REPORT NO. DOT-TSC-OST-74-39.IIB

TECHNOLOGICAL IMPROVEMENTS TO AUTOMOBILE FUEL CONSUMPTION
Volume IIB: Sections 24 and 25, and Appendixes A through I

C. W. Coon et al

DECEMBER 1974
FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
OFFICE OF THE SECRETARY
Office of the Assistant Secretary for Systems Development and Technology
Washington DC 20590
and
U.S. ENVIRONMENTAL PROTECTION AGENCY
Ann Arbor MI 48105

DISCLAIMER

Technical Report Documentation Page

1. Report No. DOT-TSC-OST-74-39.IIB	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle TECHNOLOGICAL IMPROVEMENTS TO AUTOMOBILE FUEL CONSUMPTION Volume IIB: Sections 24 and 25 and Appendixes A through I		5. Report Date December 1974
		6. Performing Organization Code
7. Author(s) C. W. Coon et al		8. Performing Organization Report No. DOT-TSC-OST-74-39.IIB
9. Performing Organization Name and Address Southwest Research Institute* Energy Conversion Systems Section Department of Automotive Research San Antonio TX 78284		10. Work Unit No. (TRAIS) OS514/R5523
		11. Contract or Grant No. DOT-TSC-628
12. JOINTLY SPONSORED BY- U.S. Department of Transportation Office of the Secretary Office of the Assistant Secretary for Systems Development and Technology Washington DC 20590 and U.S. Environmental Protection Agency Ann Arbor MI 48105		13. Type of Report and Period Covered Final Report June 1973-January 1974
		14. Sponsoring Agency Code
15. Supplementary Notes *Under Contract to: U.S. Department of Transportation Transportation Systems Center Kendall Square Cambridge MA 02142		

16. Abstract

This report is a preliminary survey of the technological feasibility of reducing the fuel consumption of automobiles. The study uses as a reference information derived from literature, automobile industry contracts, and testing conducted as part of the program requirements. The design changes, which are recommended for the purpose of maximizing fuel economy, have been derived after lengthy review against a series of constraints including regulatory requirements, technical feasibility, and cost effectiveness.

Several possible technological improvements are identified, documented, and evaluated with respect to fuel economy. Results are reported as percentage improvement in fuel economy by comparison with 1973 model year vehicles. The effect of vehicle emission control systems is considered in the evaluation procedure.

The most promising individual improvements are incorporated into improvement for these vehicles is reported.

The status of the technology reported is that available in the time period of July 1973 to January 1974.

Volume II consists of two parts, Volume II A and Volume II B.

17. Key Words Automobiles, Fuel Economy, Powerplants, Transmissions, Drive Trains, Tires, Accessories Aerodynamics, Weight, Fuel Consumption, Innovations		18. Distribution Statement DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 198	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

PREFACE

The transportation sector of the U.S. economy accounts for approximately 25 percent of the total energy demand, predominately in the form of petroleum fuels. The Government has been actively engaged in reviewing the technological and institutional actions that can be taken to reduce our transportation energy demand. One such effort is the preliminary study covered in this report on the technological feasibility of improved fuel economy in automobiles.

The work described in this report was performed by Southwest Research Institute for the U.S. Department of Transportation and the U.S. Environmental Protection Agency. The project was monitored by the Power and Propulsion Branch, Mechanical Engineering Division, Transportation Systems Center, U.S. Department of Transportation. The technical monitor for the project was H. Gould.

The authors recognize the timely significance of this study, and despite warnings to the contrary, information may be taken out of context. For these reasons, the report has been written in an instructive fashion to acquaint the uninitiated reader with facts about automobile design. Hopefully, this instruction will nullify the majority of misconceptions and provide insight into an exceedingly complex issue.

This work does not address the overall automobile transportation energy problem, but it is directed to one of the major components of the American automobile market—the "large" automobile. Specifically, this study is concerned with cars of the 4300- and 3300-lb curb weight classes. These vehicles are frequently identified by Federal Test Procedure inertia weight class with corresponding values of 3500 and 4500 lb.

The status of the technology reported is that available in the time period of July 1973 to January 1974.

The work covered in this report represents approximately a three-man year level of effort and was conducted over a six-month period. The goals of the project are ambitious, and the effort of each member of the project team was vital to the final product. Space does not permit the listing of all participants, but major efforts were contributed by:

- Dr. C. W. Coon, Senior Research Engineer
- B. C. Dial, Senior Research Engineer
- Roger Hemion, Institute Scientist
- R. W. Hull, Senior Research Engineer
- R. J. Mathis, Research Engineer
- Carlton Morrison, Technician
- Lynn Rhymes, Research Engineer
- C. D. Wood, Manager, Energy Conversion Systems
- S. W. Seale, Research Analyst
- Tom Stettler, Technician
- Clifford Reeh, Technician
- H. O. Woller, Senior Technician
- John W. Colburn, Jr., Project Manager

TABLE OF CONTENTS
Volume IIA

TABLE OF CONTENTS (Cont'd)

Volume II A (Cont'd)

TABLE OF CONTENTS (Cont'd)

Volume IIA (Cont'd)

TABLE OF CONTENTS (Cont'd)

Volume IIA (Cont'd)

TABLE OF CONTENTS (Cont'd)

Volume II B (Cont'd)

LIST OF ILLUSTRATIONS

Volume II A

LIST OF ILLUSTRATIONS (Cont'd)

Volume II A (Cont'd)

LIST OF ILLUSTRATIONS (Cont'd)

Volume II A (Cont'd)

LIST OF ILLUSTRATIONS (Cont'd)

Volume II A (Cont'd)

LIST OF ILLUSTRATIONS (Cont'd)

Volume II A (Cont'd)

LIST OF ILLUSTRATIONS (Cont'd)

LIST OF TABLES

Volume II A

LIST OF TABLES (Cont'd)

Volume II A (Cont'd)

LIST OF TABLES (Cont'd)

Volume II A (Cont'd)

24. SUMMARY OF INDIVIDUAL IMPROVEMENTS

Table 44 summarizes the results of the analyses of the various candidate methods for the improvement of fuel economy. Such a table is, in one sense, a source of confusion to the reader because the terse comments regarding the various points of comparison deal with complex engineering trade-off situations, the thorough evaluation of which was not possible under the scope of this project. For most of the individual improvements, a thorough evaluation would include actual tests on experimental equipment. It is hoped that the table will serve as an incentive for the reader to refer to the individual sections of this report for the discussion of each individual improvement and the reasoning (and assumptions) used to arrive at these results.

The comparison of fuel economy is presented on the table in two ways. The base number, calculated in the appropriate section of the text, deals with the increase in fuel economy of a vehicle incorporating the improvement by comparison with a standard vehicle. Neither vehicle is assumed to have emission controls. The standard vehicle has a curb weight of 4300 lb (4500 lb inertia weight for LA-4 test) and uses a 350-CID carbureted engine. This comparison, which is an assessment of the capability of the individual improvement without regard for emission controls, is presented in the first column of Table 44.

By means of appropriate ratios, the basic fuel economy increase for each individual improvement was modified to account for emission controls. The quantities used in formulating the ratios were as follows:

A = fuel economy of a vehicle, with modifications for improved economy, that meets the 0.4–3.4–2.0 emission standards.

B = fuel economy of the "standard" vehicle meeting 1973 emission standards.

C = fuel economy of a vehicle, with modifications for improved economy, that has uncontrolled emissions.

D = fuel economy of the "standard" vehicle with uncontrolled emissions.

E = fuel economy of the "standard" vehicle that meets the 0.4–3.4–2.0 emission standards.

The modified fuel economy increase was then expressed as, for example,

$$\frac{A}{D} = \left(\frac{C}{D}\right)\left(\frac{A}{C}\right)\left(\frac{D}{B}\right)$$

As described in the text, values for the ratios were obtained by calculation or by consultation. This procedure includes a factor for control of the reference vehicle to the 1973 standards as well as a factor which describes the effect of the individual improvement on emission control. Accordingly, the figure presented in the second column of Table 44 is a comparison of the fuel economy of the improved vehicle *meeting the 0.41–3.4–2.0 emission standards* to the reference vehicle *meeting the 1973 emission standards*. In each case, it is assumed that the individual improvement is the only change in the vehicle, except that the engine modifications necessary for compliance with the 0.41–3.4–2.0 emission standards are assumed.

TABLE 44. COMPARISON OF INDIVIDUAL IMPROVEMENTS

INDIVIDUAL IMPROVEMENT	UNCONTROLLED EMISSIONS	MODIFIED VEHICLE 0.41–3.4 2.0 STD VEHICLE 1973 STDS	ADDITIONAL COST PER VEHICLE $	VEHICLE PERFORMANCE CHANGE	VEHICLE NOISE CHANGE	WEIGHT AND SIZE CHANGE (REPLACED ITEM)	RELIABILITY CHANGE	OTHER DISADVANTAGES	OTHER ADVANTAGES	CONSUMER ACCEPTANCE	DEMONSTRATION BY 1976?	PRODUCTION BY 1980?
TURBOCHARGED CARBURETED ENGINE 250 CID, WATER-ALCOHOL INJECTION	17%	11%	75-150	TOP SPEED SAME SLIGHT LOSS OF ACCEL. PERFORM.	INCREASED	25% LESS WT. SAME BOX VOLUME	DECREASED	ENGINE MORE SENSITIVE TO FUEL QUALITY INLET AIR TEMP. PROPER WATER ALCOHOL INJECTION		DECREASED	YES	YES
TURBOCHARGED CARBURETED ENGINE 280 CID, AFTER COOLED	10%	4%	150-250	TOP SPEED SAME SLIGHT LOSS OF ACCEL. PERFORM.	INCREASED	10% LESS WT. 10% MORE BOX VOL.		SENSITIVE TO CONDITIONS ENHANCING KNOCK, BUT NOT TO EXTENT OF 250 CID ENGINE		SLIGHTLY DECREASED	YES	YES
VARIABLE DISPLACEMENT ENGINE	23%	7%	125-175	TOP SPEED SAME PROBABLE LOSS OF ACCEL.	NONE	NONE	DECREASED	COMPLEX VALVE GEAR-DIFFICULT CONTROL PROBLEM		SIGNIFICANTLY DECREASED	YES	YES
ENGINE WITH REDUCED FRICTION	0%	–5%	NOT EVALUATED	NONE	SIGNIFICANT INCREASE	NONE	DECREASED			SAME	YES	YES
LEAN MIXTURE ENGINE	8% MAX	12% MAX	NOT EVALUATED	NONE	NONE	NONE	DECREASED			SAME	NOT EVALUATED	NOT EVALUATED
NATURALLY ASPIRATED DIESEL-378 CID	24% (MPG) 16% (BTU)	35% (MPG) 26% (BTU)	160-270	NONE	SIGNIFICANT INCREASE	40% MORE WT. 20% MORE BOX VOL.	EQUAL OR BETTER	EXHAUST ODOR WEIGHT REDUCTION A MAJOR EFFORT EXHAUST PARTICULATES	POSSIBLE MULTI-FUEL CAPABILITY	DECREASED	NO	DOUBTFUL
TURBOCHARGED DIESEL 260 CID	55% (MPG) 44% (BTU)	69% (MPG) 57% (BTU)	200-300	REDUCED ACCEL PERFORM.	SIGNIFICANT INCREASE	10% MORE WT. SAME BOX VOL.	EQUAL OR BETTER	EXHAUST ODOR, BUT LESS THAN NA DIESEL WEIGHT REDUCTION EXHAUST PARTICULATES	POSSIBLE MULTI-FUEL CAPABILITY	DECREASED	YES	YES, WITH MAJOR EFFORT
CONTINUOUSLY VARIABLE TRANSMISSION	21%	3%	NONE	NONE	UNKNOWN	NONE	UNKNOWN	CHANGES OPERATING MODE OF ENGINE, REQUIRES ENGINE REDESIGN	POTENTIAL EXISTS FOR REDUCTION IN ENGINE DISPLACEMENT	SAME	DOUBTFUL	NO
HYDROMECHANICAL TRANSMISSION	17%	0 ± 5%	NONE	NONE	INCREASED	NONE	UNKNOWN	CHANGES ENGINE OPERATING MODE TRANSMISSION HAS LOW EFFICIENCY	POTENTIAL EXISTS FOR REDUCTION IN ENGINE DISPLACEMENT	SAME	DOUBTFUL	NO
LOCK-UP CLUTCH	3%	–2%	20-30	NONE	NONE	25% INCREASE IN TORQUE CONVERTER WEIGHT	SLIGHT DECREASE		CAN BE USED WITH OVERDRIVE	SAME	YES	YES
OVERDRIVE	5%	–3%	50	NONE	ENGINE SPEED (AND NOISE) REDUCED	40 POUND INCREASE	SLIGHT DECREASE		POTENTIAL EXISTS FOR DISPLACEMENT REDUCTION WITH AXLE RATIO CHANGE	SAME	YES	YES
MANUAL TRANSMISSION	11%	2%	–100	SLIGHT LOSS OF ACCEL PERFORM.	NONE	REDUCED	SLIGHT DECREASE			DECREASED	YES	YES
4-SPEED AUTOMATIC TRANSMISSION	NOT EVALUATED SEPARATELY		50	IMPROVED	NONE	SLIGHT INCREASE	NONE			SAME	YES	YES
INTAKE PORT FUEL INJECTION	NOT EVALUATED SEPARATELY		75	SLIGHTLY IMPROVED	NONE	NONE	SLIGHT DECREASE		POTENTIAL FOR BETTER FUEL-AIR RATIO CONTROL FOR CATALYST SYSTEMS	SAME	YES	YES
STRATIFIED CHARGE ENGINE (NOT CARBURETED)	29%	34%	150-200	SAME OR SLIGHTLY IMPROVED	NONE	NONE	DECREASED UNLESS ENGINE IS MADE LESS SENSITIVE TO INJECT & TIMING	POSSIBLE EXHAUST ODOR PROBLEM; HIGH EXHAUST PARTICULATES, ENGINE SENSITIVE TO INJECTION & TIMING	POTENTIAL EXISTS FOR MULTI-FUEL OPERATION	SAME	YES	YES
AIR CONDITIONING IMPROVEMENTS	2-4% MAX		15	SLIGHTLY IMPROVED	DECREASED	NONE	NONE			SAME	YES	YES
STEEL BELTED RADIAL PLY TIRES	4%		75	NONE	NONE	NONE	INCREASED		RELIABILITY NOT DECREASED BY INCREASED TIRE PRESSURE	SAME	YES	YES
WEIGHT REDUCTION	7%		200-MATERIAL CHANGE 400-SIZE REDUCTION	NONE	NONE	–	NONE			SAME	DOUBTFUL FOR MATL CHANGE-YES FOR RED. SIZE	YES
AERODYNAMIC DRAG DECREASE C_dA REDUCED 10%	2%		NONE	NONE	NONE	SMALL CHANGE IN WEIGHT	NONE			SAME	YES	YES
REFERENCE VEHICLE	0%	–5%										

During the preparation of Table 44, it was assumed that control of hydrocarbon and carbon monoxide emissions, when necessary for the attainment of the 0.41–3.4–2.0 standards, would be achieved with a catalytic reactor. In addition, it was assumed that NO_X emissions would be controlled with exhaust gas recirculation (EGR). It should be noted that a different set of assumptions would alter the numbers presented in the table. For example, the development of a truly effective aftertreatment process (reactor) for NO_X control, which would not impose a fuel economy penalty on the engine, would allow a more complete realization of the fuel economy benefit associated with the individual improvements. In this case, the numbers in the second column of Table 44 would be closer in magnitude to those in the first column. However, it was felt that EGR would be the primary control method used during the time frame specified by this study, and its use was assumed in applicable portions of the calculations for each individual improvement.

In some cases, such as the diesel and stratified charge engines, the percentage fuel economy benefit is greater for the emission controlled vehicles than for the uncontrolled vehicles. The implication of this result is that the improved vehicle incurs a smaller fuel penalty in attaining the 0.41–3.4–2.0 emission standards than the standard vehicle pays in meeting the 1973 standards. No comparison of absolute fuel economy figures is appropriate on the basis of the results presented in different columns of Table 44.

When individual improvements are considered for inclusion in a vehicle, an evaluation involving more than fuel economy must be conducted. Although the advantages and disadvantages of each option are discussed comprehensively in the text, a review of the salient characteristics would be appropriate.

The turbocharged carbureted engines, both 250 CID and 280 CID with aftercooler and reduced compression ratio, are not considered to be satisfactory choices for the vehicle powerplant. The concern lies mainly with the knock limit of the engines and the sensitivity of the engine to variables which affect knock limit. To obtain fuel economy increase, both engines must be frequently operated under conditions where slight variations in the functioning of the knock control devices will result in severe, and possibly damaging, knock. It is not believed that the type of maintenance service available is adequate to prevent serious difficulties with this engine.

The variable displacement engine is eliminated on the basis of the complex valve gear and the sophisticated controls necessary to transfer from four-cylinder to eight-cylinder operation. Idle roughness and high loading on four cylinders are also detrimental.

The reduction of engine friction, if performed according to the constraints specified for this study, has little effect on fuel economy. During most of the specified test procedures, the reference vehicle engine operates in a regime where pumping losses, rather than mechanical friction, dominate the friction horsepower loss. The fuel economy benefit as a result of reduced friction would be somewhat larger for a small, heavily loaded engine.

The operation of an engine at lean air-fuel ratios can have some effect on fuel economy. The value cited in Table 44 is somewhat optimistic; it was assumed during the calculation that close adherence to the best economy mixture could be maintained throughout the operating range of the engine. Furthermore, it was assumed that most of the required NO_X control could be achieved by combustion chamber design.

The naturally-aspirated diesel engine has the overriding problem of high weight, along with the usual considerations of odor and exhaust particulates. It is believed there is considerable risk in the assumption that the weight of the NA diesel can be reduced sufficiently to be suitable for automotive use (under the restrictions of performance used in this report). The demonstration of a suitable NA diesel by 1976 is, therefore, considered very doubtful.

The turbocharged diesel reduces considerably the problems cited above for the NA diesel. The fuel economy gains are also larger. It is felt odor can be reduced to acceptable levels. If strict particulate emission standards are not set, no difficulty will be encountered in this area. Increased noise, reduced acceleration performance, and a still-significant weight problem temper the other advantages. On balance, however, the belief is that the turbocharged diesel offers considerable promise as an automobile powerplant, and it plays a major role in one of the synthesized vehicle designs to be discussed later.

The continuously variable transmission and the hydromechanical transmission are, at the present time, only in the concept or early development stage. It is believed there is considerable risk in the assumption that the devices will work as well as the design estimates (which we used for fuel economy estimates), and that the economy improvement is not such to warrant this risk.

The evaluation of the lock-up clutch, overdrive, manual transmission, and four-speed automatic transmission involves complex interactions with other vehicle components; it is difficult to visualize the practical application of these devices as "individual" improvements. In Chapter 25 of this study, a detailed consideration of the vehicle transmission is provided during the synthesis of a vehicle design. The total effect of the transmission on fuel economy may be more clearly understood after an examination of that portion of the report.

Intake port fuel injection seems a worthwhile improvement, although the fuel economy gain is not large. The flexibility of the fuel/air ratio control obtained warrants serious consideration.

The stratified charge engine has the advantages of good fuel economy and ongoing development work. For the emission standards used in this report (0.4–3.4–2.0), there is evidently not a major economy penalty. The exact degree of sensitivity of the present engines to injection and spark timing is not known, but there is no doubt that such sensitivity exists and will serve to decrease reliability and increase maintenance. Nevertheless, the stratified charge engine is, in our opinion, a power plant worth serious consideration.

Improvement in the air-conditioning system, consisting of clutch controls for the vapor compressor and improved volumetric efficiency, appear to be a worthwhile change. The maximum improvement is not large and, of course, depends on the use factor of the air-conditioning system, but very little cost penalty is paid for the increased economy.

It is probable that steel-belted radial tires will be widely used in any event for reasons of safety and long life, and an increase in economy will be gained. Advantages of the tires are much enhanced when incorporated with other system components.

Weight reduction, by auto size reduction, is a logical step. One of the synthesized vehicles employs this improvement.

The reduction of drag by reducing the product $C_d A$ by 10 percent seems to be an improvement that can be domonstrated within the restraints of this study by 1976, and the fuel economy gain is obtained without a cost penalty.

Throughout the evaluation of the individual improvements, the emphasis has been upon a standard size vehicle as the baseline for comparison. However, there is considerable interest in the effect of the improvements as applied to intermediate or compact vehicles. Detailed prediction of the effect of each improvement would require a specific definition of an intermediate size reference vehicle. The intermediate vehicles for which data were obtained during this study should not be regarded as truly representative; each had the same engine as its larger counterpart. The effect of vehicle weight and size are considered during the synthesis of a vehicle design in Chapter 25; the details presented in that discussion illustrate the effect of some of the suggested improvements on an intermediate vehicle.

25. SYNTHESIS OF DESIGNS FOR MAXIMUM FUEL CONSUMPTION REDUCTION

Introduction

The review of various automobile design factors resulted in the conclusion that it is feasible to provide some individual methods for improving fuel consumption. In many cases, the magnitude of the fuel consumption reductions could only be targeted to be beneficial when accompanied by other design changes, such as smaller engine and transmission changes, etc.

As discussed in the previous section, certain design components emerge as suitable for incorporation in synthesized designs. In this section we will consider the following basic system components.

Engines (Including Displacement Reduction)

Fuel injected spark-ignition
Open chamber stratified charge
Turbocharged diesel

Weight Reduction (4300 lb reference)

Slight size reduction only–3800 lb
No size reduction–3800 lb

Radial Ply Tires

Three Speed Automatic and Axle Change

Reduced Aerodynamic Drag

Improved drag coefficient
or
Reduced frontal area–10-percent drag reduction with respect to baseline vehicle

Accessories

Clutch–fan

All of the above can be combined in various ways to achieve improved fuel consumption. The two nonhomogeneous mixture engines listed provide significant improvements on their own merits.

These engines also have the additional advantages that the characteristic BSFC curves (Figures 75 and 81) do not degrade as rapidly with decreasing bmep and piston speed as does the S.I. engine (Figure 2). These advantages will further accentuate the benefits of reduced rolling resistance and aerodynamic drag reduction.

In the design of a vehicle for improved fuel economy, a number of interacting factors must be considered. Of particular importance are:

(1) Compliance with regulatory requirements,

(2) Performance,

(3) Production economics,

(4) Reliability,

(5) Cost to the consumer, and

(6) Consumer acceptance.

A manufacturer, attempting to produce a vehicle for market,would not use the same analysis procedure of individual technological changes that has been employed by the authors of this report. Instead, the manufacturer is motivated primarily by economics; secondary considerations are the comfort, convenience, and other features demanded by the American public. Production of economical vehicles will occur in response to market pressure; automobiles will be produced that will, hopefully, increase the income and market share of a particular manufacturer.

A vehicle design has been synthesized by the authors of this report with attention to both the market philosophy outlined above and the constraints placed on the study by the sponsor. Although the manufacturer must consider many other facets of vehicle design, the synthesized product appears to accommodate many of the fuel economy improvements which are compatible with one another. Furthermore, the design was evolved with the attitude that the adverse effect on consumer acceptance should be minimal.

During the synthesis of the design, copious use was made of the preceding analyses; the individual studies of system components served as a source of design information and philosophy. During the selection process, serious consideration was given to minimizing both the incremental cost to the consumer and the development risk.

As is the case with any design process, various trade-offs were made by the authors during the evolution of the synthesized design. It should be recognized that any other design team, especially one whose members advocate a particular subsystem, might obtain a different result from the application of the same process.

Conventional Spark-Ignition Engine Design

The characteristics of the proposed vehicle are as follows:

(1) Engine—260 CID V-8, aluminum block, spark ignition

(2) Engine accessories

a. Electronic fuel injection with fuel shutoff during deceleration
b. Catalytic reactor in exhaust system
c. Spark advance control similar to 1973 models
d. Exhaust gas recirculation

(3) Vehicle size—intermediate; styling similar to 1973 models

(4) Tires—Radial ply, steel belted

(5) Vehicle weight—Curb, 3600 lb; fuel and one occupant, 3900 lb; emission test inertia weight, 4000 lb

(6) Transmission—Coupling biases converter or lock-up clutch with planetary gearset; four-speed automatic, gear ratios 2.5:1, 1.5:1, 1:1, 0.7:1

(7) Rear axle ratio—3.23:1

The change from full-size to intermediate size will provide a reduction of about 10 percent in the aerodynamic drag, primarily, due to the reduction in frontal area. The radial ply tires and reduced weight allow a substantial reduction in rolling resistance; these two factors can be combined as

$$0.7\left(\frac{3600}{4300}\right)$$

TABLE 45. ROAD LOAD HORSEPOWER REQUIREMENTS

Speed (mph)	Road horsepower
20	3.1
30	5.5
40	9.0
50	13.9
60	20.5
70	29.3

The vehicle weight can be reduced to 3600 lb, which is below the target weight of 3800 lb discussed in the section on weight reduction, through the use of an aluminum engine block. The aluminum block, along with redesign of the front bumper and some chassis modification, should allow a weight reduction at the front end of the vehicle sufficient to permit removal of the power steering. The weight saving due to removal of the power steering and redesign of the chassis and bumper should amount to about 100 lb; a further step toward attainment of the 3600-lb curb weight could be made by substitution of a "Space-Saver" spare tire for the standard spare.

A viscous clutch will be incorporated on the engine fan; this unit will affect a slight power saving and a substantial decrease in engine noise during acceleration.

The section of this report devoted to transmissions indicated that a manual transmission with overdrive would maximize the economy potential of a smaller engine in the 4300-lb vehicle. However, considerations of consumer acceptance and emission control dictate the use of an automatic shifting device. It should be noted that EPA regulations require that overdrive units be locked out of operation during certification testing, probably due to the fact that the overdrive unit might not be used in customer service. However, a four-speed automatic transmission having a fourth gear not subject to operator control should be permissible; this type of system has been selected for the synthesized design. The transmission will utilize a large diameter torque converter or a lock-up clutch; the internal design will be modified to reduce the converter action and emphasize the coupling mode. The selected gear ratios are consistent with existing automatic transmissions, and the fourth speed is consistent with the availability of an add-on overdrive currently on the market. The net result would be an automatic overdrive transmission with which the proper gearing for any given speed and load could be established. In operation under road load conditions, the transmission would probably shift into fourth gear (0.7:1 overdrive) at a speed of about 30 mph.

The engine displacement and rear axle gearing for the synthesized design were selected to allow equal acceleration performance for the 3600-lb vehicle and the 4300-lb reference vehicle; the criterion was 0 to 50 mph in 10 sec, or 0.238 g. The power requirement for the design vehicle is 115 hp at 4000 rpm.

Evaluation

Performance

Figures 109 and 110 illustrate the approximate performance characteristics of the power plant/drive train combinations of the reference vehicle and the candidate vehicle respectively. During first gear acceleration, the synthesized design will produce approximately the same power as the reference vehicle at the same road speed; consequently, due to the lower mass, the performance level will apparently increase. The power delivery of the reference vehicle is higher than that shown due to the use of a good torque converter (~2 to 1 stall torque ratio); however, when balanced with the greater mass of the reference vehicle, the performance of the synthesized design will still be better. Due to this margin, it is reasonable to redesign the torque converter by reducing stall speed and stall torque ratio to provide coupling performance and idle torque reduction. The displacement reduction itself will reduce idle fuel consumption and the benefits of idle torque reduction can also accrue.

