Am. Reg. Leaded, 94 RON
Odometer	5190

Consumer Information Acceleration and Passing Ability Tests (49 CFR 575.106)

Test Weight (lbs)

Performance (Actual)	Drive Gear	Manual Downshift
Low Speed (20-35 MPH)		
Secs. @ Ft.	4.1 @ 168	3.9 @ 161
High Speed (50-80 MPH)		
Secs. @ Ft.	28.0 @ 2803	27.8 @ 2784
Passing Performance (Calculated)		
Low Speed (20-35 MPH)		
Secs. @ Ft.	8.9 @ 414	8.7 @ 407
High Speed (50-80 MPH)		
Secs. @ Ft.	15.4 @ 1405	15.3 @ 1395