In addition to standing start performance, passing performance is also of interest. Here again, the performance is determined by the net power available to accelerate the vehicle mass. With the synthesized design, the passing performance can exceed that of the reference vehicle from 50 to

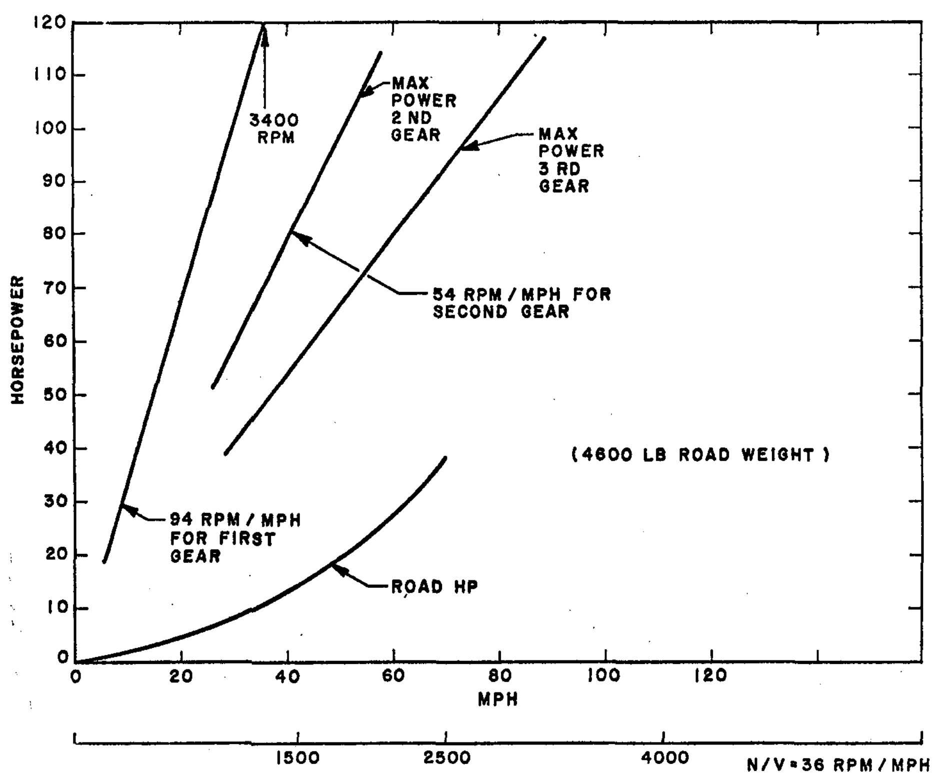


FIGURE 109. PERFORMANCE CHARACTERISTICS REFERENCE VEHICLE

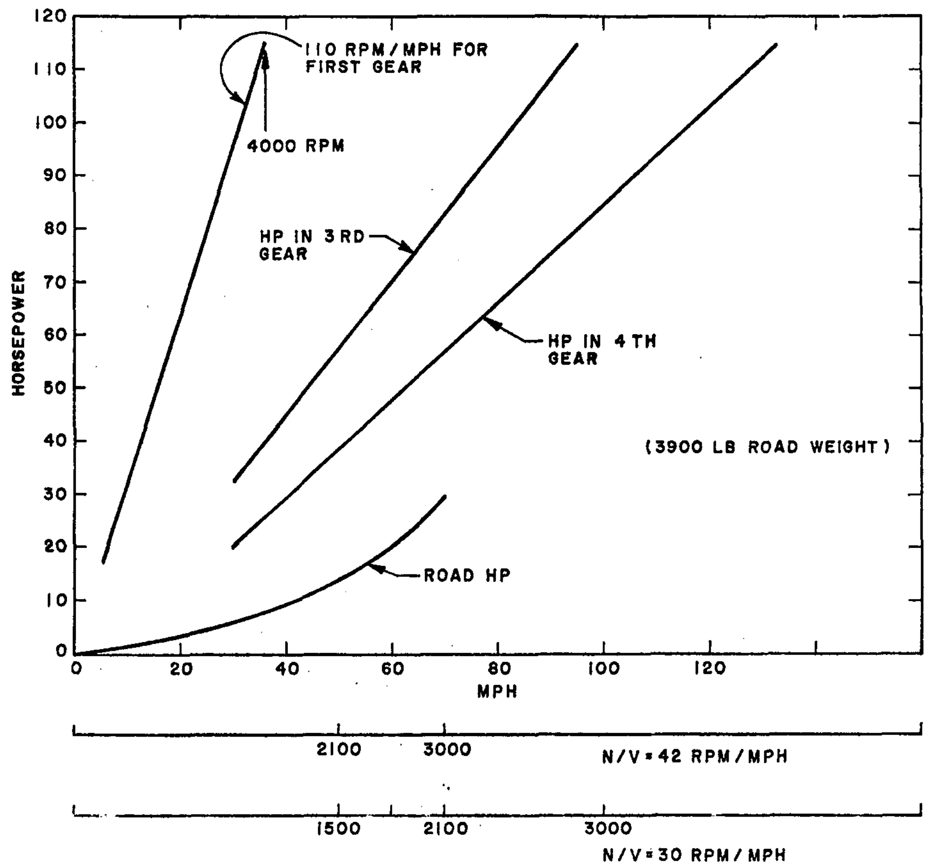


FIGURE 110. PERFORMANCE CHARACTERISTICS–CANDIDATE VEHICLE

70 mph if a downshift to third gear is made; passing performance will be lower (although probably acceptable) with the vehicle in fourth gear. It should be pointed out, however, that the reference vehicle with a downshift to second gear (passing kickdown) will have much better performance than the synthesized design.

Fuel Economy

The standard calculation procedure was employed, resulting in the following improvements in mileage:

LA-4	Road Load	Composite
31.6%	34.9%	33%

These calculations do not include the warmup benefits which can be obtained by the use of fuel injection.

The increase in fuel economy of the synthesized vehicle as calculated above must be modified to account for the different emission standards. The calculated comparison is for both vehicles–synthesized and reference–having no emission controls. The desired comparison is the fuel economy of the synthesized vehicle meeting the 0.4–3.4–2.0 emission standard against the reference vehicle meeting the 1973 emission standards. To make this comparison, the following equation is used:

$$\frac{A}{B} = \left(\frac{C}{D}\right)\left(\frac{D}{B}\right)\left(\frac{A}{C}\right)$$

where

A = fuel economy of synthesized vehicle meeting the 0.4–3.4–2.0 emission standards

B = fuel economy of reference vehicle meeting the 1973 emission standards

C = fuel economy of synthesized vehicle, uncontrolled emissions

D = fuel economy of reference vehicle, uncontrolled emissions

The ratio C/D has been calculated and is equal to 1.33. D/B is 1.09 from estimates made previously. The ratio A/C has been previously estimated to be 0.85 for the conventional engine. The engine in the synthesized vehicle should be easier to modify in order to satisfy the 0.4–3.4–2.0 emission standards than the conventional engine because of its reduced displacement, approximately equal bmep levels, port fuel injection and deceleration fuel shutoff. Therefore, A/C is estimated to be 0.90. Then

$$A/B = 1.33\ (1.09)\ (0.9)$$

$$A/B = 1.305 \text{ or 30 Percent Improvement in Fuel } \textit{Mileage}$$

Cost

The cost of a vehicle as described is evaluated as follows:

Aluminum engine	+150	Basic size change	−400
Electronic fuel injection	+75		
Radial ply tires	+100		
Four speed automatic	+50		
Clutch fan	+10		
	+335		

Based on previous rough cost estimate, it can be concluded that the cost of this synthesized design will be approximately the *same* as that of the 1973 full-size reference vehicle.

Consumer Acceptance

Cold start and driveability will be much enhanced due to the use of fuel injection.

The noise level during acceleration will be somewhat higher due to the higher N/V ratio obtained as a result of the selected gearing. At high speeds, the noise level will be decreased due to slower engine speeds.

The vehicle will not be capable of pulling loads as heavy as those which the reference vehicle can accommodate unless the road speed under heavy load is obtained by operating the vehicle in third gear. The noise level would be increased in this mode of operation. When the vehicle is loaded with the rated occupant capacity, it is conceivable that cyclic shifting between fourth and third gear would be encountered during slight elevation changes in order to maintain vehicle speed. Transmission and engine matching is an area which will require some development, but it is felt that satisfactory resolution of the problems can be achieved.

Reliability and Maintenance

Although the engine operates at a high bmep while in the fourth gear under road load, it is reasonable to expect as long a life as current production vehicles. Accessory life and belt life, although presently not a problem, would be increased.

Safety

The vehicle can meet the 1973 Safety Standards, since it is considered to be basically a modification of the intermediate chassis.

Demonstration by 1976

The development of the power plant is straightforward; however, design studies to optimize the system by considering perturbations in displacement, bore, stroke, etc.,should be conducted. The displacement recommended was available in the early 1960's, but designs were short stroke types unsuited for the proposed gearing. In this regard it is forseeable that a tolerance of perhaps 15 CID will be probable on the synthesized design displacement.

A special casting would be required for the aluminum block; however, the primary criterion for the demonstration vehicle will be verification of fuel economy through reduced weight.

Development of the emissions system can be accomplished on the engine dynamometer and the chassis dynamometer. It is only necessary that road load testing be accomplished with a vehicle of "adjusted" weight but correct aerodynamics.

In the area of transmission design, gear ratios could also be modified. For example, depending on engine fuel consumption characteristics, a 0.83 overdrive ratio and a 3.08 rear axle might also provide substantial benefits although performance would suffer.

Production

The design considered here can be implemented by 1980; the longest lead time item will be the lightweight engine development.

The approach taken to maximize the economy potential of a spark-ignition engine powered vehicle could also be considered valid for the incorporation of diesel or stratified charge engines, i.e., reduced power output and gearing to obtain the torque necessary for acceleration of a lighter vehicle.

Stratified Charge Engine Design

The characteristics of the proposed vehicle are as follows:

(1) Engine—300 CID (open chamber, stratified charge) V-8, cast iron block

(2) Engine accessories (additional)

   a. Vacuum pump for supply of functions presently produced by manifold vacuum; engine will be throttled at idle only
   b. Catalytic reactor in exhaust

(3) Vehicle size—Full; aerodynamic drag reduction of 10 percent

(4) Tires—Radial ply, steel belted

(5) Vehicle Weight—Curb, 3800 lb; fuel and one occupant, 4100 lb inertia test weight, 4000 lb

(6) Transmission—Conventional three-speed torque converter design with modified shifting controls (ratios are the same as the reference vehicle)

(7) Rear axle ratio—3.08:1

The necessity for a four-speed transmission for this stratified charge design is eliminated. The dominant reason for the overdrive ratio used with the spark-ignition engine was to elevate the bmep for a substantial change in BSFC. The benefits do not accrue as rapidly with a stratified charge engine due to the less dramatic change in BSFC with load. Consequently, the desired performance can be obtained through the use of a three-speed automatic transmission, rear axle ratio of 3.08, and engine displacement of 300 CID. Power output of 115 hp at 4000 rpm will also be adequate. This output was attained from 260 CID on the S.I. engine, but a lower specific output from the stratified charge engine is considered likely due to the potential of a smoke limit setting for the injection system.

The synthesized design consists further of a full-size vehicle with weight reduction to 3800 lb. Steel belted radial tires are incorporated as is a drag rediction of 10 percent. This design has a somewhat higher road load than the previous design. In addition, accessory power was assumed to include the reference vehicle power steering and an equivalent amount for a vacuum pump.

Evaluation

Fuel Economy

The fuel economy calculations for this design result in a composite improvement of 55 percent in mileage after correction for emission controls.

Cost

Based on the results of other sections of this report the following total costs will accrue:

Weight reduction	150
Stratified charge engine	150
Steel belted radials	75
	375

A review of Section 5 indicates that this increased initial cost can be offset by the fuel use savings.

Development Risk

The only aspect of the design which merits concern is the development risk factor with the stratified charge engine. Present designs exhibit high hydrocarbon emissions even with aftertreatment, but there is considerable optimism within the industry for compliance with the standards through improved reactor design and operating schedule. In addition, considerations such as odor must be evaluated and satisfactorily resolved before commitment to production.

In addition, the precision of coordinated timing of spark and fuel delivery presents a production tolerance control problem that probably could not be resolved until pilot production was incorporated. For this reason it would be expected that commitment to approximately one million units/year would not be attempted by 1980, although some smaller production quantities could be introduced on a limited basis.

The principal deterrent to the development of the stratified charge engine is that when it is fully emission controlled (0.4 g/mile–NO_X), in most cases, the fuel economy suffers severely to the point that it is virtually no better than a conventional carbureted engine in terms of fuel economy. Its complexity is increased due to injection requirements and add-on devices that are also required.

In the opinion of the authors, the development of the full potential of this power plant will not be achieved unless emission control regulations are frozen at a sufficiently high level for the fuel economy advantages to be exploited. If more stringent standards are ultimately proposed, development will not occur.

In addition to the basic fuel economy advantages of the stratified charge design, it is worthy to reiterate that such a design has a multifuel capability. With the shortages and inequities in management of fuels at this writing (heating oil in favor of gasoline) it would appear reasonable to have power plants that could burn a wide range of fuels to maintain mobility of the motoring public.

Demonstration by 1976

The principle difficulty with a synthesized design of smaller displacement is that such an engine is not presently in the design phase. An engine of approximately 360 CID is under development which will meet more stringent emission standards than those required by this study. Fuel economy of a test vehicle will suffer due to both the displacement effect and emission control degradation effects (0.4 g NO_X).

The other consideration for the demonstration would be the availability of a suitable road load determination with a full-size vehicle of suitable weight and aerodynamics.

This latter problem is not regarded to be severe as the potential road load economy is amenable to analysis. The LA-4 cycle economy can be evaluated in any suitable vehicle. Inertia weight and horsepower settings can establish the loading for the evaluation.

Road load economy in the 0 to 30 mph range can be reasonably estimated by tests in any vehicle of the desired weight. If a vehicle of the target aerodynamic improvement can be located, then economy testing can be accomplished at high road sppeds.

Turbocharged Diesel Design

The characteristics of the proposed vehicle are as follows:

(1) Engine–4 cylinder, 230 CID turbocharged diesel, cast iron block; 115 hp at 4000 rpm

(2) Engine Accessories

   a. Vacuum pump
   b. Clutch fan

(3) Vehicle Size–Full; aerodynamic drag reduction 10 percent

(4) Tires–Radial ply, steel belted

(5) Vehicle Weight–Curb weight, 3950 lb; loaded vehicle weight, 4250 lb, inertia test weight, 4000 lb

(6) Transmission–Four-speed torque converter type (ratios the same as those listed for the S.I. engine synthesized design)

(7) Rear axle ratio–3.23:1

The reason for the revised change to a four-speed transmission is that under road load conditions, in fourth gear the turbocharger energy input will be higher; the kickdown and transition to third gear will hopefully reduce the potential of lag to a full-power output.

This synthesized design also incorporates the full-size vehicle with reduced weight. The weight of the power plant will not appreciably increase the overall vehicle weight. It has been assumed for this study that the engine weight will be about 150 lb more than the reference vehicle engine using presently existing technology. Some of the weight advantage is lost and the additional weight on the front of the vehicle could compromise handling characteristics.

Radial ply tires and aerodynamics improvements are also incorporated in this design. Road load horsepower requirements are reduced with respect to the reference vehicle but are the highest of any of the synthesized designs, due to the increased rolling resistance.

In addition to the obvious need for power steering, a suitable vacuum pump would have to be driven to supply the various subsystems requiring vacuum power. Power requirements for this accessory were also assumed to be on the order of the power steering pump parasitic requirements.

Evaluation

Fuel Economy

The fuel economy calculations when adjusted on a Btu-basis (due to the higher density of diesel fuel) result in a 70-percent improvement in mileage with respect to the reference vehicle.

Cost

Based on foregoing cost considerations, the following total costs will accrue:

Weight reduction	150
Turbocharged diesel engine	250
Steel belted radials	75
	475 +50 four speed automatic transmission

These costs are offset by the fuel savings (See Section 5).

Development Risk

The primary difficulty lies with the power plant weight reduction or vehicle redesign to be compatible with the heavier engine. If the economy advantages can be demonstrated early, then vehicle design can be somewhat altered to minimize the weight bias of the engine.

Demonstration by 1976

The availability of diesel engines in the displacement range necessary is limited; however, it is believed reasonable to modify a light industrial four stroke, four-cylinder diesel to incorporate cam timing and injection timing changes and a turbocharger. Installation of the engine in the vehicle will probably require treatment similar to that employed by Chrysler Corp with their slant-six due to the high overall height of available engines. As with the previously described developments, the area of major concern is the engine and emissions. Primary development emphasis should be placed on engine dynamometer development followed by LA-4 chassis dynamometer testing. Performance testing in an appropriate weight vehicle should also be conducted. If sufficient development impetus is provided, several operational prototype engines can be fully developed by 1976. An operation engine could be prototyped by the end of 1974.

Production by 1980

As with the consideration of the stratified charge engine, it appears that only limited quantities could be produced on a pilot plant basis until full evaluations of the in-use characteristics of the vehicle and consumer acceptance are fully explored.

In the area of emission controls, the manufacturers anticipate that particulate emissions standards currently under consideration by the EPA will be promulgated. If the standards are as severe as discussed in the section on diesel engines, then there is no hope for the diesel engine in an automobile. The decision for a particulate standard would have to be carefully reviewed in relation to the transportation energy needs of the United States. Mere delay of such a standard would not reduce the development risk of a manufacturer.

Further reduction of the gaseous emissions standard (0.4 g/mile NO_X) will also result in a fuel consumption penalty. Sufficient data are not available to assess the degredation level which can be anticipated in automotive service.

LIST OF REFERENCES

1. Obert, Edward F., **Internal Combustion Engines**, International Textbook Company, December 1968.

2. Kruse and Huls, "Development of the Federal Urban Driving Schedule," SAE Paper 730553, 1973.

3. Scheffler, C.E. and Niepoth, G.W., "Customer Fuel Economy Estimated from Engineering Tests," SAE 650861.

4. "Motor Vehicle Facts and Statistics," published by Motor Vehicle Manufacturer's Association, 1972.

5. Jaroslav J. Taborek, *Mechanics of Vehicles* (Reprints from Machine Design) Penton Publishing Co., Cleveland, Ohio, 1957.

6. J.L. Koffman, "Vehicle Performance: The Effect of Rotating Masses on Acceleration," *Automobile Engineer*, December 1955, pp 576-578.

7. P.M. Clayton, "Forecasting Specific Fuel Economy," SAE Paper 199B SAE Summer Meeting, Chicago, Illinois, June 5-10, 1960.

8. R.K. Louden and Ivan Lukey, "Computer Simulation of Automotive Fuel Economy and Acceleration," SAE Paper 196A, SAE Summer Meeting, Chicago, Illinois, June 5-10, 1960.

9. M.A. Ordorica, "Vehicle Performance Prediction," SAE 650623, Detroit Section, May 10, 1965.

10. Jandasek, V.J., "The Design of a Single Stage Three-Element Torque Converter," SAE SP-186.

11. *Design Practices*—Passenger Car Automatic, Transmissions, Society of Automotive Engineers, Volume 3, 1973.

12. Ambs, L.L., "Passenger Car Design Influences on Fuel Consumption and Emissions," Paper 739113, 8th Intersociety Energy Conversion Engineering Conference Proceedings, University of Pennsylvania, August 13-17, 1973.

13. U.S. Department of Transportation, Federal Highway Administration, Office of Highway Planning, Highway Statistics Division, *Cost of Operating an Automobile*, April 1972, by L.L. Liston and C.L. Gauthier (Washington, D.C., Government Printing Office, 1972).

14. U.S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads, *Cost of Operating an Automobile*, February 1970, by E.M. Cope and C.L. Gauthier, (Washington, D.C., Government Printing Office, 1970).

15. Similar studies were published in 1960 and 1968.

16. "The 1973 Autos," *Consumer Report*, April 1973.

17. U.S. Congress, Senate, *Hearings, Automotive Repair Industry*, 90th and 91st Congress, 1969, pp 3548-63.

18. The price of Sears 2 polyester cord ply, 2 fiberglass belted F78-14 tires is used in this analysis. The Sears 1973 Fall and Winter catalog price is $37.94, plus $2.01 Federal excise tax and $1.30 shipping, for a total cost of $41.25 per tire. These tires are guaranteed for 28,000 miles.

19. The estimated cost of 67 cents per quart of oil is derived from the Sears 1973 Fall and Winter catalog price for 10 W-40 oil, plus shipping charges.

20. Cleveland and Bishop, "Several Possible Paths to Improved Part-Load Economy of Spark-Ignition Engines," SAE Paper 150A, March 1960.

21. Taylor, C.F., **The Internal Combustion Engine in Theory and Practice**, 2nd Edition, M.I.T. Press, p 331.

22. Warren, Glenn B., "Fuel Economy Gain from Heated Lean Air/Fuel Mixtures in Motorcar Operation," ASME Paper 65-WA/APC-1.

23. Craver, R.J. et al., "Spark Plug Design Factors and Their Effect on Engine Performance," SAE Paper 700081.

24. Henein and Patterson, **Emissions from Combustion Engines**, Ann Arbor Science Publishers, Inc., 1972.

25. "Report by the Committee on Motor Vehicle Emissions," National Academy of Sciences, 1973.

26. Chen, T.N. and R.N. Alford, "Combustion of Large Gas Engines," ASME Paper 71-DGP-6, 1971.

27. Barber, E.M., "Knock-Limited Performance of Several Automobile Engines," SAE Transactions, July 1948.

28. Schweikert, J.F. and J.H. Johnson, "A Turbocharged Spark Ignition Engine with Low Exhaust Emissions and Improved Fuel Economy," SAE Paper 730633, 1973.

29. Bishop, "Effect of Design Variables on Friction and Economy," SAE Paper 812A, Jan. 1964.

30. K.R. Kamman, et al., "Two-Ring Piston Development," SAE Paper 690750, 1969.

31. Ethyl Corporation, "The Effect of Molybdenum Disulphide in the Crankcase Oil on Engine Performance," Report No. RS-222, Feb. 1963.

32. Climax Molybdenum Co. of Michigan, "Motor Oil Tests with Climax MoS_2 Suspensions," Report No. RP-29-69-2, Feb. 1971.

33. Fawkes, et al., "The Mixture Requirements of an Internal Combustion Engine at Various Speeds and Loads," Thesis, MIT, 1941.

34. Edson and Taylor, "The Limits of Engine Performance," Vol. 7, SAE Special Publication **Progress in Technology** (TP7), 1964.

35. Schweitzer, P.H., "Control of Exhaust Pollution Through a Mixture Optimizer," SAE Paper No. 720254, Jan. 1972.

36. Stivender, Donald L., "Intake Valve Throttling (IVT)–A Sonic Throttling Intake Valve Engine," SAE Paper 680399, 1968.

37. Dolza, J., E. Kehoe, D. Stoltman, and Z. Duntov, "The GM Fuel Injection System," SAE Transactions, Vol. 65, p 739, 1957.

38. Rivard, J.G., "Closed Loop Electronic Fuel Injection Control of the Internal Combustion Engine," SAE Paper 730005, 1973.

39. Freeman, J.H., Jr. and R.C. Stahman, "Vehicle Performance and Exhaust Emission, Carburetion Versus Timed Fuel Injection," SAE Paper 650863, 1965.

40. Bascunana, J., "Divided Combustion Chamber Gasoline Engines–A Review for Emissions and Efficiency," APCA, 66th Annual Meeting, 1973.

41. Gussak, L.A., **Izvestiga ANSSSR, Enegertika i Transport,** Nr 4, 1965.

42. Rhodes, K.H., "Project Stratofire," SAE Paper 660094, 1966.

43. Anon, "An Evaluation of a 350 CID Compound Vortex Controlled Combustion (CVCC) Powered Chevrolet Impala," Environmental Protection Agency Report 74-13 DWP, October 1973.

44. Tienert, R.M., "Automotive News," June 4, 1973.

45. Heitland, H., "A Status Report on the Pre-Chamber Injection Volkswagen Stratified Charge Engine," First Symposium on Low Pollution Power System Development, October 1973.

46. Coppoc, W.J., E. Mitchell and M. Alperstein, "A Stratified Charge Multifuel Engine Meets 1976 U.S. Standards," 38th mid-year meeting of the API Division of Refining, May 1973.

47. Davis, C.W., E.M. Barber, and E. Mitchell, "Fuel Injection and Positive Ignition–A Basis for Improved Efficiency and Economy," SAE Paper 190A, SAE Summer Meeting, 1960.

48. Mitchell, E., J.M. Cobb, and R.A. Frost, "Design and Evaluation of a Stratified Charge Multifuel Military Engine," SAE Paper 680042, 1968.

49. Mitchell, E., M. Alperstein, J.M. Cobb, and C.H. Faist, "A Stratified Charge Multifuel Military Engine–A Progress Report," SAE Paper 720051, 1972.

50. Cobb, J.M. and E. Mitchell, "Performance Development and Evaluation of the Multifuel Texaco Combustion Process Model 2A042 Military Standard Engine," Final Technical Report to U.S. Army Mobility Command, Contract No. DA-44-009-AMC-991(T) Mod 1, 1967.

51. Witzky, J.E., "Stratification and Air Pollution," Institution of Mechanical Engineers, Paper C136/71, 1971.

52. Hussmann, A.W., F. Kahoun, and R.A. Taylor, "Charge Stratification by Fuel Injection into Swirling Air," Presented at 1962 SAE Combined National Fuels and Lubricants, Power Plant, and Transportation Meeting, 1962.

53. Witzky, J.E., and J.M. Clark, Jr., "A Study of the Swirl Stratified Combustion Principle," SAE Paper 660092, 1966.

54. Willis, D.A. and W.E. Meyer, "Investigation of a Stratified Charge Engine Employing the Air Swirl Induced Stratification Principle," Pennsylvania State University Interim Report to U.S. Army Mobility Command on Contract No. DA-36-034-ORD-3638T, 1964.

55. Witzky, J.E., "Stratified Charge Engines," ASME Paper 63-MD-42, 1963.

56. Bishop, I.N., and Aladar Simko, "A New Concept of Stratified Charge Combustion–The Ford Combustion Process (FCP)," SAE Paper 680041, 1968.

57. Bishop, et al., U.S. Patent 3,315,650, 1967.

58. Simko, A.M., Choma and L.L. Repko, "Exhaust Emission Control by the Ford Programmed Combustion Process," SAE Paper 720052, 1972.

59. Springer, K.J., "An Investigation of Diesel Powered Vehicle Odor and Smoke," Final Report, Automotive Research and Development Section, National Center for Air Pollution Control, U.S. Department of Health, Education and Welfare, 1968.

60. Springer, K.J., "The Low Emission Car for 1975–Enter the Diesel," SAE Paper 739133, 8th Annual Intersociety Energy Conversion Engineering Conference, 1973.

61. Taylor, C.F., "The Internal-Combustion Engine in Theory and Practice," Vol. II, MIT Press, 1968.

62. Ellis, J.R., "Performance Prediction–A Comparison of Various Methods of Estimating the Performance of a Vehicle," *Automobile Engineer*, March 1958.

63. Orshansky Transmission Corp., "Hydromechanical Passenger Car Transmission," Report No. 403, May 1973.

64. Walker, F.H., "Multiturbine Torque Converters," SAE Paper 359C, 1961.

65. Greer, J.W. and G.W. Schulz, "A New Ford 3-Speed Automatic Transmission," SAE Paper 660075, Jan. 1966.

66. Fuchs, J., "350 Turbo Hop-Up," *Hot Rod*, Sept. 1972, pp 114-5.

67. Anonymous, "Overdrives for 4-Speeds and Automatics," *Popular Hotrodding*, Jan. 1973, pp 42-44, 97.

68. B & M Automotive Products, "1973 Technical Journal and Catalog," 9152 Independence Ave., Chatsworth, Cal. 91311.

69. Fairbanks Racing Automatics, "Converters by Fairbanks," 336 Elm, Stamford, Conn. 06902.

70. A-1 Automatic Transmissions, "Catalog," 7239-1/2 Woodley, Van Nuys, Cal. 91406.

71. Chrysler Corp., "Transmissions," Chrysler Institute of Engineering Graduate School Lecture Notes, August 1957.

72. Robert Wilds, Highway Safety Research Institute, Ann Arbor, Michigan, October 9, 1973.

73. "Record for 1973: 200 million tires hipped for Autos," Automotive News, December 3, 1973.

74. Telephone Contact, Mickey Smith, Main Lincoln Mercury, San Antonio, Texas, December 7, 1973.

75. Elliott, D.R., W. K. Klamp, and W.E. Kramer, "Passenger Tire Power Consumption, Paper No. 710575, SAE Transactions 1971, pp 1885-1898.

76. Stiehler, R.D., M.N. Steel, G.G. Richy, J. Mandel, and R.H. Hobbs, "Power Loss and Operating Temperature of Tires," Proceedings, International Rubber Conference, November 8-13, 1959, Washington, D.C., pp 73-83.

77. Curtiss, W.W., "Low Power Loss Tires," Paper 690108.

78. Clark, Samuel K., ed, "Mechanics of Pneumatic Tires," National Bureau of Standards.

79. Floyd, C.W., "Power Loss Testing of Tires," Paper 710576.

80. John Abbott, Staff Engineer, Tire Design, Plant 1, Dept. 460G, Goodyear Tire & Rubber Co., Akron, Ohio, October 26, 1973.

81. Dr. Marion G. Pottinger, Section Manager, Advanced Tire Dynamics, Goodrich Research & Development Center, Brecksville, Ohio, October 15, 1973.

82. Dr. Tomkins, Firestone Tire and Rubber Co., 1200 Firestone Parkway, Akron, Ohio, January 24, 1973.

83. Roberts, G.B., "Power Wasteage in Tires," Proceedings, International Rubber Conference, November 8-13, 1959, Washington, D.C., pp 57-71.

84. Greenshields, R.G., "150 Mpg is Possible," *SAE Journal*, March 1950, pp 34-38.

85. Don Ball, Tire Evaluation, Chelsea Proving Ground, Chrysler Corporation, Chelsea, Michigan, October 15, 1973.

86. Joseph Callahan, Editor, Automotive Industries, August 3, 1973.

87. R.R. Love, Assistant Chief Engineer, Engineering Office, Chelsea Proving Ground, Chrysler Corporation, Chelsea, Michigan, October 15, 1973.

88. Robert Yeager, Group Leader, Tire Design Research & Development, Plant 1, Dept. 460G, Goodyear Tire & Rubber Co., Akron, Ohio, October 26, 1973.

89. Dr. J.D. Walter, Division Manager, Central Research Laboratories, Firestone Tire & Rubber Co., 1200 Firestone Parkway, Akron, Ohio.

90. Dr. R.H. Snyder, Director, Product Development Division, Uniroyal Co., 6600 E. Jefferson Ave., Detroit, Michigan, August 1, 1973, Letter August 6, 1973.

91. Peterson, K.G., and R.E. Rassmussen, "Mechanical Properties of Radial Tires," Paper 730500.

92. Goodenow, Gary, Thomas R. Kolhoff, and Fraser D. Smithson, "Tire-Road Friction Measuring System—A Second Generation," Paper 680137.

93. Kelly, Kent B. and Henry J. Holcomb, "Aerodynamics for Body Engineers," SAE Paper No. 649A.

94. Charles Martyn, Manager, Blue Ribbon Tire Co., San Antonio, Texas, November 16, 1973.

95. Vila, George R., "Impact of the Radial-Ply Tire on U.S. Passenger Replacement Market," *Rubber Age*, September 1972, pp 61-67.

96. *Tire Dealer*, March 1972, p 37.

97. "Rubber Industry: A Glimpse of the Future," *Chemical & Chemical Engineering News*, April 17, 1972, p 10.

98. "Radials Reshuffle Tire-Cord Lineup," *Chemical Week*, January 31, 1973, p 31.

99. *Rubber Age*, October 1973.

100. McCain, George L., "Dynamics of the Modern Automobile," SAE Journal (Transactions), July 1934, pp 248-25.

101. Zierer, W.E. and Maćanlog, J.B., Jr., "Tank Mileage," SAE Journal (Transactions), January 1939, pp 28-34.

102. Andreau, J., "European Streamlining Slashes Air Resistance," SAE Journal (Transactions), April 1939, p 350.

103. Tietjans, O.G., "Economy of Streamlining the Automobile," SAE Journal (Transactions), March 1932, pp 150-152.

104. Lay, W.E., "Is 50 Miles Per Gallon Possible with Correct Streamlining?" Part 1, SAE Journal (Transactions), April 1933, pp 144-356.

105. Lay, W.E., "Is 50 Miles Per Gannon Possible with Correct Streamlining?" Part 2, SAE Journal (Transactions), May 1933, pp 177-186.

106. Horine, M.C., Altman, P., Winter, H.G., Reid, E.G., and Upson, Ralph, "Differences Between Wind-Tunnel and Road Load Conditions," SAE Journal, August 1933, pp 261-267.

107. Wilkins, Gordon, "Next Steps in Drag Reduction," Part 1, Autocar, March 5, 1948, pp 214-216.

108. Wilkins, Gordon, "Next Steps in Drag Reduction," Part II, Autocar, March 12, 1948, pp 240-241.

109. Reid, John P.M., "Aerodynamics of Motoring," Part 1, The Autocar, June 8, 1951, pp 656-659.

110. Reid, J.P. Milford, "Aerodynamics of Motoring," Part 2, The Autocar, August 3, 1951, pp 904-907.

111. Reid, J.P. Milford, "Aerodynamic Fallacies," The Autocar, September 11, 1953, pp 322-323.

112. Hoerner, Sighard F., "Chapter XII, Drag of Land-Borne Vehicles," Fluid-Dynamic Drag 1965, Dr. Ing. S.F. Hoerner, 148 Busteed Drive, Midland Park, New Jersey, 07432, pp 12.1-12.10.

113. Costin, Frank, "A Dozen Years of Aerodynamics," Autosport, December 27, 1968.

114. "How Much is Air Drag Costing You?" Heavy Duty Trucking, October 1969, pp 25-28.

115. "Cutting Wind Drag With Airshield," Heavy Duty Trucking, October 1969, pp 28-30.

116. Wyss, Wally, "The Flying Brick," Car Life, February 1970, pp 28-30.

117. Taborek, Jaroslav J., "Resistance Forces, Mechanics of Vehicles-6," Machine Design, August 8, 1957, pp 101-102.

118. "The Automotive Assembly, Automotive Series, Engineering Design Handbook," AMC Pamphlet AMCP 706-355, February 1965, HQ. USAMC, pp 5-16.

119. Tel. Contact, Mr. Kent B. Kelly, Staff Project Engineer, Advanced Project Engines, Engineering Staff, General Motors Corp., General Motors Technical Center, Warren, Michigan (313) 575-1093.

120. Tel. Contact, Mr. William B. McNulty, Section and Development Supervisor, Performance Analysis Department, Chelsea Proving Ground, Chrysler Corp., Chelsea, Michigan (313) 475-8651, ext. 215.

121. Kelly, Kent B., and Holcomb, Harry J., "Aerodynamics for Body Engines," SAE Paper 649A, January 1963.

122. Huebner, G.J. and Gasser, Donald J., "Energy and the Automobile–General Factors Affecting Vehicle Fuel Consumption," SAE Paper 730518.

123. White, R.G.S., "Rating Scale Estimate Automobile Drag Coefficient," SAE Journal, June 1969, Vol. 77, No. 6, pp 52-53, also SAE Transactions 1969, pp 829-835.

124. *Statistical Issue, Automotive Industries,* March 15, 1960.

125. *1967 Almanac Issue, Automotive News*, April 24, 1967.

126. *1973 Almanac Issue, Automotive News*, November 19, 1973.

127. "What are cars made of?", *Automotive News*, September 10, 1973, p 29.

128. Wolf, Ralph F., "Rubber Use in 1974 Autos," *Rubber Age*, October 1973, pp 36-44.

129. Waddell, Richard L., "How Ford Decides on Plastics–or Not," *Ward's Auto World*, September 1973, p 71.

130. Williamson, Don, "Materials men stress reducing car weight," *Automotive News*, March 26, 1973, pp 29-30.

131. Remarks by Edward N. Cole, General Motors Corporation at the Society of Plastics Engineers, Detroit, Michigan, September 10, 1973.

132. "GM tests 'friendly fenders' and plastic door panels," *Automotive News*, September 24, 1973, pp 10, 16.

133. Waddell, Richard L., "How They're Battling the Bulge-Aluminum–Bumpers Now, Body Parts on the Way," *Ward's Auto World*, September 1973, pp 42-43.

134. Waddell, Richard L., "How They're Battling the Bulge–Steel-'High Strength Low Alloy' Sums it Up," *Ward's Auto World*, September 1973, pp 40-41.

135. Thompson, Donald B., "Auto's Weight Reduction Push is Challenge for Steelmakers," *Industry Week*, September 10, 1973, pp 26-29.

136. "Materials in Design Engineering," Materials Selector Issue, Mid-October 1966-67, Vol. 64, No. 5, pp 231-33.

137. "Plastics Big Savings are in the Plant," *Industry Week*, October 29, 1973, p 81.

138. "Reinforced Sheet Turns Detroit into Stamping Ground for Thermoplastics," *Plastics World*, November 1971, pp 204-05.

139. Waddell, Richard L., "How They're Battling the Bulge-Plastics–Versatility, Weight, Cost Are the Keys," Ward's Auto World, September 1973, pp 44-45.

140. Norbye, Jan P., "Plastic Auto Wheel–Stronger Than Steel, *Popular Science*, October 1973, p 18.

141. "Oil Shortage Spinoff–Automakers run short of Plastic Parts," *Industry Week*, November 26, 1973, p 85.

142. "RP Innovations vie for Auto Market," *Plastics World*, November 1973, p 204.

143. Callahan, Joseph, "Chrysler's Weight Watchers," *Automotive Industries,* October 15, 1972, pp 27-31.

144. Telephone communication August 1, 1973, with Donald J. Funk, Automotive Specialist, Reynolds Metals Co., 16000 Northland Drive, Southfield, Michigan.

145. Cochran, C. Norman, "Aluminum-Villain or Hero in Energy Crisis?" *Automotive Engineering,* June 1973, pp 57-61.

146. Telephone communications, October 1, 1973, Mr. Harry T. Tillotson, Manager, Body Safety Engineering Department, Ford Motor Company, Dearborn, Michigan.

147. Telephone communication, December 4, 1973, Mr. Donald Dunlap, Chief Salesman, Control Foundry Division, General Motors Corporation, Saginaw, Michigan (517) 754-9151.

148. Telephone communications, December 3, 1973, Dr. D.C. Williams, Professor of Metallurgical Engineering, Ohio State University, Columbus, Ohio 43210 (614) 422-5770.

149. "More Aluminum in Autos Seems Certain, but Recycling is Hurdle," *Industry Week*, December 3, 1973, pp 24-26.

150. "Aluminum Work Cut," Washington (AP) dateline, San Antonio Express Newspaper, November 29, 1973.

151. "Auto's Weight Reduction Push is Challenge for Steelmakers," *Industry Week*, September 10, 1973, pp 26-29.

152. Telephone communications,October 5, 1973, Don Horan, Automotive Marketing, U.S. Steel Corp., Detroit, Michigan (313) 354-4511.

153. Telephone communications with Stephen Sikes, General Manager, G.R.T.L. Co., Southfield, Michigan (313) 352-3935.

154. "Tradeoff & Integration Systems Studies," Final Report, Contract DOT-HS-257-2-514, Section 12, Producibility Document No. ASL-TIS-103, 30 June 1973, for U.S. Department of Transportation, National Highway Traffic Safety Administration, 400 Seventh Street, S.W., Washington, D.C. 20590, by AMF Incorporated, Advanced Systems Laboratory, Golota, California 93017.

155. Telephone communication with John R. Newell, Newell Salvage Co., San Antonio, Texas.

156. Conversation with Frank Vitiello, Southwest Research Institute Machine Shop, San Antonio, Texas.

157. Hann, M.M., "Design Considerations when Applying Hydraulic Drives to Vehicles," SAE Paper No. 670740, Society of Automotive Engineers, New York, New York.

158. "Speed Limiting Accessory Drive," Descriptive Bulletin from Borg Warner, Spring Division.

159. Moyer, D.W., "A Simple Transmission for a Deluxe Estate Tractor," SAE Paper 660586, Society of Automotive Engineers, New York, New York.

160. Zahn, Willard R., "Factors Influencing Automotive Air Conditioner Evaporator Optimization," SAE Paper 690131, 1969.

161. Akerman, Joseph R., "Automotive Air Conditioning Systems with Absorption Refrigeration," SAE Paper 710037.

162. Moore, G.H., Jr., and K.B. Bjorkman, "The Automotive Air Conditioning Compressor—A Design Challange," ASHRAE Journal, May 1964.

163. Taylor, G.J., and W.S. Harris, "Cardiac Toxicity of Aerosol Propellants," Journal American Medical Association, 214:1, p 81, 1970.

164. "Automotive News," July 30, 1973, p 16.

165. Beatenbough, P.K., "Engine Cooling Systems for Motor Trucks," SAE – SP-284, 1966.

166. Herfurth, W.R., "Twenty Years Fleet Experience with Engine Temperature Control," SAE – SP-194, 1961.

167. Tacchella, A.A., J.S. Fawcett, and A.N. Anderson, "Dual-Circuit Ebullition Cooling for Automotive Engines," SAE Paper 887B, August 1964.

168. Brabetz, J.C., and D.S. Pike, "Engines Like to be Warm," SAE Paper 891A, August 1964.

169. Kazlauskas, P.P., "Coolant Temperature Effects on Engine Life and Performance," SAE – SP-194, 1961.

170. Geschelin, J., "Dow Chemical Fills Cooling Gap," Automotive Industries, August 15, 1970.

171. "Running Costs of Motor Vehicles as Affected by Road Design and Traffic," Highway Research Board, Program Report 111, Appendix B, p 63.

172. Walter, J.D., "Energy Losses in Tires," Presented at Caltech Seminar Series on Energy Consumption in Private Transportation, December 4, 1973.

BIBLIOGRAPHY

Anderson, W. S., "R & D for Fuel Economy in Automotive Propulsion," Report of Workshop No. 8, Transportation Energy Panel for the Office of Science and Technology (sponsored by USDOT), 19 June 1972, published by U.S. Army Tank-Automotive Command.

Anonymous, "B & M 4th Speed," *Popular Hotrodding,* Jun 1970, p. 24-5.

Automotive Industrial Engineering Study, prepared for the Department of Transportation, National Highway Safety Bureau, Washington, D.C. December 1967. Springfield, Virginia: Clearinghouse, 1968.

"Brief Passenger Car Data, 1961- thru 1969," Ethyl Corporation, Petroleum Chemicals Division, 100 Park Avenue, New York, New York 10017.

Caris, D. F. and R. A. Richardson, "Engine-Transmission Relationship for Higher Efficiency," *SAE Transactions,* V. 61, 1953.

Cleveland, A. E. and I. N. Bishop, "Fuel Economy," *SAE Journ.,* Aug 1960, p. 27-31.

"Cordless Cost Tire Problems Much Like Radial Belted Type", Alliger, G., *SAE Journal,* May 1970, pp. 56-59.

Crook, G. M., "The Binary Controlled Transmission," Description brochure of Gaines M. Crook & Associates, 7252 Remmet Ave., Canoga Park, Cal. 91303, Sept. 1973 (private communication).

"Dana's 10-Speed Semi-Automatic is Electronically Controlled," *Diesel and Gas Turbine Progress,* Sept 1973.

Deimel, A. H., "Torque Converter Performance," *SAE Journ.,* Nov 1948, p. 20-21.

Federal Register, June 28, 1973 or CFR Title 40, Section 85.075-9.

Ferris, D. R., "Temperature Control Can Determine Engine Life, Efficiency, and Economy," SAE-SP-194, 1961.

Ford Marketing Corp., "The C6 Automatic Transmission Training Handbook," Course 7521, V 71S4-L2, Jul 1970.

Forester, D. D., "Temperature Control of Truck Cooling Systems," SAE-SP-194, 1961.

Gish, R. E., J. D. McCullough, J. B. Tetzlaff, and H. T. Mueller, "Determination of True Engine Friction," *SAE Trans,* V66, 1968, p. 649-667.

Hayashi, H., "Heat Dissipating Capacity of Automotive I. C. Engine Lubricating Oil System," SAE Paper 690470, 1970.

Hone Mgf. Co., "1973 Catalog–Hone Overdrive Transmissions," 11748 E. Washington Blvd., Santa Fe Springs, Cal. 90670.

"Industrie Pirelli Has Unveiled a Cordless-Body Tire," *Chemical Week*, June 27, 1973, p. 33.

Kovelan, W. J. and C. C. Moon, "Engine Cooling System Design for Optimum Temperature Control," SAE-SP194, 1961.

Kraus, C. E. and M. E. Gres, "A Transmission System for Single-Shaft Gas Turbine Powered Trucks," Society of Automotive Engineers, Paper No. 730644, June 1973.

Kraus, James H., "Traction Drive Shows Automotive Promise," *Machine Design*, V45n25, 18 Oct. 1973, p. 20-24.

Lapedes, D. E., Forrest, L., Ghahremani, F. G., Hamberg, O., Roessler, W. M., Smalley, W. M., Hinton, M., Lura, T., Moltzer, Jr., "Gas Turbine Engine Production Study," Final Report prepared for Department of Transportation, Office of the Secretary, Office of Systems Development and Technology, Washington, D.C., July 1973. Springfield, Virginia: National Technical Information Service, 1973.

W. A. Mair, "Reduction of Base Drag by Boat-Failed Afterbodies in Low-Speed Flow," *The Aeronautical Quarterly*, Vol. XX, November 1969, pp. 307-320.

New Operating Principals for Tires, *Automotive Engineering*, August 1973, p. 15.

New Process Gear, "Model 2400 Four-Speed Automatic Truck Transmission," Sales brochure.

Pond, J. B., "Borg-Warner Tools-up for New Transmissions," *Auto. Ind.*, Sep 15, 1972, p. 29-33.

Rowland, Roger, "Plastic's Car Inroads Detailed," *Automotive News*, October 22, 1973.

Saal, C., "Performance Prediction Method Proved Valid in Truck Tests," *SAE Journ.*, Oct. 1950, p. 17-21.

SAE Handbook, SAE Standards and Recommended Practices
"J643a – Hydrodynamic Drive Test Code.
J646b – Planetary Gear Terminology.
J645b – Automotive Transmission Terminology.
J648d – Automatic Transmission Control System Terminology.
J649b – Automatic Transmission Functions Terminology.
J647 – Automotive Transmission Diagrams.
J651b – Passenger Car Automatic Transmission Test Code.
J915 – Manual Control Sequence for Automatic Transmissions."

Schmidt, R. C., "Analysis of Diesel Cooling Systems," SAE Paper 887A, August, 1964.

Smith, T., "Six Speed Street/Strip Automatic," *Popular Hotrodding*, May 1971, p. 34-37, 90-92.

Stahman, R. C. and A. H. Rose, Jr., "Emissions from Carbureted and Timed Port Fuel Injected Engines," presented at Annual Meeting of Air Pollution Control Association, Houston, Texas, June 1964.

Telephone communications with Shepher Sikes, General Manager, G.R.T.L. Co., Southfield, Michigan (313) 352-3935.

Transportation Energy Panel, "Research and Development Opportunities for Improved Transportation Energy Usage," Report DOT-TSC-OST-73-14, US DOT, Sept 1972.

Warren, G. B., "Some Factors Influencing Motorcar Fuel Consumption in Service," ASME Paper 65-WA/APC-2, 1965.

Webb, C. R., "The Effect of Gradient on Fuel Consumption and Speed of a Road Vehicle," Institute of Mechanical Engineers, 1952.

APPENDIX A

SPECIFICATIONS OF REFERENCE VEHICLES

Vehicle A

Body No. PM401G3F239716

Carburetor No. 6317S 0813 326

Distributor No. 3656763482

Engine No. 3F239716

Displacement (CID)	318
Bore/Stroke	3.91 X 3.31
HP at RPM	150 at 3600
Torque (ft-lb) at RPM	265 at 2000
Compression Ratio	8.6

Transmission (Automatic)

Gear-Ratios, first	2.45
second	1.45
third	1.00

Rear Axle Ratio: 2.71

General:

Vehicle weight (full gas tank)	4190 lb
Gas tank capacity (gallons)	23
Tire size and manufacturer	G78 X 15 B.F. Goodrich Silvertown (belted)

Other Equipment:

Air Conditioning, Power Steering

Vehicle B

Base No. 3G53H258928

Carburetor No. D3AFRBB3E2

Distributor No. D3AF 12127 AA 3E9

Engine No. 3E14R3 Code K205D

Displacement (CID)	351
Bore/Stroke	4.00 X 3.50
HP at RPM	158 at 3800
Torque (ft-lb) at RPM	264 at 2400
Compression Ratio	8.0

Transmission (Automatic)

Gear-Ratios, first	2.40
second	1.466
third	1.00

Rear Axle Ratio: 2.75

General:	Vehicle weight (full gas tank)	4.270 lb
	Gas tank capacity (gallons)	72
	Tire size and manufacturer	G78 X 15 Goodyear Polyglass Custom Power Cushion

Other Equipment:

Air Conditioning, Power Steering

Vehicle C

Body No. 1L69H3C192648

Carburetor No. 7043114 074 3-BS

Distributor No. 1112168 2J2Q

Engine No. 13C182648–T0323CKL

Displacement (CID)	350
Bore/Stroke	4.00 X 3.48
HP at RPM	145 at 4000
Torque (ft-lb) at RPM	255 at 2400
Compression Ratio	8.5

Transmission (Automatic)

Gear-Ratios,	first	2.52
	second	1.52
	third	1.00

Rear Axle Ratio: 2.73

General:	Vehicle weight (full gas tank)	4360 lb
	Gas tank capacity (gallons)	26
	Tire size and manufacturer	G78 X 15 Uniroyal Fastrak (Glass Belted)

Other Equipment:

Air Conditioning, Power Steering

Vehicle D

Body No. JH23G3B455830

Carburetor No. 6317SA 1063 326

Distributor No. 3656763

Engine No. 3B455830

Displacement (CID)	318
Bore/Stroke	3.91 X 3.31
HP at RPM	150 at 3600
Torque (ft-lb) at RPM	265 at 2000
Compression Ratio	8.6

Transmission (Automatic)

Gear-Ratios, first	2.45
second	1.45
third	1.00

Rear Axle Ratio: 2.76

General:	Vehicle weight (full gas tank)	3490 lb
	Gas tank capacity (gallons)	18
	Tire size and manufacturer	7.35 X 14 Goodyear Power Cushion

Other Equipment:

Air Conditioning, Power Steering

Vehicle E

Body No. 1Q87H3N166120

Carburetor No. 7043112 1013BP2

Distributor No. 1112168 3D2

Engine No. 10424CKW 13N166120

Displacement (CID)	350
Bore/Stroke	4.00 X 3.48
HP at RPM	145 at 4000
Torque (ft-lb) at RPM	255 at 2400
Compression Ratio	8.5

Transmission (Automatic)

Gear-Ratios, first	2.52
second	1.52
third	1.00

Rear Axle Ratio: 2.73

General:	Vehicle weight (full gas tank)	3560 lb
	Gas tank capacity (gallons)	18
	Tire size and manufacturer	F70 X 14 Uniroyal Tiger Paw (belted)

Other Equipment:

Air Conditioning, Power Steering

Vehicle F

Body No. 3F01H176124

Carburetor No. D3AF DC B 3A9

Distributor No. D23F 2G26 12127

Engine No. 3A12G Code K604AG

Displacement (CID)	350
Bore/Stroke	4.00 X 3.50
HP at RPM	159 at 4000
Torque (ft-lb) at RPM	260 at 2400
Compression Ratio	8.0

Transmission (Automatic)

Gear-Ratios, first	2.40
second	1.466
third	1.00

Rear Axle Ratio: 2.75

General:

Vehicle weight (full gas tank)	3470 lb
Gas tank capacity (gallons)	19.5
Tire size and manufacturer	GR78 X 14 Uniroyal Steel Belted Radial (Zeta 40 M)

Other Equipment:

Air Conditioning, Power Steering

APPENDIX B

ACCESSORY POWER TEST DATA

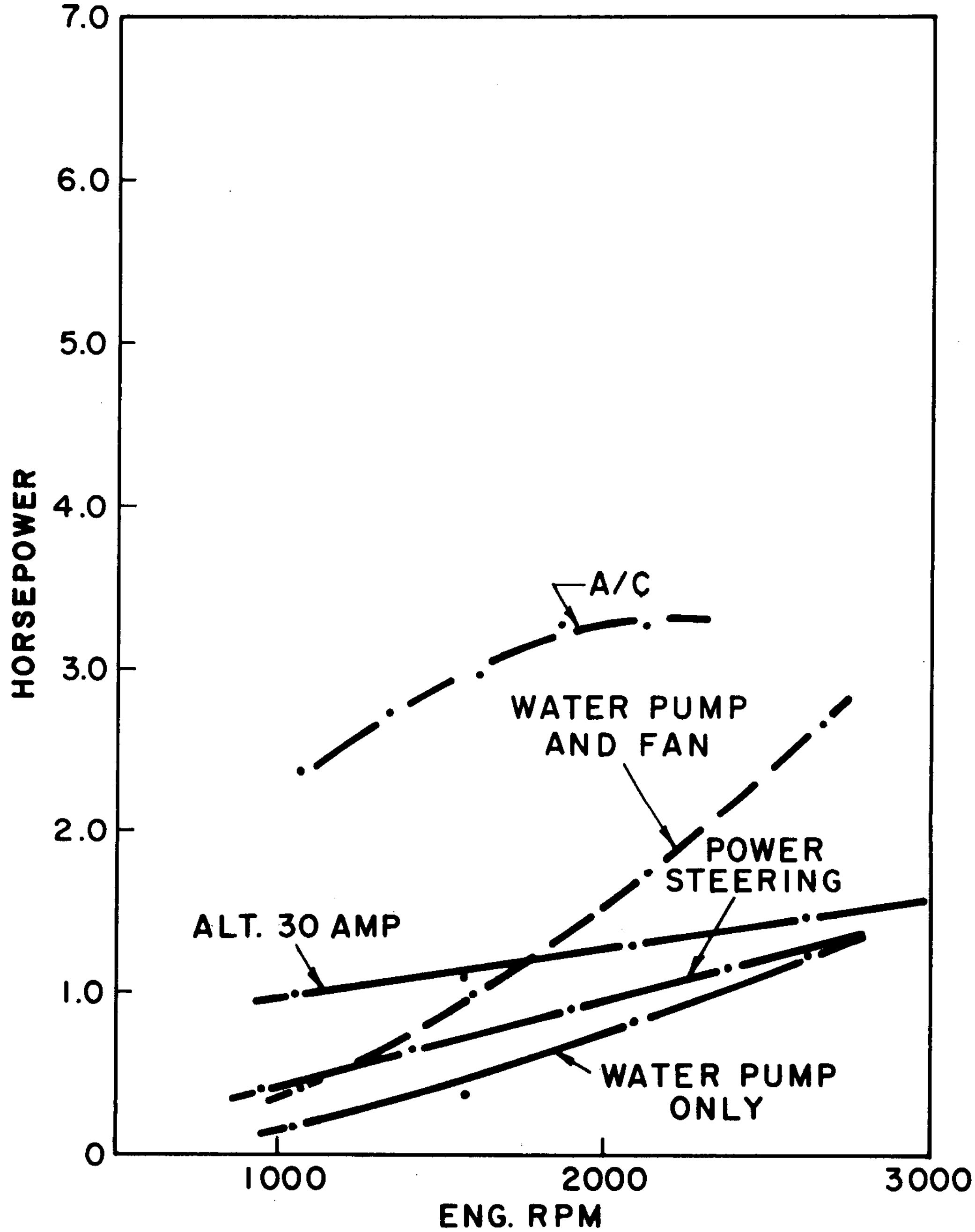


FIGURE B-1. VEHICLE A

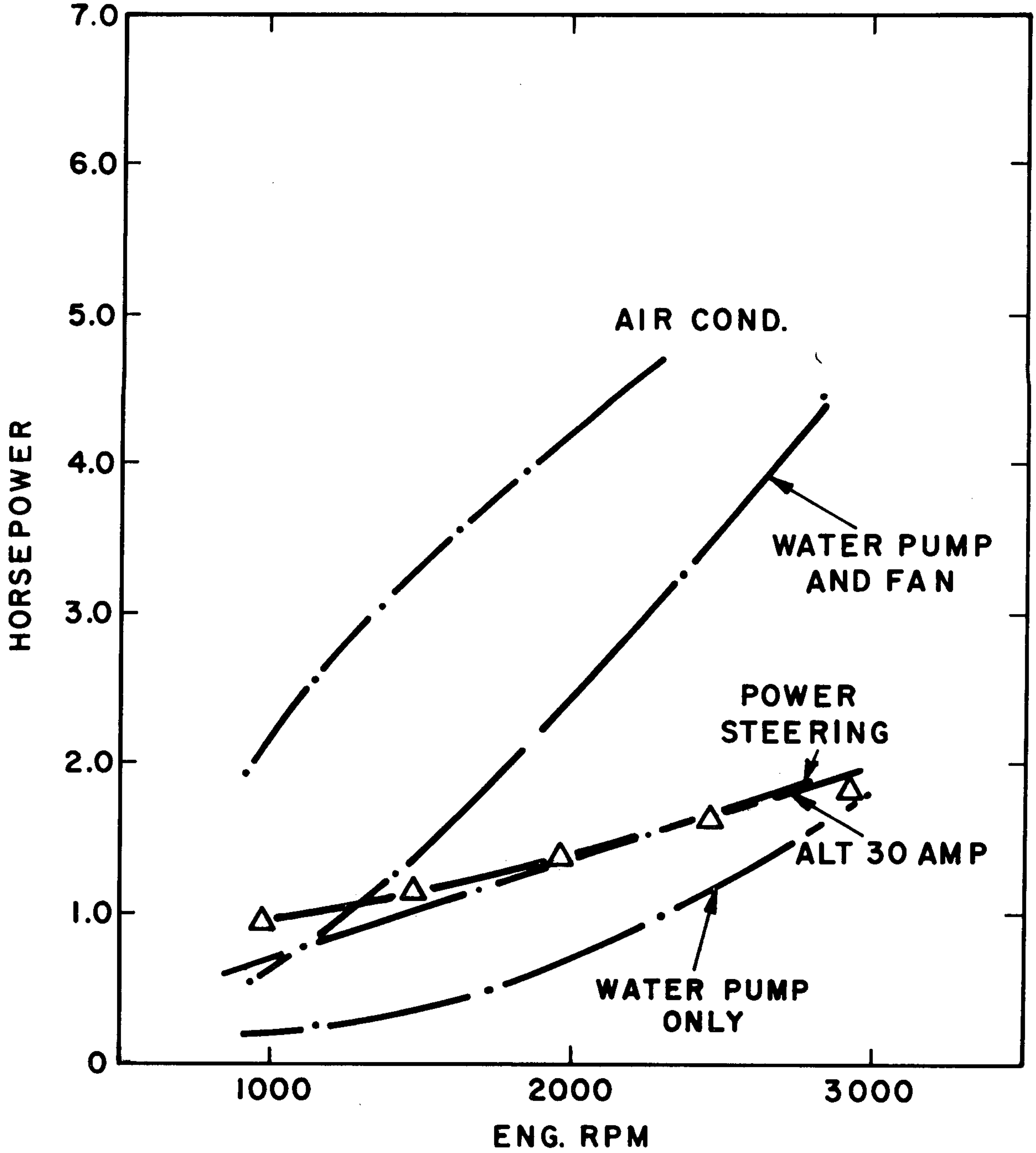


FIGURE B-2. VEHICLE B

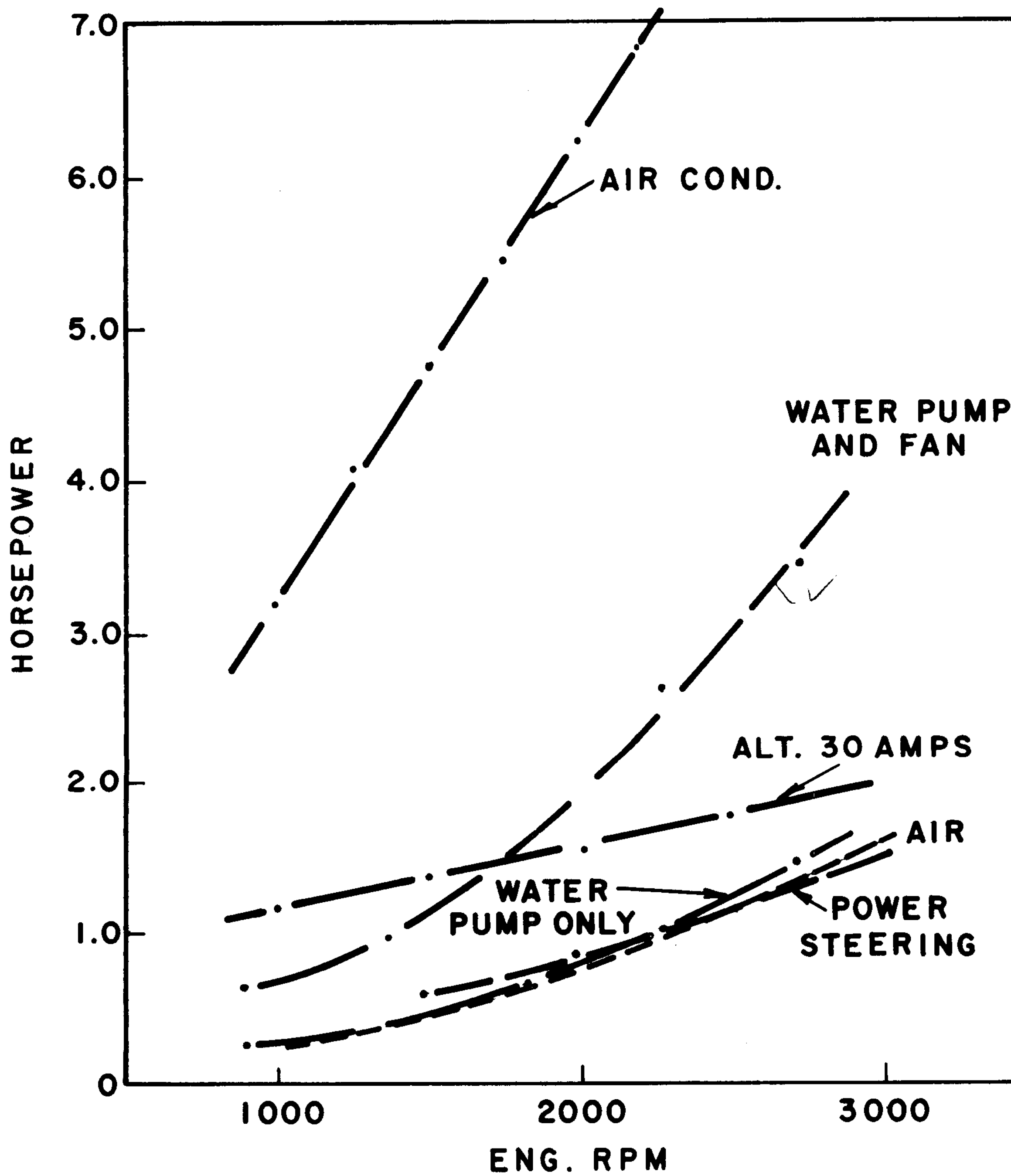


FIGURE B-3. VEHICLE C

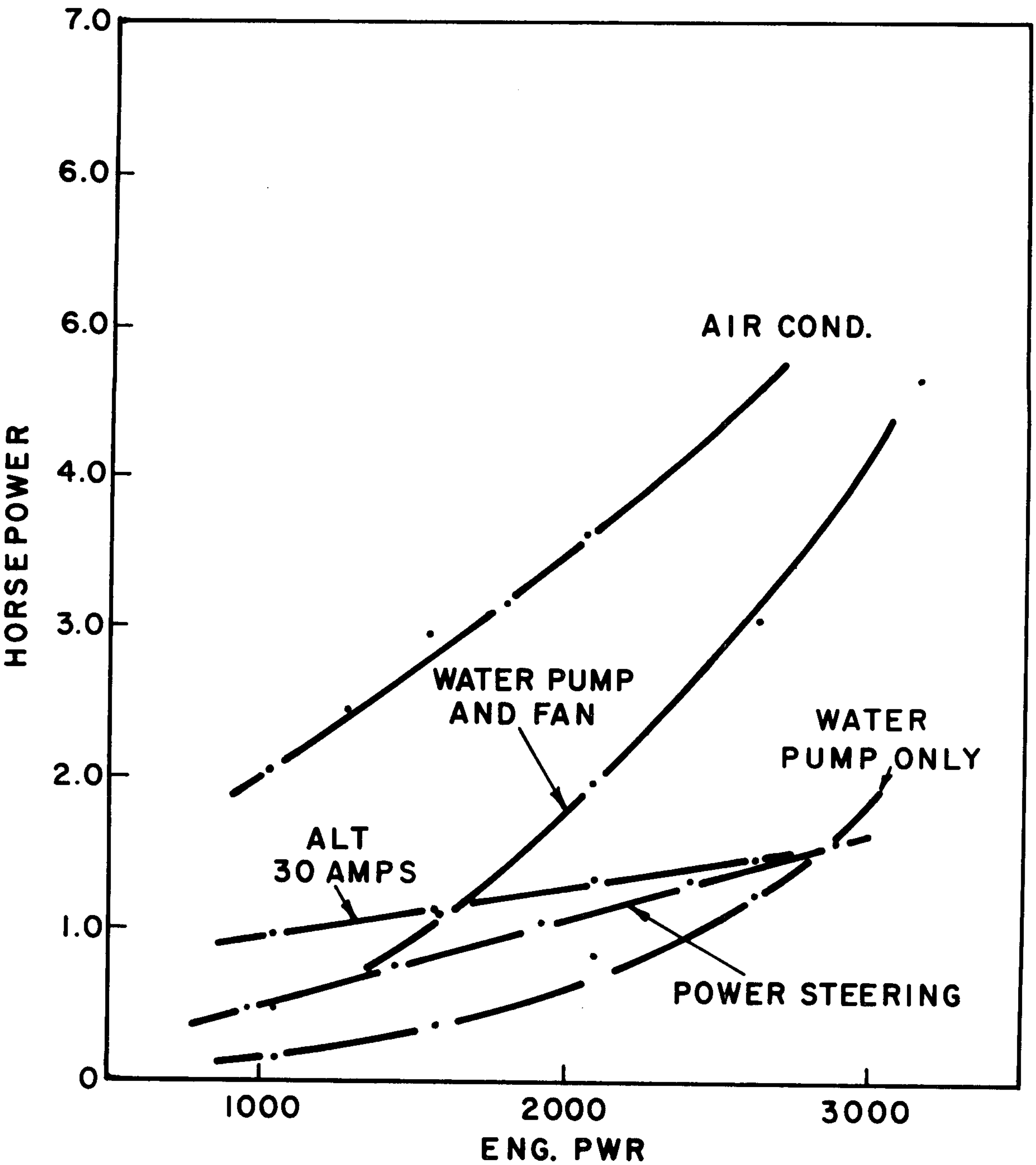


FIGURE B-4. VEHICLE D

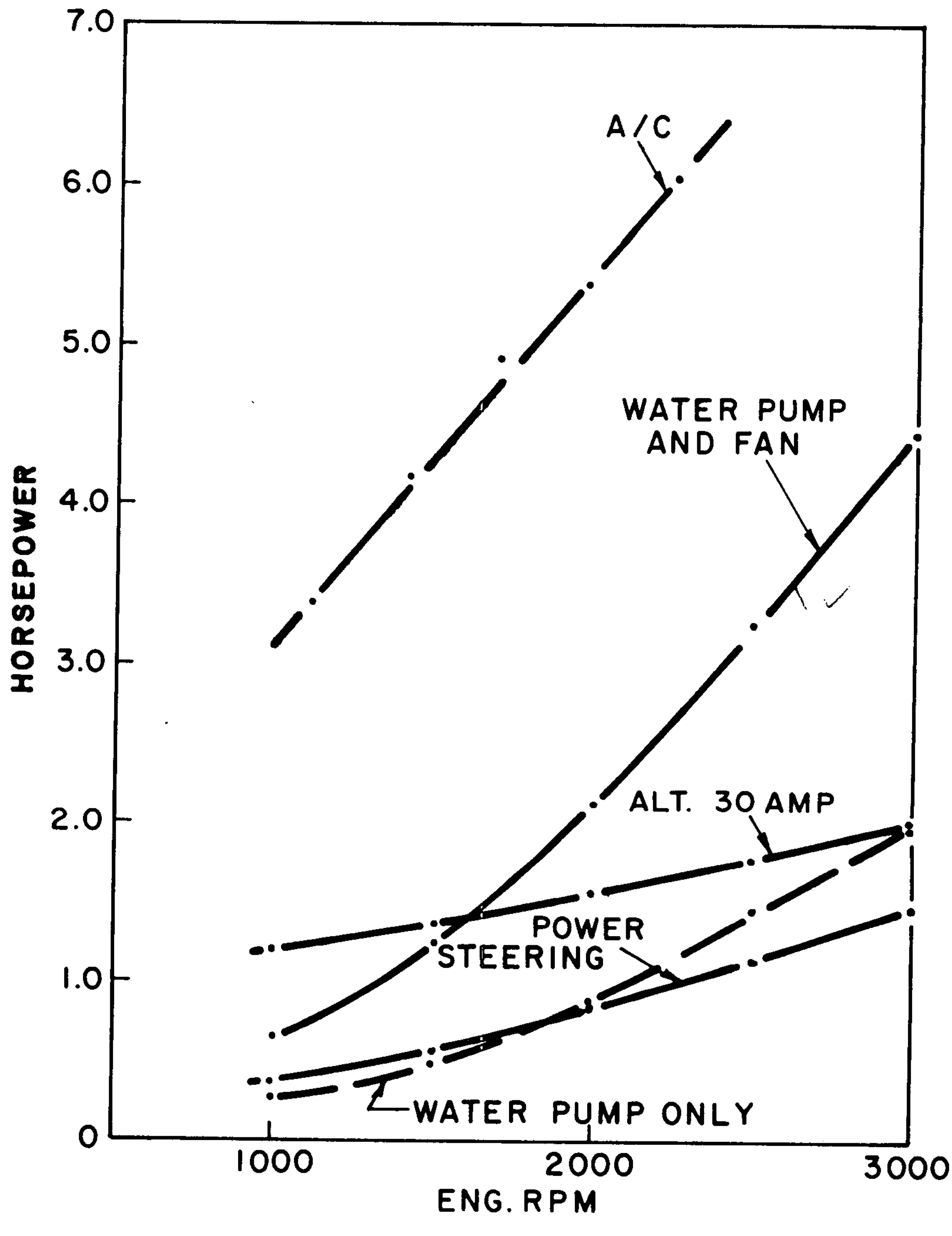


FIGURE B-5. VEHICLE E

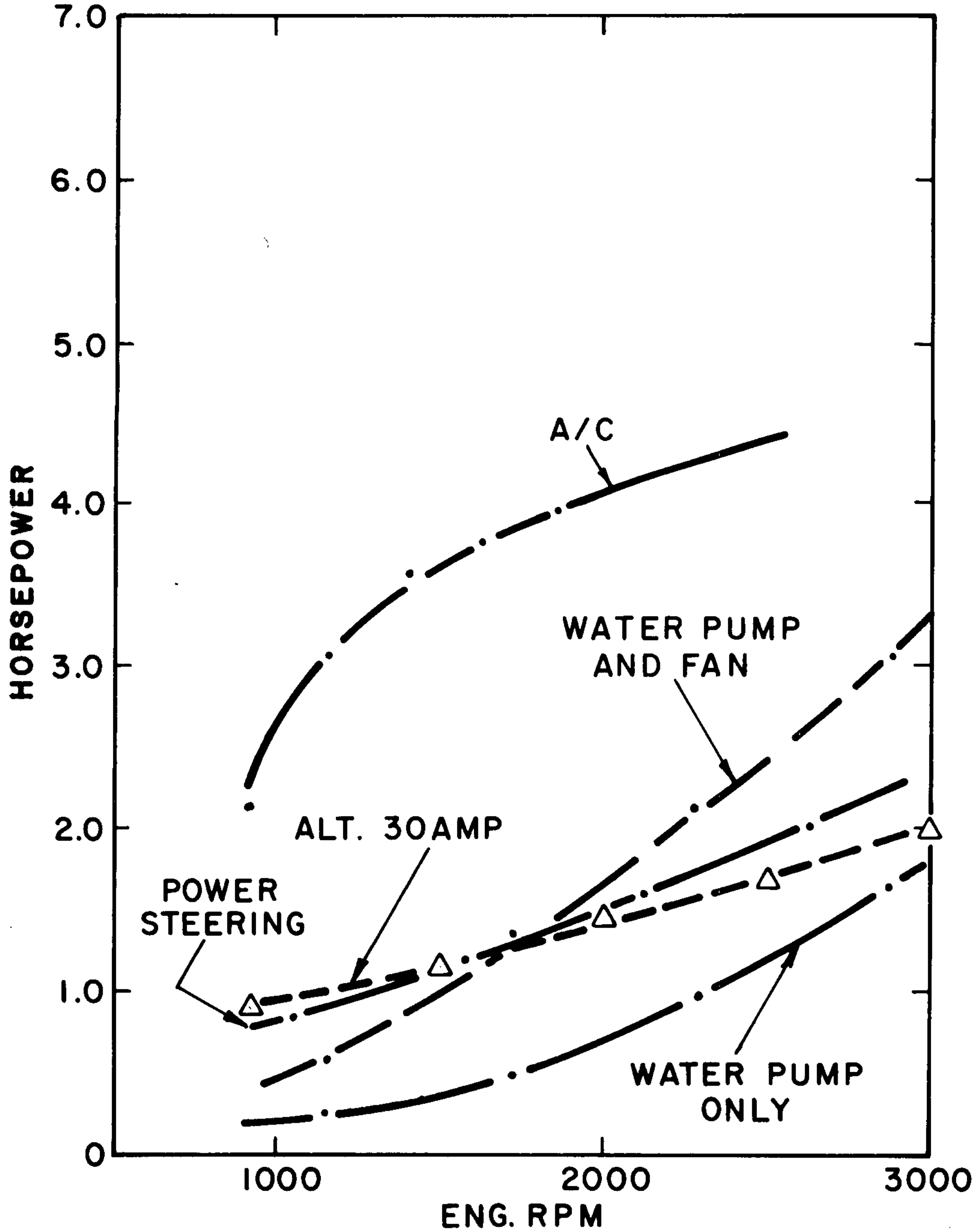


FIGURE B-6. VEHICLE F

APPENDIX C

ROAD TEST DATA

TABLE C-1

Vehicle A speed (mph)	Engine speed (rpm)	Power train operating parameters	
		Manifold vacuum (in. Hg)	Driveshaft speed (rpm)
20	1008	17.8	724
30	1228	17.6	1009
40	1558	16.5	1366
50	1884	15.5	1699
60	2186	13.9	2020
70	2420	12.3	2354

TABLE C-2

Vehicle B speed (mph)	Engine speed (rpm)	Power train operating parameters	
		Manifold vacuum (in. Hg)	Driveshaft speed (rpm)
20	815	15.5	646
30	1128	16.2	1016
40	1433	16.8	1353
50	1740	16.2	1689
60	2060	12.5	2020
70	2390	11.3	2353

TABLE C-3

Vehicle C speed (mph)	Engine speed (rpm)	Power train operating parameters	
		Manifold vacuum (in. Hg)	Driveshaft speed (rpm)
20	1144	16.4	724
30	1156	14.9	1037
40	1478	15.4	1375
50	1819	14.8	1679
60	2143	13.6	2016
70	2505	12.9	2378

TABLE C-4

Vehicle D speed (mph)	Engine speed (rpm)	Power train operating parameters	
		Manifold vacuum (in. Hg)	Driveshaft speed (rpm)
20	987	17.9	764
30	1251	18.5	1098
40	1581	17.9	1457
50	1924	17.1	1822
60	2280	15.0	2168
70	2609	13.9	2501

TABLE C-5

Vehicle E speed (mph)	Engine speed (rpm)	Power train operating parameters	
		Manifold vacuum (in. Hg)	Driveshaft speed (rpm)
20	1010	17.7	897
30	1163	15.6	1066
40	1522	16.6	1419
50	1847	15.6	1771
60	2200	14.8	2114
70	2532	13.8	2445

TABLE C-6

Vehicle F speed (mph)	Engine speed (rpm)	Power train operating parameters	
		Manifold vacuum (in. Hg)	Driveshaft speed (rpm)
20	889	13.0	762
30	1100	13.7	1005
40	1505	14.6	1415
50	1800	11.4	1720
60	2240	11.8	2150
70	2530	12.5	2450

VEHICLE A TESTS

South							North						
Mpg	Mph		Wet/dry	Barometer	A/C pressure		Mpg	Mph		Wet/dry	Barometer	A/C pressure	
	Min	Max			Suction	Discharge		Min	Max			Suction	Discharge
18.86	19	22	71/73	29.73	Off		18.45	19	21	81/88	29.78	Off	
19.13	19	22					18.41	19	22				
18.94	19	22					18.35	19	21				
19.12	19	22					18.52	19	22				
18.73	19	22					18.41	19	22				
18.96 mpg at 20 mph							18.43 mpg at 20 mph						
Composite 18.70 mpg at 20 mph													
24.44	29	32	80/95	29.72	Off		23.27	29	31	79/95	29.76	Off	
24.90	29	32					22.75	29	32				
26.64	29	32					22.53	29	31				
24.98	29	32					23.58	29	32				
24.19	29	32					22.97	29	32				
25.03 mpg at 30 mph							23.02 mpg at 30 mph						
Composite 24.03 mpg at 30 mph													
24.21	38	42	70/68	29.69	Off		20.34	39	42	76/82	29.70	Off	
23.09	38	42					20.09	39	42				
23.26	39	42					20.08	39	42				
23.23	39	43					20.10	38	41				
23.67	39	42					20.45	38	41				
23.49 mpg at 40 mph							20.21 mpg at 40 mph						
Composite 21.85 mpg at 70 mph													
21.47	49	51	75/81	29.82	Off		18.60	49	51	74/83	29.82	Off	
21.45	49	51					18.50	49	52				
21.52	49	51					18.64	49	51				
21.95	49	51					18.66	49	51				
21.46	49	51					18.36	49	52				
21.57 mpg at 50 mph							18.55 mpg at 50 mph						
Composite 20.06 mpg at 50 mph													

VEHICLE A TESTS (Cont'd)

South							North						
Mpg	Mph		Wet/dry	Barometer	A/C pressure		Mpg	Mph		Wet/dry	Barometer	A/C pressure	
	Min	Max			Suction	Discharge		Min	Max			Suction	Discharge
18.57	59	61	75/84	29.81	Off		17.29	59	61	76/85	29.78	Off	
18.63	59	61					17.55	59	61				
18.93	59	61					17.31	59	61				
18.84	59	61					17.40	59	61				
18.57	59	61					17.82	59	61				
18.71 mpg at 60 mph							17.47 mpg at 60 mph						
Composite 18.09 mpg at 60 mph													
16.55	69	71	75/86	29.76	Off		15.51	69	71	75/84	29.74	Off	
16.44	69	71					15.67	69	71				
16.89	69	71					15.63	69	71				
16.57	69	70					15.90	68	70				
16.86	68	70					15.95	68	70				
16.66 mpg at 70 mph							15.73 mpg at 70 mph						
Composite 16.20 mpg at 70 mph													
18.74	19	22	81/88	29.78	48	150	16.84	19	22	81/94	29.78	46	152
17.76	19	22			46	145	16.95	19	21			48	155
18.45	19	22			47	152	16.82	19	21			46	152
17.89	18	22			47	152	16.21	19	23			48	155
18.65	19	22			48	150	16.64	19	22			48	155
18.30 mpg at 20 mph							16.69 mpg at 20 mph						
Composite 17.50 mpg at 20 mph													
21.59	29	32	73/81	29.68	42	180	19.19	29	32	73/81	29.68	42	180
20.27	29	32			40	180	18.64	28	32			40	180
20.24	29	32			41.5	180	18.89	29	31			40	180
20.18	29	32			41	180	18.80	29	32			41	180
19.77	29	32			40	180	18.79	29	32			40	180
20.41 mpg at 30 mph							18.86 mpg at 30 mph						
Composite 19.64 mpg at 30 mph													

VEHICLE A TESTS (Cont'd)

South							North						
Mpg	Mph		Wet/dry	Barometer	A/C pressure		Mpg	Mph		Wet/dry	Barometer	A/C pressure	
	Min	Max			Suction	Discharge		Min	Max			Suction	Discharge
19.45	40	42	76/82	29.70	35	150	18.36	39	41	83/89	29.70	34	145
19.92	39	42			34	150	18.25	39	42			34	150
19.81	38	42			35	150	18.54	39	42			34	150
19.74	39	42			35	150	18.53	39	42			34	150
19.92	39	42			35	150	18.45	39	42			34	150
19.77 mpg at 40 mph							18.43 mpg at 40 mph						
Composite 19.10 mpg at 40 mph													
18.78	49	51	74/83	29.82	22	175	16.83	49	51	75/84	29.81	21	175
18.72	49	51			21	175	16.80	49	51			21	180
18.59	49	51			22	175	17.11	49	51			21	180
18.60	49	51			21	175	16.80	49	51			21	180
18.82	49	51			22	180	17.16	49	51			22	175
18.70 mpg at 50 mph							16.94 mpg at 50 mph						
Composite 17.82 mpg at 50 mph													
16.59	60	62	76/85	29.78	21	180	15.66	59	61	76/85	29.76	20	180
16.77	59	61			20	185	16.01	59	61			21	180
16.61	59	61			20	180	15.44	59	61			20	175
16.66	59	61			20	175	15.36	59	61			20	180
17.06	59	61			20	175	15.60	59	61			20	175
16.74 mpg at 60 mph							15.61 mpg at 60 mph						
Composite 16.18 mpg at 60 mph													
14.83	69	71	75/84	29.74	20	175	14.29	69	71	75/86	29.74	20	180
15.08	69	71			20	180	14.66	69	71			20	180
14.91	69	71			20	180	14.70	69	71			20	180
14.74	68	71			20	175	14.60	69	71			20	180
14.75	68	71			20	175	14.71	68	71			20	175
14.86 mpg at 70 mph							14.59 mpg at 70 mph						
Composite 14.73 mpg at 70 mph													

VEHICLE B TESTS

South							North						
Mpg	Mph		Wet/dry	Barometer	A/C pressure		Mpg	Mph		Wet/dry	Barometer	A/C pressure	
	Min	Max			Suction	Discharge		Min	Max			Suction	Discharge
18.44	21	25	67/79	29.84	Off		17.96	21	23	68/81	29.81	Off	
18.72	21	25					17.82	21	24				
18.72	21	24					17.08	20	23				
17.95	21	24					17.41	21	23				
17.52	21	24					17.41	21	23				
18.27 mpg at 20 mph							17.54 mpg at 20 mph						
Composite 17.90 mpg at 20 mph													
19.56	29	33	65/80	29.79	Off		18.85	30	32	67/82	29.78	Off	
19.82	29	32					19.12	29	33				
19.80	29	33					19.00	29	33				
20.06	29	33					19.38	29	32				
20.07	29	33					18.54	29	33				
19.86 mpg at 30 mph							18.98 mpg at 30 mph						
Composite 19.42 mpg at 30 mph													
20.55	39	43	52/54	29.81	Off		19.60	39	43	64/69	29.82	Off	
21.12	40	43					19.64	39	43				
21.13	39	43					19.77	39	42				
20.73	39	43					20.29	39	42				
21.03	38	43					19.67	39	44				
20.91 mpg at 40 mph							19.79 mpg at 30 mph						
Composite 20.35 mpg at 40 mph													
19.14	48	51	69/76	29.83	Off		18.63	49	52	67 /76	29.82	Off	
19.57	49	52			Off		18.96	50	53			Off	
19.38	50	53			Off		18.71	50	53			Off	
19.06	50	53			Off		18.77	49	54			Off	
19.48	49	54			Off		18.99	48	53			Off	
19.33 mpg at 50 mph							18.81 mpg at 50 mph						
Composite 19.07 mpg at 50 mph													

VEHICLE B TESTS (Cont'd)

South							North						
Mpg	Mph		Wet/dry	Barometer	A/C pressure		Mpg	Mph		Wet/dry	Barometer	A/C pressure	
	Min	Max			Suction	Discharge		Min	Max			Suction	Discharge
16.71	59	62	65/79	29.80	Off		16.68	59	62	66/81	29.78	Off	
16.17	59	62					16.15	59	62				
15.51	60	63					15.87	60	63				
15.72	59	62					16.04	60	62				
15.63	59	63					16.15	59	63				
15.95 mpg at 60 mph							16.18 mpg at 60 mph						
Composite 16.06 mpg at 60 mph													
14.38	69	73	65/81	29.75	Off		14.51	69	73	66/82	29.73	Off	
14.95	69	70					14.91	69	71				
14.17	69	72					14.23	69	72				
14.19	70	72					14.85	69	72				
14.96	69	73					14.01	69	73				
14.53 mpg at 70 mph							14.50 mpg at 70 mph						
Composite 14.51 mpg at 70 mph													
16.73	19	21	68/81	29.81	32	165	15.95	19	23	65/80	29.79	31	155
16.76	19	22			30	160	15.84	19	21			30	155
16.93	20	22			31	160	16.04	20	22			31	155
16.92	20	22			31	160	15.53	20	22			30	160
17.31	20	22			31	160	15.37	20	22			30	155
16.93 mpg at 20 mph							15.75 mpg at 20 mph						
Composite 16.34 mpg at 20 mph													
19.23	30	33	67/82	29.78	30	170	18.11	29	36	65/79	29.78	30	165
19.47	29	34			30	160	18.30	29	34			30	160
19.50	29	33			30	160	18.26	29	32			30	160
19.26	30	33			30	160	18.54	30	33			30	160
19.00	30	33			30	155	18.12	29	34			30	160
19.29 mpg at 30 mph							18.27 mpg at 30 mph						
Composite 18.78 mpg at 30 mph													

VEHICLE B TESTS (Cont'd)

South							North						
Mpg	Mph		Wet/dry	Barometer	A/C pressure		Mpg	Mph		Wet/dry	Barometer	A/C pressure	
	Min	Max			Suction	Discharge		Min	Max			Suction	Discharge
19.37	39	44	64/69	29.82	30	125	18.96	39	42	64/76	29.83	29	120
19.73	39	43			30	125	18.47	39	42			30	125
19.89	39	43			30	130	18.52	39	42			30	130
19.57	39	43			29	135	19.15	39	42			31	150
19.66	39	43			30	150	18.80	39	43			31	150
19.64 mpg at 40 mph							18.78 mpg at 40 mph						
Composite 19.21 mpg at 40 mph													
17.48	49	52	67/76	29.82	30	155	17.32	49	54	69/79	29.81	31	155
17.37	50	54			30	160	17.29	50	54			31	160
17.14	49	54			30	160	17.69	50	53			31	160
17.48	49	53			30	160	17.38	49	53			31	160
17.80	48	54			30	160	16.53	49	53			31	160
17.45 mpg at 50 mph							17.24 mpg at 50 mph						
Composite 17.35 mpg at 50 mph													
15.17	59	62	66/81	29.78	31	155	15.05	60	64	65/81	29.75	31	160
15.41	59	63			31	155	14.49	60	64			31	155
15.23	59	63			31	155	15.43	59	62			31	155
15.17	59	62			30	150	14.86	59	63			31	160
14.86	59	62			31	155	15.21	59	62			31	155
15.17 mpg at 60 mph							15.01 mpg at 60 mph						
Composite 15.09 mpg at 60 mph													
13.92	69	73	66/82	29.73	31	155	13.82	69	72	66/82	29.70	31	160
14.07	70	72			31	160	13.44	68	73			31	160
13.80	70	73			31	160	13.49	69	73			31	160
13.90	68	73			31	160	13.71	68	73			31	160
13.87	69	73			31	155	13.77	68	73			31	160
13.91 mpg at 70 mph							13.65 mpg at 70 mph						
Composite 13.78 mpg at 70 mph													

VEHICLE C TESTS

South							North						
Mpg	Mph		Wet/dry	Barometer	A/C pressure		Mpg	Mph		Wet/dry	Barometer	A/C pressure	
	Min	Max			Suction	Discharge		Min	Max			Suction	Discharge
13.61	20	23	79/83	29.71	Off		13.56	21	23	76/82	29.72	Off	
13.64	21	23					13.58	19	21				
13.79	19	21					13.75	19	21				
13.77	19	21					13.83	19	21				
13.75	20	22					13.71	20	22				
13.71 mpg at 20 mph							13.69 mpg at 20 mph						
Composite 13.70 mpg at 20 mph													
17.88	29	32	80/87	29.71	Off		17.39	29	31	81/90	29.69	Off	
18,09	28	31					17.56	30	32				
17.61	29	31					17.90	29	31				
17.35	29	32					17.77	29	31				
17.59	29	31					17.67	29	31				
17.70 mpg at 30 mph							17.66 mpg at 30 mph						
Composite 17.68 mpg at 30 mph													
17.14	39	41	79/89	29.65	Off		19.86	39	41	80/91	29.64	Off	
19.02	39	41					19.99	39	41				
19.59	39	41					19.00	39	41				
19.26	39	41					19.26	39	41				
17.59	39	41					18.71	39	41				
18.52 mpg at 40 mph							19.36 mpg at 40 mph						
Composite 18.94 mpg at 40 mph													
17.40	49	52	69/71		Off		14.61	49	52	69/71		Off	
16.97	49	53					14.99	49	51				
17.95	49	52					14.50	49	50				
17.49	49	52					14.73	49	51				
17.89	49	52					14.42	49	51				
17.54 mpg at 50 mph							14.65 mpg at 50 mph						
Composite 16.10 mpg at 50 mph													

VEHICLE C TESTS (Cont'd)

South							North						
Mpg	Mph		Wet/dry	Barometer	A/C pressure		Mpg	Mph		Wet/dry	Barometer	A/C pressure	
	Min	Max			Suction	Discharge		Min	Max			Suction	Discharge
15.28	59	62	66/71	29.29	Off		12.93	59	62	66/71	29.29	Off	
15.41	59	62					13.16	59	62				
15.60	59	62					13.15	59	62				
16.42	59	63					13.17	59	62				
15.95	59	60					13.21	59	62				
15.73 mpg at 60 mph							13.12 mpg at 60 mph						
Composite 14.43 mpg at 60 mph													
13.60	69	72	70/79	29.75	Off		11.77	69	72	70/79	29.75	Off	
14.03	69	72					12.24	69	72				
14.50	69	72					12.23	69	72				
14.82	69	73					12.45	69	71				
14.20	69	72					11.67	69	72				
14.23 mpg at 70 mpg							12.07 mpg at 70 mph						
Composite 13.15 mpg at 70 mph													
12.21	20	22	76/82	29.72	37	160	12.04	19	21	80/87	29.71	40	170
11.79	19	21			35	155	12.18	19	21			38	170
12.10	19	21			34	150	12.14	19	21			37	180
12.60	19	21			36	160	11.78	19	21			36	175
12.43	19	21			35	165	12.20	19	21			36	170
12.23 mpg at 20 mph							12.07 mpg at 20 mph						
Composite 12.15 mpg at 20 mph													
16.80	30	31	81/90	29.69	38	165	15.66	29	31	80/89	29.65	36	165
17.16	29	31			37	165	15.40	29	31			37	175
17.15	29	32			36	165	16.12	29	31			35	175
17.03	29	31			35	160	15.87	29	31			39	175
16.74	29	31			36	165	15.65	28	31			38	175
16.98 mpg at 30 mph							15.74 mpg at 30 mph						
Composite 16.36 mpg at 30 mph													

VEHICLE C TESTS (Cont'd)

South							North						
Mpg	Mph		Wet/dry	Barometer	A/C pressure		Mpg	Mph		Wet/dry	Barometer	A/C pressure	
	Min	Max			Suction	Discharge		Min	Max			Suction	Discharge
15.65	39	41	80/91	29.64	34	160	16.73	39	41	78/88	29.63	38	160
16.00	39	41			38	165	16.19	39	41			38	160
15.63	39	41			38	165	16.13	39	41			38	160
15.89	39	41			36	160	15.87	38	42			37	160
15.61	39	41			36	160	14.94	39	41			38	160
15.76 mpg at 40 mph							15.97 mpg at 70 mph						
Composite 15.87 mpg at 40 mph													
15.60	50	50	66/71	29.79	31	115	13.55	49	53	66/71	29.79	32	120
16.11	50	51			31	118	13.45	49	52			31	115
16.28	51	53			31	115	13.45	49	52			31	118
15.75	50	52			31	113	14.00	49	52			31	115
16.33	49	52			31	119	13.58	49	52			32	123
16.01 mpg at 50 mph							13.61 mpg at 50 mph						
Composite 14.81 mpg at 50 mph													
14.67	59	62	70/79	29.75	31	130	11.61	59	62	70/79	29.75	32	128
14.89	59	62			31	125	12.16	59	62			31	125
14.62	59	63			34	125	12.33	59	62			31	126
14.46	59	62			33	135	12.44	59	63			34	120
14.60	59	62			33	128	12.19	59	62			32	120
14.65 mpg at 60 mph							12.15 mpg at 60 mph						
Composite 13.38 mpg at 60 mph													
13.49	69	71	72/82	29.73	32	143	11.67	69	73	72/82	29.73	34	138
13.48	69	72			33	145	11.20	69	72			31	150
13.29	69	72			34	148	11.44	69	72			32	125
13.14	69	72			32	143	11.38	69	72			32	150
13.38	69	72			33	150	11.55	69	72			33	146
13.36 mpg at 70 mph							11.45 mpg at 70 mph						
Composite 12.41 mpg at 70 mph													

VEHICLE D TESTS

South							North						
Mpg	Mph		Wet/dry	Barometer	A/C pressure		Mpg	Mph		Wet/dry	Barometer	A/C pressure	
	Min	Max			Suction	Discharge		Min	Max			Suction	Discharge
19.00	18	22	83/77	29.68	Off		19.26	18	22	89/79	29.66	Off	
18.98	19	22					19.60	19	21				
19.42	19	22					19.35	19	22				
18.92	19	22					19.64	19	22				
19.17	19	22					19.47	18	22				
19.10 mpg at 20 mph							19.46 mpg at 20 mph						
Composite 19.29 mpg at 20 mph													
24.81	29	31	79/97	29.97	Off		23.42	29	32	79/93	29.58	Off	
25.33	29	32					24.13	29	32				
24.96	29	32					23.74	29	32				
24.37	28	32					23.61	29	32				
24.99	28	32					23.91	28	32				
24.89 mpg at 30 mph							23.76 mpg at 30 mph						
Composite 24.33 at 30 mph													
25.26	39	41	78/93	29.65	Off		23.79	39	41	79/93	29.63	Off	
25.78	39	42					22.71	39	42				
24.60	39	42					23.68	39	42				
24.89	39	42					23.50	39	42				
24.66	38	42					23.46	39	42				
25.04 mpg at 40 mph							23.43 mpg at 40 mph						
Composite 24.24 mpg at 40 mph													
22.27	49	52	74/75	29.70	Off		21.23	49	52	73/74	29.70	Off	
23.43	49	52					21.10	49	52				
23.43	49	52					21.09	49	52				
22.93	48	52					21.22	49	52				
22.72	49	52					20.58	49	52				
22.96 mpg at 50 mph							21.04 mpg at 50 mph						
Composite 22.0 mpg at 50 mph													

VEHICLE D TESTS (Cont'd)

South							North						
Mpg	Mph		Wet/dry	Barometer	A/C pressure		Mpg	Mph		Wet/dry	Barometer	A/C pressure	
	Min	Max			Suction	Discharge		Min	Max			Suction	Discharge
19.10	59	62	73/74	29.71	Off		18.40	59	62	77/80	29.71	Off	
19.32	59	62					18.79	59	62				
19.68	58	62					18.89	59	62				
19.74	59	62					18.18	59	62				
19.76	59	62					18.38	59	62				
19.52 mpg at 60 mph							18.53 mpg at 60 mph						
Composite 19.03 mpg at 60 mph													
16.54	69	72	81/85	29.72	Off		16.81	68	72	81/87	29.72	Off	
17.13	69	72					17.00	69	72				
16.76	69	72					17.61	69	72				
17.28	69	72					16.90	69	72				
17.23	69	72					16.57	69	72				
16.99 mph at 70 mph							16.98 mpg at 70 mph						
Composite 16.985 mpg at 70 mph													
18.91	19	22	87/79	29.66	38	200	19.65	19	21	78/92	29.65	38	200
18.56	19	22			38	200	18.57	19	22			38	210
18.51	19	22			38	210	19.41	19	22			38	210
18.11	19	22			38	205	19.14	19	22			39	215
19.24	19	22			40	215	18.75	19	22			39	220
18.67 mpg at 20 mph							19.10 mpg at 20 mph						
Composite 18.89 mpg at 20 mph													
20.38	29	32	79/93	29.58	33	200	20.37	29	32	74/87	29.59	33	210
21.25	29	32			33	210	20.41	29	32			33	210
21.17	29	32			34	220	20.21	29	32			31	210
21.80	28	32			33	225	20.68	29	32			31	210
21.35	29	32			33	220	19.19	29	32			31	215
21.19 mpg at 30 mph							20.17 mpg at 30 mph						
Composite 20.18 mpg at 30 mph													

VEHICLE D TESTS (Cont'd)

South							North						
Mpg	Mph		Wet/dry	Barometer	A/C pressure		Mpg	Mph		Wet/dry	Barometer	A/C pressure	
	Min	Max			Suction	Discharge		Min	Max			Suction	Discharge
19.93	39	42	79/93	29.63	29	225	19.96	39	42	79/95	29.61	30	220
20.42	39	41			30	225	20.13	40	41			30	225
20.70	39	42			30	225	20.21	39	42			31	230
20.62	39	42			30	225	19.96	39	42			30	230
19.45	39	42			30	225	19.76	39	42			32	230
20.22 mpg at 40 mph							20.00 mpg at 40 mph						
Composite 20.11 mpg at 40 mph													
19.49	49	52	73/74	29.70	25	170	18.43	49	52	73/74	29.71	24	155
19.85	49	52			25	170	18.70	49	52			25	175
19.85	49	52			25	165	18.51	49	52			26	175
19.98	49	52			20	180	18.22	49	52			24	150
19.50	49	52			24	150	18.61	49	52			24	160
19.73 mpg at 50 mph							18.49 mpg at 50 mph						
Composite 19.11 mpg at 50 mph													
17.19	59	62	77/80	29.71	25	200	16.87	59	62	81/85	29.72	26	195
16.89	59	62	77/80		26	195	17.29	59	62			26	180
17.24	59	62			26	190	16.68	59	62			26	190
17.50	59	62			25	185	17.10	59	62			25	190
17.46	59	62			27	200	16.89	59	62			25	190
17.26 mpg at 60 mph							16.97 mpg at 60 mph						
Composite 17.12 mpg at 60 mph													
15.15	69	72	81/87	29.72	26	215	15.20	69	72	82/89	29.72	24	200
15.75	69	72			25	200	15.91	69	72			25	185
15.82	69	72			25	200	15.70	69	72			25	180
15.76	69	72			26	200	15.68	69	72			26	200
15.83	69	72			25	195	15.45	69	72			25	195
15.66 mpg at 70 mph							15.59 mpg at 70 mph						
Composite 15.63 mpg at 70 mph													

VEHICLE E TESTS

South							North						
Mpg	Mph		Wet/dry	Barometer	A/C pressure		Mpg	Mph		Wet/dry	Barometer	A/C pressure	
	Min	Max			Suction	Discharge		Min	Max			Suction	Discharge
14.138	19	22	74/75	29.62	Off		14.039	19	22	75/76	29.62	Off	
14.310	19	22					13.738	19	22				
13.928	18	22					13.812	19	22				
14.378	19	22					13.051	19	22				
14.176	19	22					13.768	19	22				
14.186 mpg at 20 mph							13.682 mpg at 20 mph						
Composite 13.934 mpg at 20 mph													
16.782	29	32	78/80	29.63	Off		17.969	29	32	77/82	29.63	Off	
17.541	28	32					17.714	29	32				
17.992	28	32					17.623	29	32				
17.545	29	32					17.867	29	32				
17.791	29	32					17.884	29	32				
17.530 mpg at 30 mph							17.811 mpg at 30 mph						
Composite 17.671 mpg at 30 mph													
17.539	39	42	78/86	29.62	Off		17.751	38	42	78/86	29.59	Off	
17.988	39	42					18.299	38	42				
17.962	39	42					18.359	39	42				
18.073	38	43					18.545	39	42				
17.984	39	42					18.337	39	42				
17.909 mpg at 40 mph							18.258 mpg at 40 mph						
Composite 18.084 mpg at 40 mph													
18.48	49	52	82/87	29.67	Off		16.93	48	52	82/87	29.67	Off	
19.05	48	50					16.98	48	50				
18.94	48	50					17.30	48	50				
19.11	48	50					16.92	48	50				
18.84	48	50					17.20	48	51				
18.88 mpg at 50 mph							17.07 mpg at 50 mph						
Composite 17.98 mpg at 50 mph													

VEHICLE E TESTS (Cont'd)

South							North						
Mpg	Mph		Wet/dry	Barometer	A/C pressure		Mpg	Mph		Wet/dry	Barometer	A/C pressure	
	Min	Max			Suction	Discharge		Min	Max			Suction	Discharge
15.58	59	61	81/88	29.64	Off		17.28	59	61	81/88	29.64	Off	
15.96	59	61					17.41	59	61				
16.76	58	61					17.40	59	61				
15.85	58	60					17.40	59	60				
15.81	58	60					17.62	58	60				
15.89 mpg at 60 mph							17.42 mpg at 60 mph						
Composite 16.65 mpg at 60 mph													
15.22	69	71	82/91	29.60	Off		13.70	69	71	82/91	29.60	Off	
15.39	68	70					14.24	68	70				
14.85	68	70					14.43	68	70				
14.83	68	70					14.05	68	70				
14.64	68	70					14.15	68	70				
14.99 mpg at 70 mph							14.11 mpg at 70 mph						
Composite 14.55 mpg at 70 mph													
11.93	19	22	75/76	29.62	35	167	11.72	19	22	75/76	29.62	34	170
12.04	19	22			34	176	11.93	19	22			34	171
12.18	19	22			34	172	12.00	19	22			34	174
12.24	19	22			34	175	11.98	19	22			34	175
12.16	19	22			34	176	11.95	19	22			35	177
12.11 mpg at 20 mph							11.92 mpg at 20 mph						
Composite 12.02 mpg at 20 mph													
15.35	29	32	77/82	29.63	35	165	15.66	29	32	78/86	29.62	36	176
15.87	29	32			35	175	15.90	29	32			35	175
16.22	29	32			37	175	15.96	29	32			33	175
16.11	28	32			37	180	15.88	29	32			36	185
16.08	29	32			36	178	16.08	29	32			36	185
15.93 mpg at 30 mph							15.90 mpg at 30 mph						
Composite 15.92 mpg at 30 mph													

VEHICLE E TESTS (Cont'd)

South							North						
Mpg	Mph		Wet/dry	Barometer	A/C pressure		Mpg	Mph		Wet/dry	Barometer	A/C pressure	
	Min	Max			Suction	Discharge		Min	Max			Suction	Discharge
16.02	39	42	79/87	29.59	36	180	16.52	38	42	78/86	29.58	37	180
16.32	39	42			35	180	16.50	39	42			37	185
16.24	39	42			34	180	16.32	39	42			35	190
16.71	38	42			34	180	16.72	39	42			36	190
16.62	38	42			33	180	16.50	38	42			35	190
16.38 mpg at 40 mph							16.51 mpg at 40 mph						
Composite 16.45 mpg at 40 mph													
16.46	48	50	80/85	29.66	35	180	15.55	48	50	81/88	29.64	36	175
16.84	48	50			37	180	15.76	48	50			33	165
16.98	48	50			38	185	15.68	48	50			34	175
17.10	48	50			36	185	15.78	48	50			32	175
17.12	48	50			36	185	15.83	46	50			32	170
16.90 mpg at 50 mph							15.72 mpg at 50 mph						
Composite 16.31 mpg at 50 mph													
15.43	58	61	82/89	29.63	38	185	14.34	58	60	82/91	29.60	34	175
15.76	58	60			34	180	14.55	58	60			34	180
16.48	58	60			39	190	14.39	58	60			32	175
15.82	58	60			37	185	14.78	58	60			33	175
15.55	58	60			37	185	14.68	58	60			32	175
15.81 mpg at 60 mph							14.55 mpg at 60 mph						
Composite 15.18 mpg at 60 mph													
13.14	68	70	84/92	29.57	34	175	13.00	68	70	81/91	29.55	35	180
13.23	68	70			38	185	13.09	69	70			35	180
13.58	68	70			33	175	13.08	68	70			35	180
13.65	68	70			34	180	12.80	68	70			34	170
13.70	68	70			33	175	13.07	68	70			33	170
13.46 mpg at 70 mph							13.01 mpg at 70 mph						
Composite 13.24 mpg at 70 mph													

VEHICLE F TESTS

South							North						
Mpg	Mph		Wet/dry	Barometer	A/C pressure		Mpg	Mph		Wet/dry	Barometer	A/C pressure	
	Min	Max			Suction	Discharge		Min	Max			Suction	Discharge
18.35	21	23	83/88	29.57	Off		15.58	20	21	85/93	29.55	Off	
17.69	20	22					15.07	20	21				
17.38	20	22					15.12	20	21				
19.28	20	22					15.88	20	21				
19.94	21	23					15.37	20	21				
18.53 mpg at 20 mph							15.40 mpg at 20 mph						
Composite 16.97 mpg at 20 mph													
17.52	31	32	85/93	29.53	Off		15.97	30	31	76/76	29.50	Off	
17.05	30	31					16.18	30	31				
17.93	30	31					16.11	30	31				
17.77	29	31					16.44	30	31				
17.86	29	31					15.89	30	31				
17.63 mpg at 30 mpg							16.12 mpg at 30 mph						
Composite 16.88 mpg at 30 mph													
16.78	40	41	77/80	29.49	Off		15.75	40	41	77/79	29.49	Off	
16.48	39	41					15.85	39	41				
16.46	39	41					15.34	39	41				
15.42	39	41					15.22	39	41				
16.53	39	41					16.00	39	41				
16.33 mpg at 30 mph							15.63 mpg at 30 mph						
Composite 15.98 at 40 mph													
15.03	49	51	77/80	29.71	Off		14.86	49	51	77/80	29.72	Off	
15.50	49	51					14.88	49	51				
15.30	49	51					14.31	49	51				
15.29	49	51					14.83	49	51				
15.28	49	51					14.88	49	59				
15.28 mpg at 50 mph							14.75 mpg at 50 mpg						
Composite 15.02 mpg at 50 mph													

VEHICLE F TESTS (Cont'd)

South							North						
Mpg	Mph		Wet/dry	Barometer	A/C pressure		Mpg	Mph		Wet/dry	Barometer	A/C pressure	
	Min	Max			Suction	Discharge		Min	Max			Suction	Discharge
16.38	59	61		29.71	Off		14.45	59	61		29.71	Off	
16.51	59	61		29.71			14.43	59	61				
15.07	59	61					14.35	59	61				
15.20	59	61					15.69	39	61				
15.32	59	61					14.50	59	61				
15.70 mpg at 60 mph							14.68 mpg at 60 mph						
Composite 15.19 mpg at 60 mph													
14.26	69	71		29.69	Off		13.64	69	71		29.65	Off	
15.05	69	71					13.80	69	71				
15.22	69	71					13.85	69	71				
14.88	69	71					14.09	69	71				
15.36	69	71					13.16	69	71				
14.95 mpg at 70 mph							13.71 mpg at 70 mph						
Composite 14.33 mpg at 70 mph													
13.51	20	21	80/82	29.46	27	225	16.03	20	21	77/80	29.49	26	230
12.31	20	21			26	225	13.07	20	21			25	225
12.86	20	21			26	225	12.79	20	21			26	225
14.28	20	21			26	225	11.52	20	21			25	225
13.66	20	21			26	225	11.78	20	21			26	225
13.32 mpg at 20 mph							13.04 mpg at 20 mph						
Composite 13.18 mpg at 20 mph													
14.21	30	32	76/76	29.50	20	210	14.71	30	31	80/82	29.46	20	210
14.04	29	31			21	215	14.11	29	31			20	210
14.82	29	31			22	215	14.16	29	31			20	215
14.70	30	31			22	220	14.49	30	31			21	220
14.57	30	31			22	220	15.08	30	31			20	220
14.47 mpg at 30 mph							14.51 mpg at 30 mph						
Composite 14.49 mpg at 30 mph													

VEHICLE F TESTS (Cont'd)

South							North						
Mpg	Mph		Wet/dry	Barometer	A/C pressure		Mpg	Mph		Wet/dry	Barometer	A/C pressure	
	Min	Max			Suction	Discharge		Min	Max			Suction	Discharge
13.15	40	42	77/79	29.49	16	200	13.24	40	42	76/77	29.49	15	205
13.67	40	42			15	200	13.63	39	41			15	200
15.82	39	41			14	200	11.67	39	41			15	200
16.00	38	41			15	200	13.87	39	41			14	200
16.09	39	41			15	200	14.89	39	40			15	200
14.95 mpg at 40 mph							13.46 mpg at 40 mph						
Composite 14.21 mpg at 40 mph													
14.72	49	51		29.72	12	195	13.85	49	51		29.71	11	195
14.66	49	51			12	205	13.96	49	51			11	200
14.61	49	51			11	200	13.93	49	51			11	200
14.53	49	51			12	205	14.00	49	51			11	200
14.75	49	51			12	205	13.98	49	51			11	200
14.65 mpg at 50 mph							13.94 mpg at 50 mph						
Composite 14.30 mpg at 50 mph													
14.69	59	61		29.71	10	195	13.64	59	61		29.69	10	200
14.68	59	61			11	200	13.73	59	61			10	200
14.26	59	61			11	200	13.13	59	61			10	195
14.51	59	61			10	200	13.81	59	61			10	200
15.00	59	61			10	200	13.17	59	61			10	195
14.63 mpg at 60 mph							13.50 mpg at 60 mph						
Composite 14.07 mpg at 60 mph													
14.20	69	71		29.65	10	205	12.78	69	71		29.62	9	200
14.13	69	71			10	205	12.86	69	71			9	200
14.42	69	71			10	205	12.86	69	71			9	195
14.70	69	71			10	205	12.88	69	71			9	195
14.46	69	71			10	205	13.04	69	71			9	195
14.38 mpg at 70 mph							12.88 mpg at 70 mph						
Composite 13.63 mpg at 70 mph													

APPENDIX D

LA-4 CHASIS DYNAMOMETER TEST RESULTS

TABLE D-1. TEST SEQUENCE
(REFER TO TEXT, SECTION 4)

1.	Cold start
2.	Hot start (no A/C)
3.	Hot start (no A/C0)
4.	Cold start
5.	Hot start (with A/C)
6.	Hot start (with A/C)

TABLE D-2. REFERENCE VEHICLE MILEAGE
(MPG) ON LA-4

Vehicle	Test no.					
	1	2	3	4	5	6
A	11.52	12.79	12.65	11.92	11.90	11.61
B	10.17	10.62	10.59	9.89	11.23	10.73
C	10.97	12.19	11.82	10.34	10.42	10.36
D	12.59	13.72	13.46	12.43	12.88	12.95
E	12.09	12.63	11.76	11.16	11.54	11.37
F	9.53	9.95	9.76	9.33	9.58	9.69

TABLE D-3. SUMMARY OF FUEL CONSUMPTION
(LBS) FOR FIRST 505 SECONDS OF LA-4

Vehicle	Test no.					
	1	2	3	4	5	6
A	2.04	1.62	1.66	1.86	1.84	1.83
B	2.20	1.79	1.80	2.44	1.82	1.99
C	2.07	1.81	1.87	2.31	2.12	2.20
D	1.85	1.52	1.59	1.84	1.67	1.68
E	1.86	1.64	1.81	2.00	1.92	1.96
F	2.29	2.18	2.19	2.30	2.29	2.28

EXAMPLE DATA SEGMENT FROM LA-4 CYCLE TEST
(VEHICLE D, TEST 4)

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.5	241.9	0.0	0.0	0.02	0.0	0.0
1.0	0.0	0.0	0.0	0.04	0.0	0.0
1.5	2338.1	0.0	6.58	0.04	0.0	0.0
2.0	1481.3	0.0	19.02	0.06	0.0	0.0
2.5	943.1	0.0	19.05	0.08	0.0	0.0
3.0	800.0	0.0	17.97	0.10	0.0	0.0
3.5	705.7	0.0	16.42	0.11	0.0	0.0
4.0	679.1	0.0	15.66	0.11	0.0	0.0
4.5	619.4	0.0	14.97	0.11	0.0	0.0
5.0	631.9	0.0	14.93	0.11	0.0	0.0
5.5	639.3	0.0	15.08	0.11	0.0	0.0
6.0	655.5	0.0	14.85	0.12	0.0	0.0
6.5	658.5	0.0	14.99	0.12	0.0	0.0
7.0	631.9	0.0	14.79	0.12	0.0	0.0
7.5	612.8	0.0	14.50	0.12	0.0	0.0
8.0	611.3	0.0	14.50	0.13	0.0	0.0
8.5	642.3	0.0	14.64	0.13	0.0	0.0
9.0	608.3	0.0	14.06	0.14	0.0	0.0
9.5	609.8	0.0	14.50	0.15	0.0	0.0
10.0	634.1	0.0	14.66	0.15	0.0	0.0
10.5	619.4	0.0	14.41	0.15	0.0	0.0
11.0	608.3	0.0	14.21	0.15	0.0	0.0
11.5	631.9	0.0	14.55	0.15	0.0	0.0
12.0	655.5	0.0	14.55	0.15	0.0	0.0
12.5	584.7	0.0	14.13	0.16	0.0	0.0
13.0	619.4	0.0	14.23	0.16	0.0	0.0
13.5	609.8	0.0	14.08	0.16	0.0	0.0
14.0	608.3	0.0	14.24	0.16	0.0	0.0
14.5	631.9	0.0	14.64	0.16	0.0	0.0
15.0	612.8	0.0	14.24	0.16	0.0	0.0
15.5	631.9	0.0	14.50	0.16	0.0	0.0
16.0	655.5	0.0	14.21	0.16	0.0	0.0
16.5	655.5	0.0	14.82	0.16	0.0	0.0
17.0	655.5	0.0	15.08	0.16	0.0	0.0
17.5	631.9	0.0	14.50	0.16	0.0	0.0
18.0	631.9	0.0	14.50	0.16	0.0	0.0
18.5	679.1	0.0	14.99	0.16	0.0	0.0
19.0	655.5	0.0	14.98	0.16	0.0	0.0
19.5	639.3	0.0	14.56	0.16	0.0	0.0
20.0	639.3	0.0	14.93	0.16	0.0	0.0
20.5	631.9	0.0	14.79	0.16	0.0	0.0
21.0	655.5	–	14.79	0.16	25.7	0.0
21.5	592.1	0.0	13.06	0.16	49.9	0.0
22.0	584.7	0.0	13.05	0.16	60.3	0.0
22.5	608.3	0.0	13.63	0.16	67.2	0.0
23.0	584.7	0.0	13.64	0.16	67.2	0.0

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
23.5	631.9	0.0	13.63	0.16	71.8	0.0
24.0	631.9	0.0	13.82	0.16	71.8	0.0
24.5	608.3	0.0	13.64	0.16	74.1	0.0
25.0	608.3	0.0	13.36	0.16	72.3	0.0
25.5	603.3	0.0	11.23	0.16	67.2	0.0
26.0	891.5	0.0	10.29	0.16	105.8	0.0
26.5	1202.6	0.0	12.76	0.16	198.7	0.0
27.0	631.9	0.0	14.38	0.16	0.0	0.0
27.5	1269.0	0.0	13.05	0.18	248.5	0.0
28.0	1387.0	77.6	12.76	0.19	251.5	3.7
28.5	1397.3	227.6	11.79	0.19	237.3	10.3
29.0	1528.5	371.6	10.73	0.19	235.0	16.6
29.5	1581.6	418.1	10.58	0.19	233.5	18.6
30.0	1646.5	468.3	10.44	0.19	229.9	20.5
30.5	1699.6	529.1	10.44	0.19	221.1	22.3
31.0	1773.3	577.1	10.37	0.19	219.5	24.1
31.5	1740.9	604.1	11.89	0.20	196.4	22.6
32.0	1552.1	660.3	11.79	0.21	181.9	22.9
32.5	1481.3	673.1	12.48	0.22	157.2	20.1
33.0	1504.9	703.1	12.37	0.22	146.8	19.7
33.5	1552.1	745.1	12.18	0.22	143.4	20.3
34.0	1563.2	756.3	12.36	0.22	140.7	20.3
34.5	1563.2	793.1	12.47	0.22	137.5	20.8
35.0	1563.2	797.6	12.50	0.22	131.0	19.9
35.5	1563.2	841.1	13.77	0.23	124.2	19.9
36.0	1410.5	826.1	15.80	0.23	78.9	12.4
36.5	1344.2	852.3	15.22	0.23	81.5	13.2
37.0	902.5	842.6	18.77	0.23	60.3	9.7
37.5	844.3	817.1	17.46	0.23	25.7	4.0
38.0	808.2	794.6	17.12	0.23	11.8	1.8
38.5	808.2	795.3	17.10	0.23	5.6	0.8
39.0	805.9	756.3	16.96	0.23	0.0	0.0
39.5	808.2	756.3	16.86	0.23	0.0	0.0
40.0	783.8	745.1	16.67	0.23	0.0	0.0
40.5	779.4	728.6	16.52	0.23	0.0	0.0
41.0	773.5	721.1	16.40	0.23	0.0	0.0
41.5	773.5	721.1	16.26	0.23	0.0	0.0
42.0	773.5	697.1	16.40	0.24	6.0	0.8
42.5	749.9	660.3	15.94	0.24	0.0	0.0
43.0	749.9	649.1	15.85	0.24	6.4	0.8
43.5	726.3	608.6	15.80	0.24	9.0	1.0
44.0	729.3	581.6	15.80	0.24	11.8	1.3
44.5	707.1	556.1	15.53	0.24	12.5	1.3
45.0	702.7	553.1	15.37	0.24	11.8	1.2
45.5	705.7	553.1	15.52	0.24	11.8	1.2
46.0	726.3	553.1	15.37	0.24	12.3	1.3
46.5	867.9	554.6	13.19	0.24	16.7	1.8

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
47.0	1161.3	553.1	10.73	0.24	41.1	4.3
47.5	1339.8	564.3	12.19	0.24	88.8	9.5
48.0	1363.4	601.1	12.32	0.24	109.7	12.6
48.5	1387.0	635.6	12.47	0.25	119.1	14.4
49.0	1392.9	660.3	12.18	0.25	122.6	15.4
49.5	1444.5	676.1	10.44	0.25	124.2	16.0
50.0	1537.4	721.1	9.49	0.26	140.3	19.3
50.5	1599.3	749.6	8.90	0.26	151.8	21.7
51.0	1622.9	793.1	8.84	0.26	161.9	24.4
51.5	1646.5	821.6	9.13	0.27	165.6	25.9
52.0	1445.	850.1	12.90	0.27	143.4	23.2
52.5	1176.1	841.1	17.61	0.27	98.4	15.8
53.0	870.8	841.1	17.61	0.27	46.4	7.4
53.5	867.9	803.6	17.28	0.27	18.7	2.9
54.0	902.5	841.1	17.29	0.27	13.4	2.2
54.5	820.7	802.8	18.30	0.28	9.0	1.4
55.0	776.4	793.1	17.61	0.28	0.0	0.0
55.5	749.9	756.3	17.25	0.28	0.0	0.0
56.0	758.8	745.1	17.46	0.28	0.0	0.0
56.5	758.8	725.6	17.25	0.28	0.0	0.0
57.0	713.0	697.1	16.81	0.28	0.0	0.0
57.5	702.7	635.6	16.43	0.28	0.0	0.0
58.0	704.9	629.6	16.55	0.30	0.0	0.0
58.5	689.4	601.1	16.38	0.30	0.0	0.0
59.0	664.4	577.1	15.99	0.30	0.0	0.0
59.5	679.1	577.1	15.68	0.31	6.4	0.7
60.0	1245.4	577.1	9.42	0.31	32.6	3.6
60.5	1434.1	625.1	10.87	0.31	98.6	11.7
61.0	1504.9	659.6	9.00	0.31	124.2	15.6
61.5	1603.7	699.3	7.97	0.31	153.7	20.5
62.0	1646.5	745.1	7.68	0.31	171.1	24.3
62.5	1655.3	778.1	7.55	0.31	178.0	26.4
63.0	1657.5	818.6	7.97	0.31	178.0	27.7
63.5	1563.2	841.1	10.29	0.32	164.3	26.3
64.0	1504.9	889.1	11.02	0.34	140.8	23.8
64.5	1466.6	890.6	11.74	0.34	124.2	21.1
65.0	1292.6	893.6	15.12	0.35	94.9	16.1
65.5	1292.6	892.1	14.84	0.35	77.6	13.2
66.0	1221.8	913.1	17.97	0.35	67.2	11.7
66.5	902.5	899.6	17.97	0.35	29.1	5.0
67.0	985.8	889.1	16.84	0.35	13.4	2.3
67.5	1065.5	889.1	16.44	0.35	19.6	3.3
68.0	1080.2	889.1	16.54	0.36	25.7	4.3
68.5	1058.1	889.1	16.52	0.36	25.7	4.3
69.0	1089.1	895.1	16.58	0.37	29.1	5.0
69.5	1111.2	889.1	15.51	0.37	30.0	5.1
70.0	1292.6	891.3	15.08	0.37	46.4	7.9

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
70.5	1324.3	913.1	15.22	0.37	63.7	11.1
71.0	1292.6	913.1	16.96	0.37	65.0	11.3
71.5	869.4	916.1	18.77	0.38	32.6	5.7
72.0	985.8	913.1	17.97	0.38	13.4	2.3
72.5	985.8	889.1	16.96	0.38	12.5	2.1
73.0	1080.2	890.6	16.14	0.38	19.2	3.3
73.5	1504.9	875.6	11.02	0.38	134.1	22.3
74.0	1277.8	914.6	14.13	0.38	46.7	8.1
74.5	1363.4	923.6	14.94	0.38	63.7	11.2
75.0	1339.8	937.1	14.97	0.38	70.7	12.6
75.5	1339.8	937.1	14.93	0.38	68.7	12.3
76.0	1339.8	943.0	15.66	0.38	68.8	12.4
76.5	1198.2	961.0	16.96	0.39	57.9	10.6
77.0	1179.0	961.0	16.67	0.39	48.0	8.8
77.5	1103.8	937.1	17.25	0.39	36.1	6.4
78.0	1080.2	937.1	17.61	0.39	29.6	5.3
78.5	1036.0	937.1	17.61	0.39	22.9	4.1
79.0	996.9	944.5	19.28	0.39	19.8	3.6
79.5	919.5	923.6	19.13	0.39	6.4	1.1
80.0	900.3	913.1	18.55	0.39	0.0	0.0
80.5	1033.0	890.6	15.24	0.39	0.0	0.0
81.0	1159.9	913.1	14.93	0.39	25.7	4.5
81.5	1323.5	937.1	14.06	0.39	47.1	8.4
82.0	1443.0	944.5	14.06	0.39	72.2	13.0
82.5	1410.5	961.0	15.80	0.39	84.5	15.5
83.0	1269.0	944.5	15.80	0.39	68.7	12.4
83.5	1056.6	946.0	17.97	0.40	46.4	8.4
84.0	1127.4	962.5	17.25	0.40	36.7	6.7
84.5	1080.2	945.3	17.03	0.40	29.4	5.3
85.0	1081.7	943.0	16.81	0.41	26.3	4.7
85.5	1245.4	938.5	12.37	0.41	32.6	5.8
86.0	1444.5	961.0	13.92	0.41	67.2	12.3
86.5	1457.7	1009.0	13.83	0.41	82.6	15.9
87.0	1459.9	1009.0	13.92	0.41	88.0	16.9
87.5	1457.7	1015.0	13.81	0.42	88.8	17.2
88.0	1457.7	1015.0	13.92	0.42	88.0	17.0
88.5	1484.3	1042.0	13.95	0.43	88.7	17.6
89.0	1504.9	1057.0	14.10	0.43	89.5	18.0
89.5	1504.9	1063.0	14.06	0.43	88.2	17.9
90.0	1507.1	1081.0	14.13	0.43	88.2	18.2
90.5	1504.9	1105.0	14.51	0.43	88.0	18.5
91.0	1345.7	1082.5	16.81	0.43	71.8	14.8
91.5	1363.4	1105.0	16.67	0.44	60.7	12.8
92.0	1363.4	1105.0	16.16	0.44	55.0	11.6
92.5	1440.0	1112.5	15.22	0.44	60.9	12.9
93.0	1481.3	1112.5	15.22	0.45	70.7	15.0
93.5	1457.7	1129.0	15.37	0.46	70.7	15.2

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
94.0	1444.5	1129.0	15.71	0.46	70.7	15.2
94.5	1391.4	1153.0	16.96	0.46	63.7	14.0
95.0	1269.0	1139.5	19.03	0.46	44.5	9.7
95.5	1174.6	1129.0	20.62	0.46	29.8	6.4
96.0	1056.6	1105.0	20.29	0.46	8.4	1.8
96.5	1221.8	1107.3	17.25	0.46	9.2	1.9
97.0	1198.2	1105.0	17.10	0.46	18.7	3.9
97.5	1224.7	1106.5	16.98	0.46	25.7	5.4
98.0	1280.0	1105.0	13.92	0.46	27.3	5.7
98.5	1504.9	1107.3	13.37	0.46	55.0	11.6
99.0	1410.5	1129.0	16.52	0.46	67.2	14.4
99.5	1277.8	1115.5	17.10	0.47	49.9	10.6
100.0	1202.6	1129.0	18.55	0.47	33.9	7.3
100.5	1185.7	1105.0	17.61	0.47	25.7	5.4
101.0	1221.8	1108.0	17.61	0.47	23.4	4.9
101.5	1127.4	1088.5	19.13	0.47	16.6	3.4
102.0	1127.4	1084.0	18.77	0.47	8.4	1.7
102.5	1154.0	1090.0	18.17	0.47	11.8	2.5
103.0	1127.4	1058.5	17.83	0.47	9.0	1.8
103.5	1221.8	1064.5	14.64	0.47	13.4	2.7
104.0	1374.4	1081.0	14.79	0.47	39.5	8.1
104.5	1410.5	1105.0	13.93	0.47	53.6	11.3
105.0	1552.1	1129.0	12.82	0.47	74.1	15.9
105.5	1484.3	1105.0	13.05	0.47	77.6	16.3
106.0	1457.7	1129.0	14.50	0.49	74.1	15.9
106.5	1417.9	1139.5	15.43	0.49	68.3	14.8
107.0	1434.1	1135.0	15.80	0.49	63.7	13.8
107.5	1394.3	1153.0	16.23	0.50	60.6	13.3
108.0	1209.3	1129.0	19.28	0.50	40.0	8.6
108.5	1174.6	1129.0	20.73	0.51	27.3	5.9
109.0	1033.0	1105.0	20.44	0.51	0.0	0.0
109.5	1033.0	1105.0	20.34	0.51	0.0	0.0
110.0	1015.3	1088.5	19.44	0.51	0.0	0.0
110.5	1056.6	1060.8	18.33	0.51	0.0	0.0
111.0	1154.7	1044.3	15.68	0.51	0.0	0.0
111.5	1363.4	1037.0	14.25	0.51	29.1	6.0
112.0	1387.0	1105.0	14.40	0.51	47.3	10.0
112.5	1374.4	1105.0	14.50	0.51	54.7	11.5
113.0	1364.8	1105.0	14.27	0.51	55.0	11.6
113.5	1481.3	1105.0	12.76	0.51	63.7	13.4
114.0	1457.7	1129.0	12.49	0.51	70.7	15.2
114.5	1482.8	1135.0	12.76	0.51	70.7	15.3
115.0	1461.4	1135.8	12.47	0.51	70.7	15.3
115.5	1457.7	1138.0	12.47	0.51	68.6	14.9
116.0	1463.6	1156.0	12.37	0.52	67.4	14.8
116.5	1465.1	1177.0	12.47	0.52	67.6	15.2
117.0	1481.3	1187.5	12.92	0.52	68.5	15.5

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
117.5	1481.3	1180.0	13.93	0.52	67.4	15.1
118.0	1316.2	1177.0	17.84	0.53	53.8	12.1
118.5	1248.3	1177.0	18.77	0.54	33.2	7.5
119.0	1174.6	1156.0	20.44	0.54	20.0	4.4
119.5	1080.2	1156.0	20.73	0.54	0.0	0.0
120.0	1090.5	1057.0	17.54	0.54	0.0	0.0
120.5	938.7	1044.3	19.61	0.55	0.0	0.0
121.0	891.5	1009.0	19.16	0.55	0.0	0.0
121.5	844.3	937.1	18.74	0.55	−10.8	0.0
122.0	803.0	898.1	17.97	0.55	0.0	0.0
122.5	713.8	841.1	16.96	0.55	0.0	0.0
123.0	702.7	756.3	16.38	0.55	0.0	0.0
123.5	685.0	728.6	16.09	0.55	0.0	0.0
124.0	682.1	680.6	15.80	0.55	0.0	0.0
124.5	655.5	649.1	15.53	0.55	0.0	0.0
125.0	636.4	601.1	15.08	0.55	0.0	0.0
125.5	633.4	529.1	15.08	0.55	0.0	0.0
126.0	608.3	457.1	14.64	0.55	11.8	1.0
126.5	593.6	371.6	14.13	0.55	11.8	0.3
127.0	593.6	289.1	14.13	0.55	16.6	0.9
127.5	631.9	174.3	14.64	0.55	22.2	0.7
128.0	612.8	–	14.68	0.55	23.7	0.0
128.5	608.3	0.0	14.50	0.55	36.9	0.0
129.0	608.3	0.0	14.50	0.55	47.8	0.0
129.5	587.7	0.0	14.06	0.55	60.3	0.0
130.0	631.9	–	14.64	0.55	68.8	0.0
130.5	609.8	0.0	14.40	0.55	75.1	0.0
131.0	608.3	0.0	14.38	0.55	74.8	0.0
131.5	584.7	0.0	13.95	0.55	74.1	0.0
132.0	584.7	0.0	13.92	0.55	74.8	0.0
132.5	637.8	–	14.64	0.55	78.2	0.0
133.0	642.3	0.0	15.22	0.55	82.7	0.0
133.5	584.7	0.0	14.10	0.55	81.1	0.0
134.0	587.7	0.0	14.08	0.55	77.6	0.0
134.5	609.8	0.0	14.35	0.55	79.1	0.0
135.0	608.3	0.0	14.50	0.55	81.1	0.0
135.5	612.8	0.0	14.35	0.56	81.1	0.0
136.0	608.3	0.0	14.12	0.56	77.6	0.0
136.5	608.3	0.0	14.35	0.56	78.7	0.0
137.0	608.3	0.0	14.35	0.56	81.1	0.0
137.5	611.3	0.0	13.92	0.56	81.1	0.0
138.0	608.3	0.0	14.11	0.57	77.6	0.0
138.5	609.1	0.0	14.50	0.57	81.1	0.0
139.0	571.5	0.0	14.06	0.57	78.2	0.0
139.5	631.9	–	14.50	0.57	81.1	0.0
140.0	614.2	0.0	14.50	0.57	81.1	0.0
140.5	609.8	0.0	14.53	0.57	81.1	0.0

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
141.0	567.0	0.0	14.13	0.57	77.6	0.0
141.5	592.1	0.0	14.64	0.57	77.8	0.0
142.0	619.4	–	14.39	0.57	84.5	0.0
142.5	608.3	0.0	14.06	0.57	81.1	0.0
143.0	595.1	0.0	13.97	0.58	78.2	0.0
143.5	540.5	0.0	13.05	0.58	74.1	0.0
144.0	608.3	0.0	14.11	0.58	74.1	0.0
144.5	631.9	–	14.09	0.58	78.5	0.0
145.0	590.6	0.0	13.82	0.58	77.6	0.0
145.5	608.3	0.0	13.94	0.58	74.8	0.0
146.0	584.7	0.0	14.06	0.58	75.2	0.0
146.5	589.2	0.0	13.77	0.58	72.3	0.0
147.0	619.4	0.0	14.64	0.58	81.1	0.0
147.5	608.3	0.0	14.35	0.58	78.7	0.0
148.0	584.7	0.0	13.93	0.58	77.6	0.0
148.5	584.7	0.0	13.63	0.58	74.1	0.0
149.0	608.3	0.0	14.50	0.58	77.6	0.0
149.5	631.9	0.0	14.71	0.58	81.1	0.0
150.0	609.8	0.0	14.41	0.58	81.1	0.0
150.5	589.9	0.0	13.77	0.58	77.8	0.0
151.0	564.1	0.0	14.06	0.58	74.2	0.0
151.5	586.2	0.0	13.97	0.58	74.6	0.0
152.0	590.6	0.0	13.92	0.58	74.1	0.0
152.5	608.3	0.0	14.21	0.58	77.8	0.0
153.0	608.3	0.0	14.27	0.58	77.8	0.0
153.5	584.7	0.0	14.13	0.58	77.6	0.0
154.0	608.3	0.0	14.35	0.59	77.6	0.0
154.5	584.7	0.0	13.77	0.59	77.6	0.0
155.0	561.1	0.0	13.24	0.59	70.7	0.0
155.5	593.6	0.0	13.66	0.59	71.6	0.0
156.0	590.6	0.0	14.24	0.59	72.2	0.0
156.5	584.7	0.0	13.96	0.59	75.0	0.0
157.0	584.7	0.0	13.54	0.59	72.0	0.0
157.5	587.7	0.0	14.21	0.59	75.2	0.0
158.0	608.3	0.0	14.50	0.59	78.9	0.0
158.5	561.1	0.0	13.79	0.59	74.3	0.0
159.0	561.1	0.0	13.19	0.59	71.1	0.0
159.5	564.1	0.0	13.24	0.59	63.7	0.0
160.0	584.7	0.0	13.81	0.59	70.9	0.0
160.5	584.7	0.0	13.48	0.59	77.6	0.0
161.0	567.0	0.0	13.64	0.59	70.7	0.0
161.5	592.1	0.0	13.92	0.59	75.0	0.0
162.0	570.7	0.0	13.77	0.59	77.6	0.0
162.5	584.7	0.0	13.53	0.59	74.1	0.0
163.0	562.6	0.0	13.80	0.59	74.6	0.0
163.5	584.7	0.0	13.77	0.59	74.1	0.0
164.0	584.7	0.0	14.06	0.59	74.1	0.0

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
164.5	547.9	0.0	13.19	0.59	71.3	0.0
165.0	608.3	0.0	13.96	0.59	72.0	0.0
165.5	609.8	0.0	14.35	0.59	77.8	0.0
166.0	586.2	0.0	14.13	0.59	77.6	0.0
166.5	619.4	0.0	14.11	0.59	77.6	0.0
167.0	584.7	0.0	13.77	0.59	74.7	0.0
167.5	608.3	0.0	13.92	0.59	74.6	0.0
168.0	608.3	0.0	13.77	0.59	75.6	0.0
168.5	985.8	0.0	9.71	0.59	105.3	0.0
169.0	1177.6	0.0	12.91	0.59	217.6	0.0
169.5	1269.0	0.0	9.28	0.59	250.7	0.0
170.0	1487.2	–	10.15	0.59	319.9	0.0
170.5	1488.7	227.6	9.86	0.59	309.5	13.4
171.0	1520.5	361.1	9.74	0.59	286.4	19.7
171.5	1575.7	409.1	9.17	0.61	254.1	19.8
172.0	1699.6	481.1	8.91	0.61	250.9	23.0
172.5	1835.2	553.1	7.60	0.61	262.4	27.6
173.0	1907.5	625.1	7.74	0.61	265.2	31.6
173.5	1811.7	652.1	6.14	0.62	243.9	30.3
174.0	1788.1	721.1	4.78	0.63	240.3	33.0
174.5	1954.7	793.1	4.49	0.63	268.2	40.5
175.0	2025.5	889.1	5.80	0.63	286.1	48.4
175.5	1953.2	937.1	8.03	0.63	264.5	47.2
176.0	1840.4	938.5	9.77	0.63	220.4	39.4
176.5	1622.9	961.0	9.71	0.65	165.6	30.3
177.0	1457.7	985.0	16.43	0.65	136.4	25.6
177.5	991.7	961.0	18.77	0.66	65.3	11.9
178.0	962.3	937.1	19.13	0.67	29.6	5.3
178.5	921.0	920.6	18.99	0.67	11.8	2.1
179.0	891.5	913.1	18.77	0.67	0.0	0.0
179.5	891.5	913.1	18.70	0.67	0.0	0.0
180.0	878.2	913.1	18.55	0.68	0.0	0.0
180.5	1158.4	913.1	14.24	0.68	11.8	2.1
181.0	1249.8	890.6	15.37	0.68	40.1	6.8
181.5	1221.8	916.1	15.08	0.69	53.4	9.3
182.0	1221.8	913.1	14.79	0.69	50.3	8.8
182.5	1255.7	943.0	15.08	0.69	55.0	9.9
183.0	1221.8	937.1	14.51	0.69	54.4	9.5
183.5	1245.4	937.1	14.13	0.70	53.8	9.6
184.0	1277.8	940.0	13.19	0.70	56.8	10.2
184.5	1484.3	961.0	12.18	0.70	77.6	14.2
185.0	1512.3	991.8	11.77	0.70	94.9	17.9
185.5	1339.8	1009.0	18.47	0.70	85.8	16.5
186.0	988.8	967.0	19.62	0.70	39.5	7.3
186.5	988.7	947.5	19.28	0.70	16.3	2.9
187.0	867.9	913.1	18.77	0.70	0.0	0.0
187.5	849.4	893.6	18.41	0.70	0.0	0.0

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
188.0	797.1	865.1	17.61	0.70	0.0	0.0
188.5	752.9	841.1	16.96	0.70	0.0	0.0
189.0	749.9	817.1	16.84	0.70	0.0	0.0
189.5	707.9	756.3	16.23	0.70	0.0	0.0
190.0	710.1	721.1	16.01	0.71	0.0	0.0
190.5	679.1	673.1	15.70	0.71	0.0	0.0
191.0	682.1	649.1	15.84	0.71	0.0	0.0
191.5	690.2	649.1	15.70	0.71	0.0	0.0
192.0	683.5	656.6	14.06	0.71	0.0	0.0
192.5	891.5	656.6	14.36	0.71	13.4	1.7
193.0	990.3	673.1	12.32	0.71	27.3	3.5
193.5	1108.2	660.3	12.34	0.71	53.6	6.7
194.0	1297.0	697.1	12.18	0.71	78.9	10.5
194.5	1387.0	706.1	11.60	0.71	99.9	13.4
195.0	1457.7	751.1	10.58	0.71	122.6	17.5
195.5	1462.2	756.3	9.13	0.71	127.1	18.3
196.0	1605.2	802.1	8.13	0.71	144.2	22.0
196.5	1678.9	844.1	7.26	0.71	164.6	26.4
197.0	1673.0	874.1	4.80	0.71	174.5	29.0
197.5	1911.9	947.5	3.68	0.71	200.3	36.1
198.0	2212.8	1033.0	3.33	0.71	235.0	46.2
198.5	2293.9	1129.0	3.39	0.73	278.8	59.9
199.0	2354.3	1201.0	3.91	0.73	295.7	67.6
199.5	2341.1	1250.5	4.39	0.74	289.2	68.9
200.0	2318.2	1321.0	5.95	0.74	271.4	68.3
200.5	2283.5	1345.0	6.83	0.75	235.0	60.2
201.0	2001.9	1345.0	5.22	0.75	205.7	52.7
201.5	2003.4	1372.8	4.68	0.75	191.8	50.1
202.0	2047.6	1417.0	6.38	0.77	191.8	51.8
202.5	2032.8	1465.0	5.84	0.77	181.4	50.6
203.0	2028.4	1489.0	6.70	0.77	171.5	48.6
203.5	2000.4	1513.0	7.39	0.79	160.9	46.3
204.0	1979.8	1517.5	7.54	0.79	150.3	43.4
204.5	1954.7	1524.3	7.39	0.79	139.9	40.6
205.0	2001.1	1571.5	7.54	0.79	139.9	41.9
205.5	2003.4	1609.0	7.54	0.79	137.7	42.2
206.0	2024.0	1633.0	7.39	0.80	136.4	42.4
206.5	2000.4	1633.0	7.83	0.80	131.0	40.7
207.0	1976.8	1640.5	7.83	0.82	124.2	38.8
207.5	2025.5	1691.5	8.16	0.82	124.2	40.0
208.0	2003.4	1705.0	9.43	0.82	122.6	39.8
208.5	1978.3	1711.0	10.15	0.83	110.3	35.9
209.0	1931.1	1705.0	10.34	0.83	96.5	31.3
209.5	1929.6	1711.0	10.48	0.83	89.3	29.1
210.0	1957.6	1735.0	11.47	0.84	88.0	29.1
210.5	1882.4	1732.0	13.24	0.84	75.3	24.8
211.0	1841.1	1716.3	14.35	0.85	61.2	20.0

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
211.5	1835.2	1711.0	14.64	0.85	53.4	17.4
212.0	1813.1	1705.0	15.37	0.86	46.4	15.1
212.5	1835.2	1729.0	16.52	0.86	46.4	15.3
213.0	1976.8	1499.5	7.39	0.86	154.3	44.1
213.5	1812.4	1706.5	17.00	0.87	39.5	12.8
214.0	1788.1	1705.0	16.96	0.87	36.1	11.7
214.5	1794.0	1705.0	16.71	0.87	36.5	11.8
215.0	1835.2	1716.3	16.67	0.87	41.1	13.4
215.5	1836.7	1716.3	16.14	0.87	46.7	15.2
216.0	1869.2	1714.0	15.43	0.88	50.1	16.4
216.5	1835.2	1708.0	15.94	0.88	50.1	16.3
217.0	1811.7	1705.0	17.17	0.89	43.8	14.2
217.5	1811.7	1705.0	17.15	0.89	40.4	13.1
218.0	1835.2	1716.3	16.67	0.89	41.1	13.4
218.5	1886.9	1711.8	14.26	0.90	50.3	16.4
219.0	1940.7	1735.8	13.64	0.90	68.5	22.6
219.5	1891.3	1729.0	14.37	0.91	63.7	21.0
220.0	1906.0	1753.0	14.35	0.91	61.8	20.6
220.5	1911.9	1753.0	14.11	0.91	63.7	21.3
221.0	1940.7	1760.5	13.69	0.91	67.2	22.5
221.5	1929.6	1753.0	13.63	0.91	67.2	22.4
222.0	1931.1	1761.2	13.63	0.91	67.2	22.5
222.5	1953.2	1781.5	13.77	0.91	70.7	24.0
223.0	1953.2	1787.5	13.69	0.91	70.7	24.1
223.5	2000.4	1801.0	13.34	0.91	74.1	25.4
224.0	2000.4	1801.0	12.76	0.91	74.8	25.6
224.5	2000.4	1805.5	12.47	0.92	78.0	26.8
225.0	2031.4	1825.0	12.37	0.92	81.1	28.2
225.5	2047.6	1829.5	12.32	0.92	84.5	29.4
226.0	2024.0	1849.0	12.61	0.93	84.5	29.8
226.5	2028.4	1849.0	12.76	0.93	81.3	23.6
227.0	2026.9	1852.0	12.76	0.93	78.9	27.8
227.5	2029.2	1873.0	12.78	0.93	77.6	27.7
228.0	2050.5	1873.0	12.20	0.94	78.5	28.0
228.5	2165.6	1921.0	10.58	0.94	91.4	33.4
229.0	2174.4	1921.0	9.86	0.95	102.3	37.4
229.5	2175.9	1945.0	10.15	0.96	108.7	40.3
230.0	2165.6	1945.0	11.17	0.96	103.1	38.2
230.5	2167.0	1969.0	11.22	0.96	98.8	37.0
231.0	2165.6	1975.0	11.89	0.96	94.9	35.7
231.5	21420	1976.5	12.32	0.96	88.0	33.1
232.0	2142.0	1973.5	13.08	0.96	81.5	30.6
232.5	2125.8	1993.0	13.05	0.97	77.6	29.4
233.0	2142.0	1993.0	13.24	0.98	74.3	28.2
233.5	2128.0	2000.5	14.64	0.98	74.1	28.2
234.0	2071.2	1993.0	14.79	0.99	60.3	22.9
234.5	2072.7	1976.5	15.22	0.99	51.4	19.3

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
235.0	2073.4	1993.0	15.37	0.99	50.6	19.2
235.5	2100.7	1993.0	15.94	1.00	50.1	19.0
236.0	2094.8	1993.0	15.95	1.00	48.0	18.2
236.5	2071.2	1978.0	15.37	1.00	46.4	17.5
237.0	2142.0	1993.0	13.63	1.01	56.8	21.6
237.5	2142.0	1993.0	13.65	1.01	67.2	25.5
238.0	2142.0	2017.0	14.93	1.01	63.7	24.5
238.5	2118.4	2000.5	14.93	1.01	57.9	22.1
239.0	2118.4	1993.0	14.64	1.02	56.8	21.6
239.5	2142.0	2002.0	13.77	1.02	61.4	23.4
240.0	2175.2	2017.0	13.77	1.02	67.3	25.9
240.5	2171.5	2041.0	13.63	1.03	70.7	27.5
241.0	2199.5	2048.5	13.92	1.03	74.1	28.9
241.5	2165.6	2017.0	14.06	1.03	67.2	25.8
242.0	2146.4	2041.0	14.64	1.03	64.1	24.9
242.5	2147.9	2024.5	14.50	1.03	60.3	23.2
243.0	2214.2	2065.0	14.11	1.03	67.2	26.4
243.5	2212.8	2065.0	14.06	1.03	70.7	27.8
244.0	2125.8	2044.0	15.68	1.04	60.9	23.7
244.5	2142.0	2041.0	15.94	1.04	53.4	20.7
245.0	2125.8	2041.0	15.83	1.04	49.9	19.4
245.5	2147.9	2044.0	15.85	1.06	51.4	20.0
246.0	2128.7	2050.0	15.80	1.06	50.1	19.6
246.5	2142.0	2041.0	15.66	1.06	49.9	19.4
247.0	2150.8	2047.0	15.66	1.06	53.4	20.8
247.5	2150.8	2041.0	15.51	1.06	53.4	20.7
248.0	2147.9	2065.0	15.51	1.07	53.4	21.0
248.5	2172.9	2050.0	15.54	1.07	54.2	21.2
249.0	2165.6	2041.0	15.51	1.07	53.4	20.7
249.5	2142.0	2045.5	15.51	1.07	53.4	20.8
250.0	2165.6	2048.5	15.54	1.07	53.4	20.8
250.5	2175.9	2065.0	15.67	1.07	53.6	21.1
251.0	2165.6	2050.0	15.66	1.07	53.4	20.8
251.5	2165.6	2041.9	16.09	1.09	50.1	19.5
252.0	2119.1	2042.5	16.98	1.10	46.4	18.1
252.5	2118.4	2041.0	17.61	1.10	40.0	15.5
253.0	2129.4	2041.0	18.16	1.10	39.5	15.4
253.5	2118.4	2026.0	18.28	1.11	36.3	14.0
254.0	2094.8	2017.0	18.41	1.11	32.6	12.5
254.5	2078.6	2002.0	18.77	1.11	29.1	11.1
255.0	2071.2	1993.0	19.28	1.11	25.7	9.7
255.5	2047.6	2002.7	19.93	1.11	22.2	8.5
256.0	2029.2	1993.0	20.06	1.11	13.4	5.1
256.5	2010.7	1975.0	19.93	1.11	12.5	4.7
257.0	2000.4	1945.0	19.86	1.11	11.8	4.4
257.5	2000.4	1945.0	19.77	1.11	9.8	3.6
258.0	1954.7	1927.0	19.71	1.12	11.8	4.3

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
258.5	2000.4	1930.0	19.57	1.12	13.1	4.8
259.0	2024.0	1931.5	18.41	1.12	19.4	7.1
259.5	2165.6	2065.0	15.67	1.12	54.9	21.6
260.0	2031.4	1924.0	17.54	1.12	36.3	13.3
260.5	2031.4	1931.5	17.31	1.12	39.6	14.6
261.0	2047.6	1927.0	17.26	1.13	41.1	15.1
261.5	2026.9	1945.0	17.25	1.14	41.1	15.2
262.0	2026.9	1925.5	17.13	1.14	43.6	16.0
262.5	2024.0	1921.0	16.98	1.14	41.1	15.0
263.0	2024.0	1927.0	17.10	1.14	41.1	15.1
263.5	2025.5	1921.0	17.25	1.14	41.1	15.0
264.0	2024.0	1928.5	17.56	1.14	41.1	15.1
264.5	1986.4	1904.5	17.61	1.14	39.5	14.3
265.0	1985.7	1904.5	18.26	1.14	32.8	11.9
265.5	1976.8	1897.0	18.55	1.15	29.1	10.5
266.0	2000.4	1906.0	18.74	1.15	29.1	10.6
266.5	1976.8	1897.0	18.70	1.16	29.1	10.5
267.0	1959.9	1897.0	19.05	1.16	25.7	9.3
267.5	1929.6	1855.7	19.01	1.16	20.3	7.2
268.0	1953.2	1880.5	19.19	1.16	22.2	8.0
268.5	1959.1	1873.0	18.19	1.16	25.7	9.2
269.0	1979.0	1877.5	17.61	1.16	30.2	10.8
269.5	1940.7	1858.0	18.12	1.16	32.6	11.5
270.0	1911.9	1849.0	19.13	1.17	27.3	9.6
270.5	1931.1	1856.5	18.77	1.17	23.5	8.3
271.0	1962.1	1858.0	17.97	1.17	30.8	10.9
271.5	1961.3	1873.0	17.97	1.18	36.1	12.9
272.0	1953.2	1850.5	17.87	1.18	36.7	12.9
272.5	1929.6	1831.0	17.87	1.18	33.0	11.5
273.0	1934.0	1849.0	18.26	1.18	33.5	11.8
273.5	1931.1	1849.0	18.19	1.18	34.1	12.0
274.0	1954.7	1849.0	17.28	1.18	36.9	13.0
274.5	2000.4	1849.0	15.82	1.18	47.3	16.7
275.0	1960.6	1849.0	15.22	1.18	53.8	18.9
275.5	2007.8	1873.0	15.37	1.18	57.0	20.3
276.0	2024.0	1873.0	15.38	1.18	60.3	21.5
276.5	2024.0	1879.0	14.79	1.18	61.4	22.0
277.0	2024.0	1873.7	14.21	1.18	63.7	22.7
277.5	2047.6	1878.	13.93	1.19	67.2	24.0
278.0	2094.8	1903.0	13.39	1.19	74.1	26.9
278.5	2071.2	1921.0	13.11	1.19	75.2	27.5
279.0	2094.8	1922.5	12.95	1.19	77.8	28.5
279.5	2119.9	1922.5	12.61	1.19	81.3	29.7
280.0	2145.7	1945.0	11.74	1.19	85.6	31.7
280.5	2212.8	1975.0	11.16	1.20	95.6	35.9
281.0	2192.1	1993.0	11.06	1.20	98.4	37.3
281.5	2218.7	2000.5	11.31	1.21	101.8	38.8

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
282.0	2189.2	1997.5	12.39	1.21	96.5	36.7
282.5	2118.4	2000.5	12.78	1.22	85.3	32.5
283.0	2143.4	2003.5	13.65	1.22	77.6	29.6
283.5	2192.1	2017.0	12.76	1.2	78.7	30.2
284.0	2165.6	2041.0	15.00	1.22	81.1	31.5
284.5	2099.2	1999.0	14.93	1.22	57.5	21.9
285.0	2100.7	2000.5	15.80	1.23	55.0	20.9
285.5	2118.4	2000.5	16.23	1.23	51.1	19.5
286.0	2105.1	2000.5	17.25	1.23	46.4	17.7
286.5	2094.8	2003.5	18.70	1.24	40.4	15.4
237.0	2047.6	1993.0	18.39	1.24	29.1	11.1
287.5	2024.0	1953.2	19.20	1.24	22.2	8.3
288.0	2001.9	1971.2	20.15	1.24	19.2	7.2
288.5	1976.8	1945.0	20.75	1.26	11.8	4.4
289.0	1932.6	1946.5	21.63	1.26	0.0	0.0
289.5	1657.5	1906.0	22.76	1.26	–12.4	0.0
290.0	1646.5	1873.0	22.32	1.26	–28.1	0.0
290.5	1701.1	1849.0	21.49	1.26	–29.3	0.0
291.0	1835.2	1849.0	20.48	1.26	–19.3	0.0
291.5	1846.3	1853.5	19.42	1.26	–11.8	0.0
292.0	1916.4	1849.0	17.57	1.26	0.0	0.0
292.5	1906.0	1849.0	17.26	1.26	15.3	5.4
293.0	1936.3	1849.0	17.39	1.26	25.7	9.0
293.5	1908.2	1849.0	17.61	1.26	25.7	9.0
294.0	1906.0	1852.0	18.46	1.26	25.7	9.1
294.5	1838.2	1812.2	19.00	1.26	12.5	4.3
295.0	1819.0	1801.0	18.45	1.27	8.4	2.9
295.5	1906.0	1801.0	16.81	1.27	13.4	4.6
296.0	1914.9	1808.5	16.59	1.27	32.6	11.2
296.5	1929.6	1825.0	17.25	1.28	36.1	12.5
297.0	1846.3	1804.0	19.28	1.29	27.3	9.4
297.5	1811.7	1777.0	19.31	1.31	12.0	4.1
298.0	1885.4	1777.0	16.86	1.31	22.2	7.5
298.5	1882.4	1786.0	17.02	1.31	32.6	11.1
299.0	1906.0	1804.0	17.39	1.31	39.5	13.6
299.5	1867.7	1777.0	17.26	1.31	36.5	12.3
300.0	1861.8	1781.5	17.26	1.33	37.1	12.6
300.5	1869.9	1777.0	17.39	1.33	38.5	11.3
301.0	1861.8	1780.0	17.46	1.33	36.1	12.2
301.5	1864.7	1801.0	18.15	1.33	34.1	11.7
302.0	1820.5	1777.0	18.33	1.33	27.0	9.1
302.5	1844.1	1760.5	18.85	1.33	25.8	8.6
303.0	1774.8	1738.0	19.49	1.33	18.7	6.2
303.5	1764.5	1733.5	20.50	1.33	13.4	4.4
304.0	1764.5	1735.8	20.58	1.33	8.8	2.9
304.5	1746.0	1716.3	20.48	1.33	8.4	2.7
305.0	1720.2	1705.0	20.30	1.33	0.0	0.0

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
305.5	1698.1	1681.0	20.17	1.33	0.0	0.0
306.0	1889.8	1811.5	17.25	1.33	32.6	11.2
306.5	1693.7	1685.5	21.45	1.33	0.0	0.0
307.0	1528.5	1636.0	21.64	1.33	0.0	0.0
307.5	1457.7	1618.0	21.64	1.33	–17.8	0.0
308.0	1410.5	1610.5	22.03	1.33	–22.8	0.0
308.5	1389.2	1592.5	21.93	1.33	–26.0	0.0
309.0	1363.4	1585.0	21.89	1.33	–25.8	0.0
309.5	1297.7	1543.0	21.60	1.33	–28.6	0.0
310.0	1339.8	1546.0	21.66	1.34	–26.2	0.0
310.5	1300.7	1513.0	21.45	1.34	–29.0	0.0
311.0	1301.4	1514.5	21.62	1.34	–26.2	0.0
311.5	1276.4	1489.0	21.48	1.34	–26.2	0.0
312.0	1232.1	1451.5	21.17	1.34	–24.6	0.0
312.5	1221.8	1427.5	21.19	1.34	–22.4	0.0
313.0	1185.7	1393.0	20.87	1.34	–22.8	0.0
313.5	1174.6	1369.0	20.78	1.34	–22.8	0.0
314.0	1158.4	1352.5	20.77	1.34	–19.3	0.0
314.5	1127.4	1321.0	20.47	1.34	–22.4	0.0
315.0	1127.4	1298.5	20.44	1.34	–18.9	0.0
315.5	1083.2	1249.0	20.17	1.34	–19.3	0.0
316.0	1033.0	1232.5	19.88	1.35	–18.0	0.0
316.5	1033.0	1225.0	19.86	1.35	–15.9	0.0
317.0	1009.4	1177.8	19.71	1.35	–15.9	0.0
317.5	947.5	1153.0	19.18	1.35	–15.9	0.0
318.0	902.5	[illegible]29.0	18.73	1.35	–18.7	0.0
318.5	894.4	1105.0	18.41	1.35	–15.9	0.0
319.0	941.6	1108.0	18.99	1.35	–14.8	0.0
319.5	902.5	1105.0	18.71	1.35	–15.9	0.0
320.0	962.3	1091.5	18.77	1.35	–14.6	0.0
320.5	902.5	1044.3	18.77	1.35	–15.6	0.0
321.0	875.2	1034.5	18.19	1.35	–14.8	0.0
321.5	891.5	1033.0	18.18	1.35	–12.4	0.0
322.0	850.9	1016.5	18.04	1.35	–12.2	0.0
322.5	798.6	989.5	17.54	1.35	–12.4	0.0
323.0	808.2	961.0	17.42	1.35	–12.4	0.0
323.5	829.5	961.0	17.57	1.35	0.0	0.0
324.0	797.1	923.6	16.81	1.35	0.0	0.0
324.5	779.4	895.1	16.72	1.35	0.0	0.0
325.0	751.4	865.1	16.38	1.35	0.0	0.0
325.5	749.9	817.1	16.23	1.35	0.0	0.0
326.0	726.3	756.3	15.80	1.35	0.0	0.0
326.5	732.2	721.1	16.11	1.35	0.0	0.0
327.0	709.4	697.1	15.39	1.35	0.0	0.0
327.5	702.7	673.1	15.41	1.35	0.0	0.0
328.0	679.1	634.1	14.93	1.35	0.0	0.0
328.5	702.7	631.1	15.26	1.35	8.4	1.0

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
329.0	658.5	605.6	14.40	1.35	8.4	1.0
329.5	686.5	586.1	14.69	1.35	11.8	1.3
330.0	662.2	553.1	14.79	1.35	11.8	1.2
330.5	619.4	505.1	14.06	1.35	11.8	1.1
331.0	614.2	488.6	13.48	1.35	12.3	1.1
331.5	631.9	457.1	14.09	1.35	13.4	1.2
332.0	608.3	433.1	13.63	1.35	18.7	1.5
332.5	614.2	385.1	13.34	1.35	18.7	1.4
333.0	608.3	337.1	13.93	1.35	20.3	1.3
333.5	612.8	217.1	13.34	1.35	25.7	1.1
334.0	639.3	76.1	13.93	1.35	25.7	0.4
334.5	686.5	0.0	14.50	1.35	22.2	0.0
335.0	655.5	0.0	14.68	1.35	32.6	0.0
335.5	619.4	0.0	13.55	1.35	39.5	0.0
336.0	619.4	0.0	13.48	1.35	53.4	0.0
336.5	608.3	0.0	13.48	1.35	72.0	0.0
337.0	608.3	0.0	13.36	1.35	85.6	0.0
337.5	619.4	0.0	13.77	1.35	88.0	0.0
338.0	584.7	0.0	13.21	1.35	88.0	0.0
338.5	631.9	0.0	13.81	1.35	91.4	0.0
339.0	631.9	0.0	13.77	1.35	94.9	0.0
339.5	640.8	0.0	13.77	1.35	92.8	0.0
340.0	631.9	0.0	13.92	1.35	95.8	0.0
340.5	608.3	0.0	13.67	1.35	92.1	0.0
341.0	631.9	0.0	13.77	1.35	94.9	0.0
341.5	609.8	0.0	13.48	1.35	91.9	0.0
342.0	619.4	0.0	13.24	1.35	91.4	0.0
342.5	608.3	0.0	13.77	1.35	91.4	0.0
343.0	631.9	0.0	13.65	1.35	91.4	0.0
343.5	660.7	0.0	14.35	1.35	94.9	0.0
344.0	608.3	0.0	13.55	1.35	94.9	0.0
344.5	655.5	0.0	13.77	1.35	94.9	0.0
345.0	593.6	0.0	13.19	1.35	91.4	0.0
345.5	631.9	0.0	13.92	1.35	91.4	0.0
346.0	655.5	0.0	14.06	1.35	94.9	0.0
346.5	619.4	0.0	13.63	1.35	92.1	0.0
347.0	631.9	0.0	13.68	1.36	92.7	0.0
347.5	619.4	0.0	13.77	1.36	95.3	0.0
348.0	631.9	0.0	13.92	1.37	94.9	0.0
348.5	595.1	0.0	13.34	1.37	91.9	0.0
349.0	664.4	0.0	14.06	1.37	93.0	0.0
349.5	661.4	0.0	14.13	1.37	98.4	0.0
350.0	631.9	0.0	13.48	1.37	91.4	0.0
350.5	609.8	0.0	12.32	1.37	84.5	0.0
351.0	969.6	0.0	12.37	1.37	130.4	0.0
351.5	1009.4	0.0	12.76	1.37	186.0	0.0
352.0	1062.5	0.0	11.16	1.37	203.1	0.0

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
352.5	618.7	0.0	13.63	1.37	91.4	0.0
353.0	1342.0	79.1	12.37	1.38	265.1	4.0
353.5	1391.4	169.1	12.18	1.38	262.7	8.5
354.0	1528.5	361.1	11.46	1.38	268.4	18.5
354.5	1580.1	468.3	11.16	1.38	258.9	23.1
355.0	1674.5	482.6	10.00	1.38	243.7	22.4
355.5	1846.3	553.1	8.85	1.38	261.1	27.5
356.0	17704	611.6	8.41	1.38	261.4	30.4
356.5	1698.1	658.1	7.84	1.38	251.5	31.5
357.0	1764.5	745.1	8.26	1.38	248.4	35.2
357.5	1770.4	756.3	8.41	1.38	235.0	33.8
358.0	1789.5	817.1	8.55	1.38	223.8	34.8
358.5	1789.5	844.1	8.84	1.38	213.5	34.3
359.0	1811.7	889.1	9.13	1.38	188.4	31.9
359.5	1693.7	943.0	8.30	1.39	184.9	33.2
360.0	1696.6	961.0	8.42	1.39	175.4	32.1
360.5	1693.7	985.0	8.70	1.40	171.1	32.1
361.0	1657.5	1009.0	8.55	1.41	164.1	31.5
361.5	1693.7	1044.3	8.70	1.41	162.0	32.2
362.0	1657.5	1089.3	10.00	1.41	157.2	32.6
362.5	1575.7	1105.0	11.20	1.42	136.4	28.7
363.0	1563.2	1111.0	11.19	1.42	119.1	25.2
363.5	1504.9	1108.0	12.76	1.42	[illegible]	[illegible]
364.0	1552.1	1132.8	13.19	1.43	99.0	21.4
364.5	1556.5	1163.5	13.98	1.43	99.9	22.1
365.0	1504.9	1153.0	14.13	1.43	88.6	19.5
365.5	1504.9	1177.0	14.50	1.44	84.8	19.0
366.0	1457.7	1156.0	14.21	1.44	77.7	17.1
366.5	1512.3	1186.0	14.64	1.44	81.1	18.3
367.0	1538.8	1225.0	14.79	1.44	84.5	19.7
367.5	1509.3	1225.0	14.64	1.45	81.1	18.9
368.0	1528.5	1225.0	14.55	1.45	78.2	18.3
368.5	1507.1	1225.0	14.50	1.45	77.6	18.1
369.0	1552.1	1249.0	14.93	1.46	81.1	19.3
369.5	1528.5	1249.0	15.51	1.46	78.0	18.6
370.0	1481.3	1249.0	15.66	1.46	70.7	16.8
370.5	1481.3	1273.0	16.81	1.46	67.2	16.3
371.0	1374.4	1231.8	18.85	1.46	51.1	12.0
371.5	1322.8	1249.0	19.63	1.46	36.1	8.6
372.0	1316.2	1249.0	19.86	1.47	29.1	6.9
372.5	1339.8	1234.0	19.62	1.47	26.1	6.1
373.0	1364.8	1225.0	17.97	1.47	29.1	6.8
373.5	1528.5	1249.0	14.79	1.47	50.8	12.1
374.0	1563.2	1250.5	14.68	1.47	68.7	16.4
374.5	1583.1	1297.0	14.93	1.47	81.1	20.0
375.0	1534.4	1297.0	15.87	1.47	77.6	19.2
375.5	1481.3	1297.0	17.10	1.49	68.3	16.9

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
376.0	1434.1	1273.0	17.61	1.49	54.7	13.2
376.5	1434.1	1297.0	17.98	1.49	49.9	12.3
377.0	1434.1	1297.0	17.61	1.49	47.1	11.6
377.5	1463.6	1297.0	17.54	1.49	49.9	12.3
378.0	1440.0	1297.0	17.43	1.49	49.9	12.3
378.5	1457.7	1297.0	17.57	1.49	49.9	12.3
379.0	1457.7	1297.0	17.83	1.49	49.9	12.3
379.5	1457.7	1321.0	18.14	1.49	47.7	12.0
380.0	1457.7	1303.0	18.01	1.49	46.4	11.5
380.5	1457.7	1321.0	18.12	1.49	46.4	11.7
381.0	1444.5	1297.0	17.57	1.49	44.5	11.0
381.5	1491.7	1304.5	16.96	1.49	49.9	12.4
382.0	1504.9	1321.0	16.96	1.49	53.4	13.4
382.5	1510.8	1321.0	17.16	1.49	56.8	14.3
383.0	1504.9	1324.8	17.54	1.49	55.0	13.9
383.5	1363.4	1297.0	19.86	1.50	43.0	10.6
384.0	1374.4	1321.0	20.31	1.50	32.6	8.2
384.5	1185.7	1297.0	21.02	1.50	13.4	3.3
385.0	1151.0	1273.0	20.58	1.51	0.0	0.0
385.5	1179.0	1273.0	20.80	1.51	0.0	0.0
386.0	1127.4	1225.0	20.44	1.51	−11.1	0.0
386.5	1131.8	1235.5	20.58	1.52	0.0	0.0
387.0	1134.8	1228.0	20.58	1.52	0.0	0.0
387.5	1103.8	1225.0	20.45	1.52	0.0	0.0
388.0	1080.2	1210.0	20.35	1.52	0.0	0.0
388.5	1080.2	1177.0	20.00	1.52	−11.1	0.0
389.0	996.9	1153.0	19.61	1.52	0.0	0.0
389.5	985.8	1106.5	19.43	1.52	0.0	0.0
390.0	985.8	1063.0	19.28	1.52	0.0	0.0
390.5	918.0	1019.5	18.77	1.52	0.0	0.0
391.0	867.9	945.3	18.12	1.52	0.0	0.0
391.5	827.3	923.6	17.59	1.52	0.0	0.0
392.0	797.1	889.1	17.25	1.52	0.0	0.0
392.5	773.5	826.1	16.52	1.52	0.0	0.0
393.0	773.5	775.1	16.58	1.52	0.0	0.0
393.5	681.3	721.1	15.66	1.52	0.0	0.0
394.0	729.3	660.3	15.80	1.52	6.2	0.8
394.5	688.0	649.1	14.84	1.52	11.8	1.5
395.0	713.8	610.1	15.22	1.52	16.4	1.9
395.5	655.5	532.1	14.50	1.52	18.7	1.9
396.0	662.9	468.3	14.70	1.52	20.0	1.8
396.5	631.9	436.1	13.95	1.52	23.3	1.9
397.0	679.1	372.3	14.41	1.52	26.1	1.9
397.5	679.1	300.3	14.25	1.53	30.6	1.8
398.0	608.3	97.1	13.34	1.53	29.1	0.5
398.5	679.1	0.0	14.35	1.53	29.1	0.0
399.0	966.7	1105.0	19.28	1.53	0.0	0.0

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
399.5	631.9	0.0	13.92	1.53	57.3	0.0
400.0	679.1	0.0	14.50	1.53	71.1	0.0
400.5	639.3	0.0	13.92	1.53	81.1	0.0
401.0	611.3	0.0	13.63	1.53	84.5	0.0
401.5	655.5	–	13.92	1.53	92.7	0.0
402.0	655.5	0.0	14.22	1.53	95.6	0.0
402.5	657.0	–	14.10	1.53	102.0	0.0
403.0	655.5	0.0	14.13	1.53	101.8	0.0
403.5	637.8	0.0	14.12	1.53	96.5	0.0
404.0	655.5	0.0	14.13	1.53	102.0	0.0
404.5	631.9	0.0	13.53	1.53	99.2	0.0
405.0	665.8	0.0	13.96	1.53	98.4	0.0
405.5	608.3	0.0	13.34	1.53	96.5	0.0
406.0	655.5	0.0	13.83	1.53	92.7	0.0
406.5	640.8	0.0	13.55	1.53	94.9	0.0
407.0	1151.0	0.0	11.60	1.53	148.1	0.0
407.5	1276.4	0.0	13.77	1.54	268.0	0.0
408.0	1254.2	0.0	12.36	1.54	279.9	0.0
408.5	1363.4	–	11.45	1.54	285.5	0.0
409.0	1504.9	275.6	12.32	1.54	302.6	15.9
409.5	1481.3	372.3	11.89	1.54	271.4	19.2
410.0	1578.7	437.6	11.16	1.54	255.5	21.3
410.5	1657.5	489.3	10.58	1.54	254.1	23.7
411.0	1740.9	531.3	10.64	1.54	235.0	23.8
411.5	1508.4	564.3	8.91	1.54	226.4	24.3
412.0	1599.3	629.6	9.14	1.54	219.5	26.3
412.5	1673.0	679.1	3.88	1.54	219.7	28.4
413.0	1740.9	728.6	8.44	1.54	224.1	31.1
413.5	1811.7	779.6	7.99	1.54	229.9	34.1
414.0	1822.0	841.1	7.98	1.54	229.9	36.8
414.5	1846.8	889.1	8.84	1.54	224.1	37.9
415.0	1740.9	913.1	11.16	1.54	175.5	30.5
415.5	1693.7	937.1	8.03	1.54	168.7	30.1
416.0	1751.2	971.5	7.68	1.54	179.1	33.1
416.5	1749.7	1009.0	7.73	1.54	181.4	34.9
417.0	1725.4	1042.0	9.28	1.56	178.0	35.3
417.5	1628.8	1084.0	11.60	1.57	158.4	32.7
418.0	1556.5	1081.0	10.75	1.57	124.2	25.6
418.5	1575.7	1086.3	13.34	1.58	119.9	24.8
419.0	1299.9	1091.5	16.10	1.58	85.3	17.7
419.5	1202.6	1081.0	18.74	1.58	60.3	12.4
420.0	1037.5	1081.0	19.57	1.60	27.0	5.6
420.5	1060.3	1064.5	19.86	1.61	13.4	2.7
421.0	985.8	1033.0	19.28	1.63	0.0	0.0
421.5	1080.2	1033.0	18.16	1.64	0.0	0.0
422.0	1127.4	1033.0	18.26	1.64	11.8	2.3
422.5	1136.3	1057.0	19.00	1.64	22.2	4.5

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
423.0	971.1	1033.0	19.14	1.64	9.1	1.8
423.5	963.7	1009.0	19.20	1.64	0.0	0.0
424.0	921.0	985.0	18.70	1.64	0.0	0.0
424.5	867.9	940.0	18.03	1.64	0.0	0.0
425.0	854.6	924.3	17.85	1.64	0.0	0.0
425.5	829.5	871.1	17.61	1.64	0.0	0.0
426.0	798.6	802.1	16.96	1.64	0.0	0.0
426.5	752.9	756.3	16.54	1.64	0.0	0.0
427.0	713.8	698.6	15.67	1.64	0.0	0.0
427.5	708.6	656.6	15.67	1.64	11.8	1.5
428.0	684.3	577.1	15.37	1.64	13.4	1.5
428.5	679.1	515.6	15.08	1.64	18.7	1.8
429.0	608.3	438.3	13.97	1.64	18.7	1.6
429.5	655.5	371.6	14.79	1.64	25.7	1.8
430.0	655.5	276.3	14.35	1.64	32.6	1.7
430.5	679.1	180.3	14.64	1.64	33.2	1.1
431.0	686.5	0.0	14.79	1.64	29.6	0.0
431.5	679.1	0.0	15.22	1.64	43.0	0.0
432.0	609.8	0.0	13.93	1.64	53.4	0.0
432.5	631.9	0.0	13.98	1.64	70.7	0.0
433.0	639.3	0.0	14.21	1.64	81.2	0.0
433.5	612.8	0.0	13.65	1.64	88.0	0.0
434.0	631.9	0.0	14.21	1.64	95.1	0.0
434.5	631.9	0.0	14.50	1.64	99.0	0.0
435.0	679.1	0.0	14.2	1.64	102.3	0.0
435.5	655.5	0.0	14.40	1.64	105.3	0.0
436.0	642.3	0.0	14.24	1.64	102.0	0.0
436.5	631.9	0.0	14.26	1.64	101.8	0.0
437.0	631.9	0.0	14.35	1.64	105.3	0.0
437.5	660.7	0.0	14.50	1.64	108.7	0.0
438.0	631.9	0.0	13.79	1.64	102.8	0.0
438.5	655.5	0.0	14.35	1.64	103.3	0.0
439.0	611.3	0.0	13.64	1.64	99.7	0.0
439.5	619.4	0.0	13.93	1.64	101.8	0.0
440.0	679.1	0.0	14.35	1.64	103.1	0.0
440.5	609.8	0.0	13.92	1.64	103.3	0.0
441.0	631.9	0.0	14.06	1.64	101.8	0.0
441.5	639.3	0.0	14.07	1.64	101.8	0.0
442.0	637.1	0.0	14.21	1.64	102.3	0.0
442.5	641.5	0.0	14.13	1.64	105.7	0.0
443.0	631.9	0.0	13.92	1.64	102.3	0.0
443.5	655.5	0.0	14.06	1.64	105.3	0.0
444.0	643.0	0.0	14.35	1.64	101.8	0.0
444.5	655.5	0.0	14.38	1.64	102.9	0.0
445.0	655.5	0.0	14.35	1.64	105.3	0.0
445.5	655.5	0.0	14.50	1.64	102.3	0.0
446.0	631.9	0.0	13.92	1.64	105.3	0.0

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
446.5	655.5	0.0	14.21	1.65	102.0	0.0
447.0	608.3	0.0	13.92	1.65	101.8	0.0
447.5	634.9	0.0	14.12	1.65	102.8	0.0
448.0	631.9	0.0	13.77	1.65	102.0	0.0
448.5	679.1	0.0	14.13	1.65	105.3	0.0
449.0	655.5	0.0	14.64	1.65	105.3	0.0
449.5	631.9	0.0	14.13	1.65	105.3	0.0
450.0	631.9	0.0	13.77	1.65	102.9	0.0
450.5	637.1	0.0	14.06	1.65	105.9	0.0
451.0	631.9	0.0	13.65	1.65	102.1	0.0
451.5	609.8	0.0	13.35	1.65	96.5	0.0
452.0	1155.4	0.0	13.19	1.65	164.3	0.0
452.5	1159.9	0.0	14.08	1.65	240.3	0.0
453.0	1151.0	0.0	13.64	1.65	244.9	0.0
453.5	1229.9	0.0	12.47	1.65	241.2	0.0
454.0	1387.0	145.1	12.19	1.65	262.7	7.3
454.5	1559.5	337.1	11.02	1.65	295.7	19.0
455.0	1563.2	409.1	10.58	1.65	283.1	22.1
455.5	1677.5	484.1	10.44	1.65	275.3	25.4
456.0	1740.9	538.1	9.86	1.65	264.9	27.1
456.5	1701.8	581.6	8.26	1.65	255.4	28.3
457.0	1751.2	649.1	7.30	1.65	262.6	32.4
457.5	1846.3	721.1	6.09	1.65	272.7	37.4
458.0	1976.8	796.1	5.51	1.66	286.8	43.5
458.5	2024.0	871.1	5.43	1.66	299.1	49.6
459.0	2030.6	937.1	5.52	1.66	289.6	51.7
459.5	1960.6	970.0	8.61	1.66	268.2	49.5
460.0	1811.7	1009.0	9.42	1.67	219.5	42.2
460.5	1740.9	1039.0	7.83	1.67	193.3	38.2
461.0	1811.7	1081.0	7.25	1.68	191.8	39.5
461.5	1835.2	1105.0	7.16	1.70	191.8	40.4
462.0	1842.6	1133.5	7.54	1.70	188.4	40.7
462.5	1835.2	1177.0	8.12	1.70	181.4	40.7
463.0	1742.3	1225.0	10.87	1.70	167.6	39.1
463.5	1648.0	1211.5	11.02	1.70	136.4	31.5
464.0	1751.2	1225.0	8.55	1.71	124.2	29.0
464.5	1764.5	1250.5	10.58	1.71	139.9	33.3
465.0	1646.5	1273.0	12.08	1.73	119.9	29.1
465.5	1602.3	1297.0	13.54	1.74	101.8	25.1
466.0	1603.7	1297.0	13.66	1.74	94.9	23.4
466.5	1488.7	1282.0	15.37	1.74	81.1	19.8
467.0	1504.9	1297.0	15.37	1.74	70.7	17.5
467.5	1535.9	1297.0	14.99	1.74	70.7	17.5
468.0	1552.1	1321.0	16.55	1.74	74.5	18.7
468.5	1434.1	1321.0	18.19	1.74	60.3	15.2
469.0	1417.9	1297.0	18.12	1.74	47.3	11.7
469.5	1435.6	1298.5	17.61	1.74	46.4	11.5

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
470.0	1434.1	1297.0	17.61	1.75	41.1	10.2
470.5	1457.7	1321.0	17.61	1.75	46.7	11.7
471.0	1440.0	1297.0	17.61	1.75	46.4	11.5
471.5	1434.1	1297.0	17.59	1.76	46.4	11.5
472.0	1420.9	1297.0	18.41	1.77	41.1	10.2
472.5	1420.1	1297.0	18.62	1.77	41.1	10.2
473.0	1410.5	1304.5	19.03	1.78	40.4	10.0
473.5	1388.4	1297.0	18.91	1.78	36.1	8.9
474.0	1441.5	1297.0	17.43	1.78	37.4	9.2
474.5	1509.3	1298.5	15.57	1.78	50.2	12.4
475.0	1410.5	1300.0	19.13	1.78	53.4	13.2
475.5	1348.6	1300.0	20.76	1.78	40.2	9.9
476.0	1269.0	1280.5	20.87	1.78	18.7	4.6
476.5	1245.4	1253.5	19.71	1.78	0.0	0.0
477.0	1363.4	1273.0	18.99	1.78	18.7	4.5
477.5	1339.8	1255.0	18.91	1.78	22.2	5.3
478.0	1345.7	1259.5	19.13	1.78	22.5	5.4
478.5	1341.2	1256.5	19.04	1.78	22.2	5.3
479.0	1366.3	1249.0	17.57	1.78	25.7	6.1
479.5	1345.7	1232.5	17.25	1.78	30.4	7.1
480.0	1363.4	1249.0	17.39	1.78	36.1	8.6
430.5	1387.0	1255.0	17.39	1.78	39.5	9.4
481.0	1410.5	1253.5	17.39	1.78	39.5	9.4
481.5	1394.3	1259.5	17.25	1.78	40.8	9.8
482.0	1363.4	1249.0	17.01	1.78	39.5	9.4
482.5	1387.0	1249.0	17.17	1.78	40.2	9.6
483.0	1387.0	1273.0	17.10	1.78	43.6	10.6
483.5	1410.5	1255.0	17.10	1.78	44.1	10.5
484.0	1418.7	1273.0	17.97	1.78	46.4	11.3
484.5	1320.6	1232.5	18.62	1.78	33.0	7.8
485.0	1316.2	1226.5	18.71	1.80	29.4	6.9
485.5	1387.0	1250.5	17.61	1.30	36.1	8.6
486.0	1419.4	1252.8	17.02	1.80	41.1	9.8
486.5	1434.1	1259.5	16.98	1.80	48.0	11.5
487.0	1485.8	1249.0	15.43	1.80	53.4	12.7
487.5	1504.9	1259.5	15.69	1.81	63.7	15.3
488.0	1509.3	1301.5	17.61	1.81	68.7	17.0
488.5	1245.4	1253.5	20.92	1.81	32.6	7.8
489.0	1339.8	1256.5	19.17	1.81	22.2	5.3
489.5	1342.7	1249.0	18.26	1.81	27.2	6.5
490.0	1316.2	1225.0	18.14	1.81	25.7	6.0
490.5	1339.8	1256.5	18.55	1.81	32.6	7.8
491.0	1325.0	1249.0	18.55	1.81	29.1	6.9
491.5	1317.6	1234.0	18.18	1.82	29.1	6.8
492.0	1410.5	1252.8	17.25	1.82	41.1	9.8
492.5	1387.0	1234.0	16.28	1.82	40.0	9.4
493.0	1434.1	1249.0	16.38	1.82	47.7	11.4

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
493.5	1434.1	1256.5	16.41	1.82	50.9	12.2
494.0	1434.1	1249.0	16.39	1.82	51.2	12.2
404.5	1410.5	1249.0	16.81	1.82	50.8	12.1
495.0	1269.0	1249.0	20.15	1.83	39.5	9.4
495.5	1185.7	1249.0	20.94	1.83	13.4	3.2
496.0	1185.7	1226.5	20.94	1.83	6.4	1.5
496.5	1127.4	1201.0	20.59	1.83	0.0	0.0
497.0	1112.7	1156.0	20.47	1.83	0.0	0.0
497.5	1089.8	1138.0	20.29	1.84	0.0	0.0
498.0	1080.2	1129.0	20.29	1.84	0.0	0.0
498.5	1080.2	1105.0	19.93	1.84	0.0	0.0
499.0	962.3	1033.0	19.13	1.84	0.0	0.0
499.5	945.3	985.0	18.99	1.84	0.0	0.0
500.0	896.6	937.1	18.41	1.84	0.0	0.0
500.5	844.3	889.1	17.61	1.84	0.0	0.0
501.0	797.1	820.1	16.99	1.84	5.2	0.8
501.5	780.1	756.3	16.41	1.84	8.4	1.2
502.0	730.7	679.1	15.80	1.84	9.4	1.2
502.5	682.8	631.1	14.84	1.84	13.1	1.6
503.0	679.1	601.1	14.85	1.84	16.4	1.9
503.5	702.7	553.1	15.13	1.84	20.0	2.1
504.0	679.1	529.8	14.64	1.84	23.1	2.3
504.5	657.0	468.3	14.80	1.84	23.1	2.1
505.0	634.9	416.6	14.13	1.84	25.7	2.0
505.5	680.6	394.1	14.64	1.84	29.1	2.2
506.0	682.1	365.6	14.79	1.84	32.6	2.3
506.5	655.5	178.1	14.06	1.84	36.1	1.2
507.0	662.9	–	14.50	1.84	29.4	0.0
507.5	702.7	0.0	15.28	1.84	41.1	0.0
508.0	659.2	0.0	14.79	1.84	55.0	0.0
508.5	679.1	0.0	14.69	1.84	71.8	0.0
509.0	679.1	0.0	14.13	1.84	88.0	0.0
509.5	655.5	0.0	14.35	1.84	99.4	0.0
510.0	619.4	0.0	13.77	1.85	101.8	0.0
510.5	679.1	0.0	14.64	1.85	105.3	0.0
511.0	614.2	0.0	14.13	1.85	106.0	0.0
511.5	689.4	0.0	14.93	1.85	110.2	0.0
512.0	619.4	0.0	14.13	1.85	108.7	0.0
512.5	655.5	0.0	14.24	1.85	105.3	0.0
513.0	661.4	0.0	14.70	1.85	108.7	0.0
513.5	655.5	0.0	14.35	1.85	110.4	0.0
514.0	679.1	0.0	14.39	1.85	110.3	0.0
514.5	655.5	0.0	13.55	1.85	101.8	0.0
515.0	727.8	0.0	10.58	1.85	101.8	0.0
515.5	1080.2	0.0	16.96	1.85	191.8	0.0
516.0	867.9	0.0	13.34	1.86	165.4	0.0
516.5	971.1	0.0	14.25	1.86	168.0	0.0

SAMPLE–DATA FROM DYNAMOMETER PROCEDURE (Cont'd)

Time (sec)	Engine rpm	Drive shaft rpm	Vacuum (in. Hg)	Fuel weight (lb)	Torque (ft-lb)	Horse-power
517.0	972.6	0.0	13.67	1.86	165.8	0.0
517.5	988.8	0.0	13.92	1.86	164.1	0.0
518.0	1064.7	0.0	14.64	1.86	161.1	0.0
518.5	1080.2	–	15.37	1.86	157.2	0.0
519.0	1103.8	145.1	15.22	1.86	143.4	4.0
519.5	1151.0	169.1	15.37	1.86	133.2	4.3
520.0	1156.9	313.1	15.51	1.86	129.7	7.7
520.5	1160.6	338.6	15.66	1.86	123.0	7.9
521.0	1185.7	371.6	16.30	1.87	120.4	8.5
521.5	1185.7	409.1	16.85	1.87	112.2	8.7
522.0	1151.0	385.1	16.38	1.87	98.4	7.2
522.5	1179.0	433.1	13.93	1.87	112.2	9.3
523.0	1316.2	457.1	13.68	1.87	137.7	12.0
523.5	1439.3	505.1	12.47	1.87	165.8	15.9
524.0	1528.5	556.1	12.18	1.87	193.4	20.5
524.5	1504.9	578.6	11.89	1.87	192.9	21.3

FUEL USE SUMMARY

3500 lb
11.2 hp (EPA)

22 October 1973

Relative Start	Relative Stop	Absolute Start	Absolute Stop	Fuel weight avg start	Fuel weight avg stop	Fuel weight difference	Integral
Acceleration							
21.0	29.0	27.9	35.9	0.185	0.224	0.040	0.043
55.0	60.5	61.9	67.4	0.312	0.352	0.040	0.026
163.0	170.0	169.9	176.9	0.590	0.648	0.058	0.056
187.5	205.0	194.4	211.9	0.698	0.862	0.164	0.192
346.0	365.0	352.9	371.9	1.352	1.467	0.114	0.124
402.9	414.0	408.9	420.9	1.533	1.643	0.110	0.082
447.5	478.0	454.4	484.9	1.648	1.788	0.141	0.166
510.5	528.0	517.4	534.9	1.861	1.911	0.051	0.060
568.0	575.0	574.9	581.9	1.970	1.990	0.020	0.025
644.5	657.5	651.4	664.4	2.102	2.138	0.036	0.063
692.5	701.0	699.4	707.9	2.198	2.217	0.019	0.025
727.5	739.0	734.4	745.9	2.284	2.335	0.051	0.068
765.0	778.0	771.9	784.9	2.409	2.455	0.046	0.077
958.0	968.5	964.9	975.4	2.883	2.933	0.050	0.063
1052.0	1066.0	1058.9	1072.9	3.056	3.135	0.079	0.065
1100.0	1112.0	1106.9	1118.9	3.171	3.208	0.037	0.043
1167.0	1175.0	1173.9	1181.9	3.327	3.367	0.040	0.030
1196.0	1202.0	1202.9	1208.9	3.406	3.409	0.003	0.010
1255.0	1263.0	1261.9	1269.9	3.506	3.535	0.029	0.012
1267.0	1273.0	1273.9	1279.9	3.559	3.565	0.006	0.020
1336.0	1345.0	1342.9	1351.9	3.681	3.718	0.036	0.033
					Total	1.171	
Deceleration							
37.0	39.0	43.9	45.9	0.232	0.231	0.001	0.001
49.0	53.0	55.9	59.9	0.276	0.311	0.035	0.000
113.0	122.0	119.9	128.9	0.540	0.549	0.009	0.001
181.0	187.5	187.9	194.4	0.699	0.703	0.004	0.004
299.0	333.0	305.9	339.9	1.321	1.344	0.023	0.003
385.0	396.0	391.9	402.9	1.499	1.499	0.0	0.002
421.0	428.5	427.9	435.4	1.643	1.643	0.0	0.001
491.0	505.0	497.9	511.9	1.829	1.847	0.018	0.003
544.0	552.0	550.9	558.9	1.940	1.940	0.0	0.001
611.0	620.0	617.9	626.9	2.075	2.089	0.014	0.002
668.0	679.0	674.9	685.9	2.176	2.190	0.015	0.003
714.0	726.0	720.9	732.9	2.258	2.285	0.028	0.003
751.0	762.0	755.9	768.9	2.371	2.396	0.025	0.003
946.0	954.0	952.9	960.9	2.857	2.891	0.034	0.002
1015.0	1023.0	1021.9	1029.9	3.051	3.060	0.010	0.000
1093.0	1098.0	1099.9	1104.9	3.167	3.169	0.002	0.0
1140.0	1152.0	1146.9	1158.9	3.276	3.290	0.014	0.002
1178.0	1184.0	1184.9	1190.9	3.369	3.373	0.004	0.000

FUEL USE SUMMARY (Cont'd)

Relative Start	Relative Stop	Absolute Start	Absolute Stop	Fuel weight avg start	Fuel weight avg stop	Fuel weight difference	Integral
Deceleration (Cont'd)							
1234.0	1243.0	1240.9	1249.9	3.479	3.477	0.002	0.000
1303.0	1307.0	1309.9	1313.9	3.625	3.642	0.017	0.000
1356.0	1365.0	1362.9	1371.9	3.735	3.727	0.008	0.001
					Total	0.262	
Cruise							
29.0	37.0	35.9	43.9	0.218	0.233	0.014	0.006
39.0	49.0	45.9	55.9	0.233	0.272	0.040	0.030
53.0	55.0	59.9	61.9	0.308	0.312	0.003	0.008
60.5	113.0	67.4	119.9	0.351	0.539	0.188	0.134
170.0	181.0	176.9	187.9	0.662	0.701	0.039	0.023
205.0	299.0	211.9	305.9	0.856	1.326	0.470	0.452
365.0	385.0	371.9	391.9	1.463	1.497	0.034	0.044
414.0	421.0	420.9	427.9	1.643	1.643	0.0	0.002
478.0	491.0	484.9	497.9	1.793	1.829	0.036	0.028
528.0	544.0	534.9	550.9	1.904	1.940	0.036	0.024
575.0	611.0	581.9	617.9	1.988	2.059	0.071	0.075
657.5	668.0	664.4	674.9	2.152	2.178	0.026	0.017
701.0	714.0	707.9	720.9	2.218	2.279	0.061	0.037
726.0	727.0	732.9	733.9	2.281	2.291	0.010	0.003
739.0	751.0	745.9	757.9	2.341	2.376	0.035	0.016
762.0	765.0	768.9	771.9	2.384	2.410	0.026	0.002
778.0	946.0	784.9	952.9	2.455	2.853	0.398	0.347
968.5	1015.0	975.4	1021.9	2.933	3.052	0.119	0.059
1052.0	1093.0	1058.9	1099.9	3.056	3.169	0.113	0.073
1112.0	1140.0	1118.9	1146.9	3.211	3.273	0.062	0.052
1175.0	1178,0	1181.9	1184.9	3.369	3.382	0.013	0.001
1202.0	1234.0	1208.9	1240.0	3.409	3.482	0.072	0.054
1249.0	1255.0	1255.9	1261.9	3.498	3.513	0.016	0.0
1263.0	1267.0	1269.9	1273.9	3.527	3.547	0.021	0.029
1273.0	1303.0	1279.9	1309.9	3.568	3.621	0.053	0.061
1345.0	1356.0	1351.9	1362.9	3.715	3.727	0.012	0.005
					Total	1.967	
Idle							
0.0	21.0	6.9	27.9	0.185	0.188	0.003	
125.0	163.0	131.9	169.9	0.546	0.594	0.047	
333.0	346.0	339.9	352.9	1.349	1.373	0.025	
396.0	402.0	402.9	408.9	1.502	1.538	0.037	
428.5	447.5	435.4	454.4	1.643	1.645	0.002	
505.0	510.5	511.9	517.4	1.852	1.861	0.009	
552.0	568.0	558.9	574.9	1.948	1.964	0.016	
620.0	644.5	626.9	651.4	2.072	2.099	0.027	

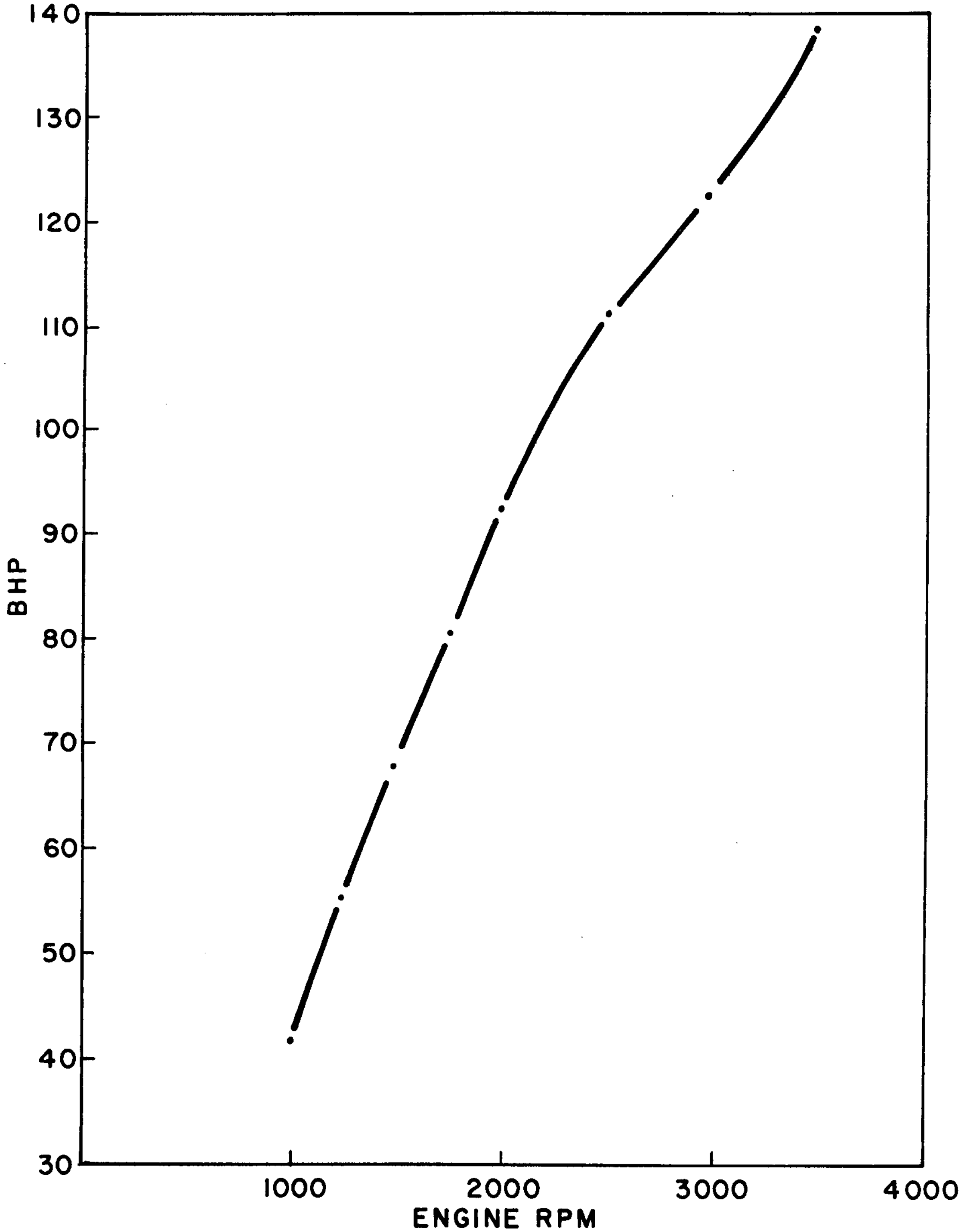
FUEL USE SUMMARY (Cont'd)

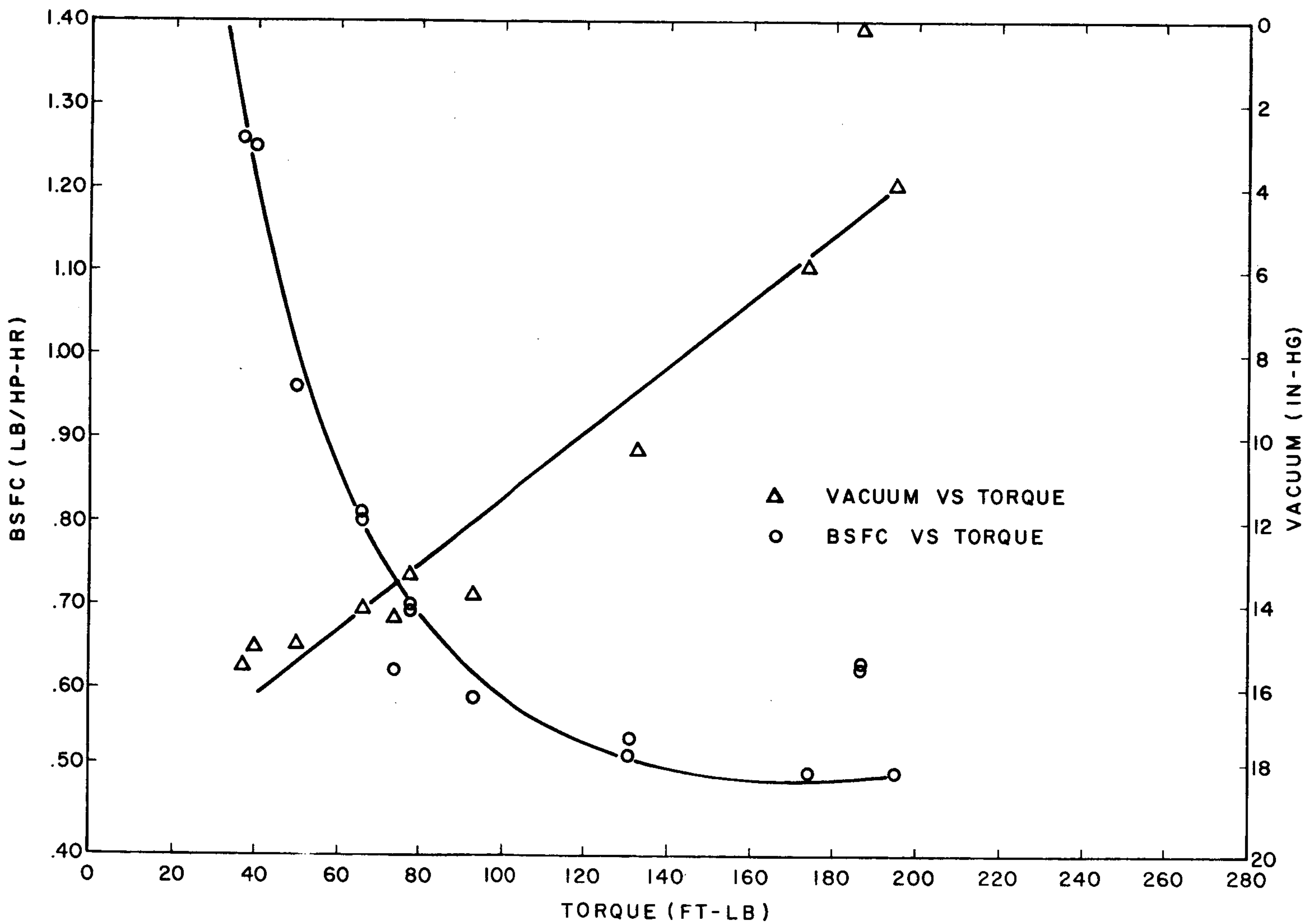
Relative Start	Relative Stop	Absolute Start	Absolute Stop	Fuel weight avg start	Fuel weight avg stop	Fuel weight difference	Integral
Idle (Cont'd)							
679.0	692.5	685.9	699.4	2.178	2.186	0.008	
954.0	958.0	960.9	964.9	2.888	2.892	0.003	
1023.0	1052.0	1029.9	1058.9	3.055	3.064	0.008	
1152.0	1167.0	1158.9	1173.9	3.303	3.330	0.027	
1184.0	1196.0	1190.9	1202.9	3.389	3.407	0.018	
1243.0	1249.0	1249.9	1255.9	3.485	3.502	0.017	
1307.0	1336.0	1313.9	1342.9	3.643	3.663	0.019	
Data ended at time equal 1374.4							
					Total	0.266	

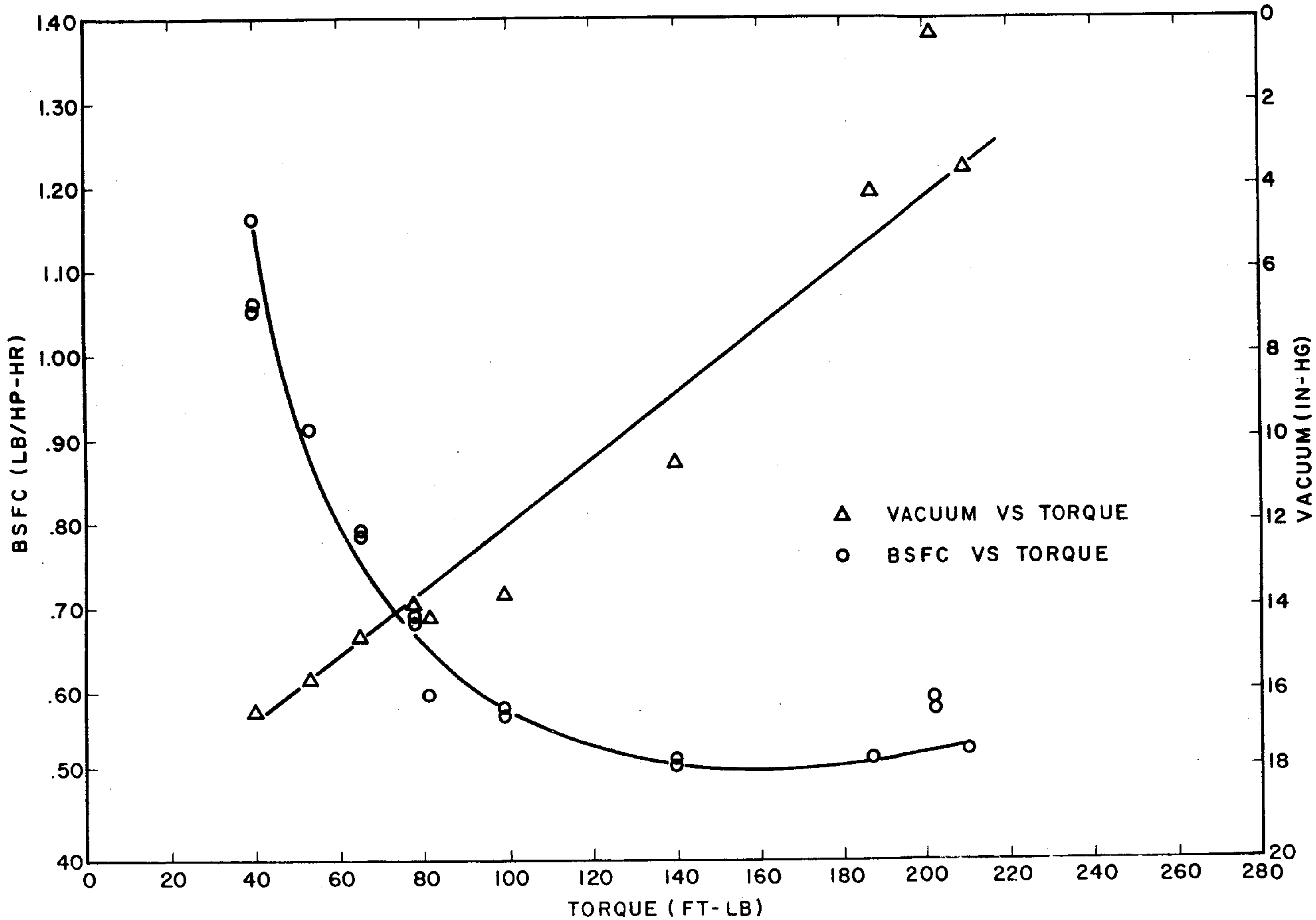
APPENDIX E

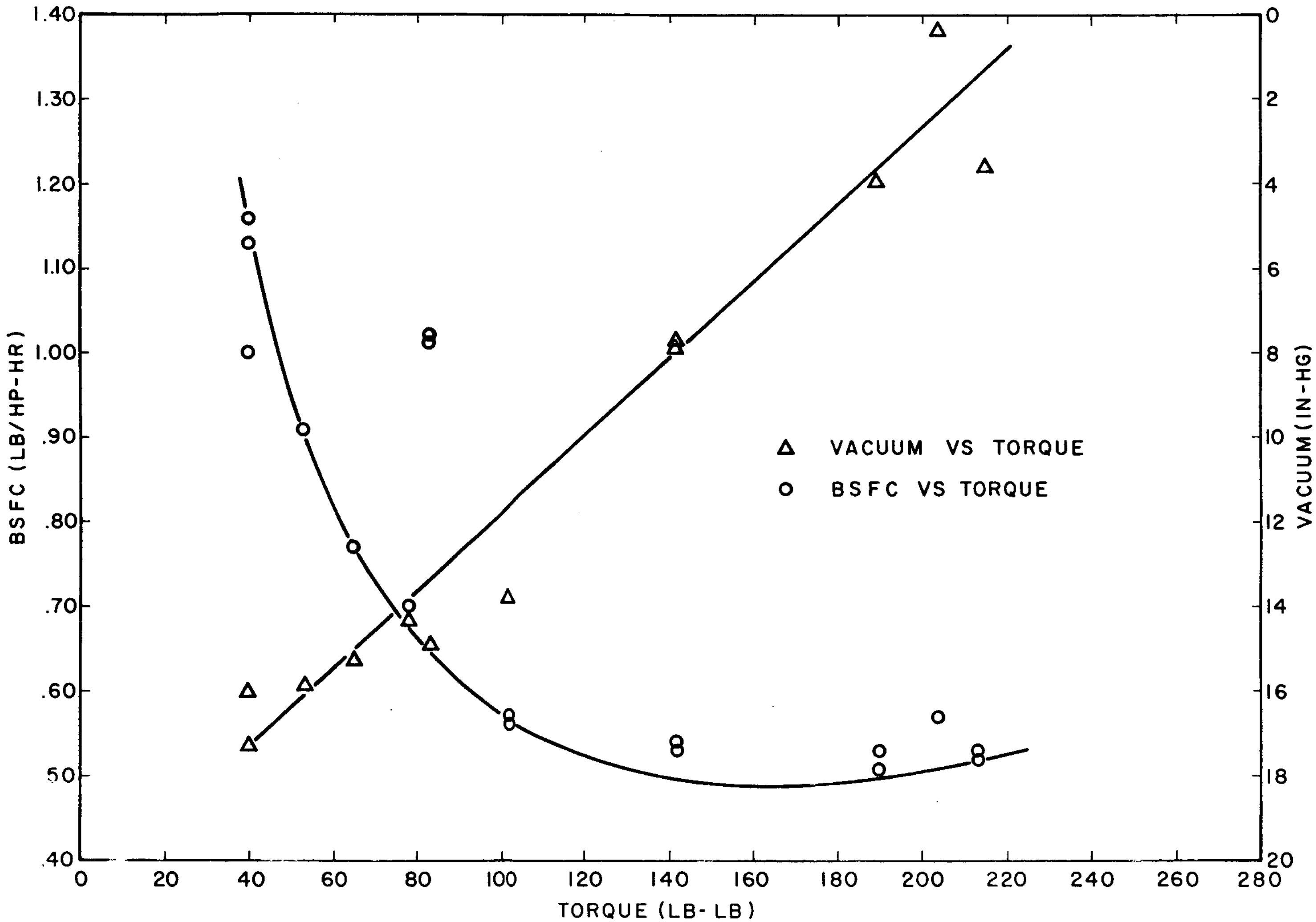
INSTALLED ENGINE POWER/BSFC DATA

TEST DATA FOR THE ENGINE FROM VEHICLE B

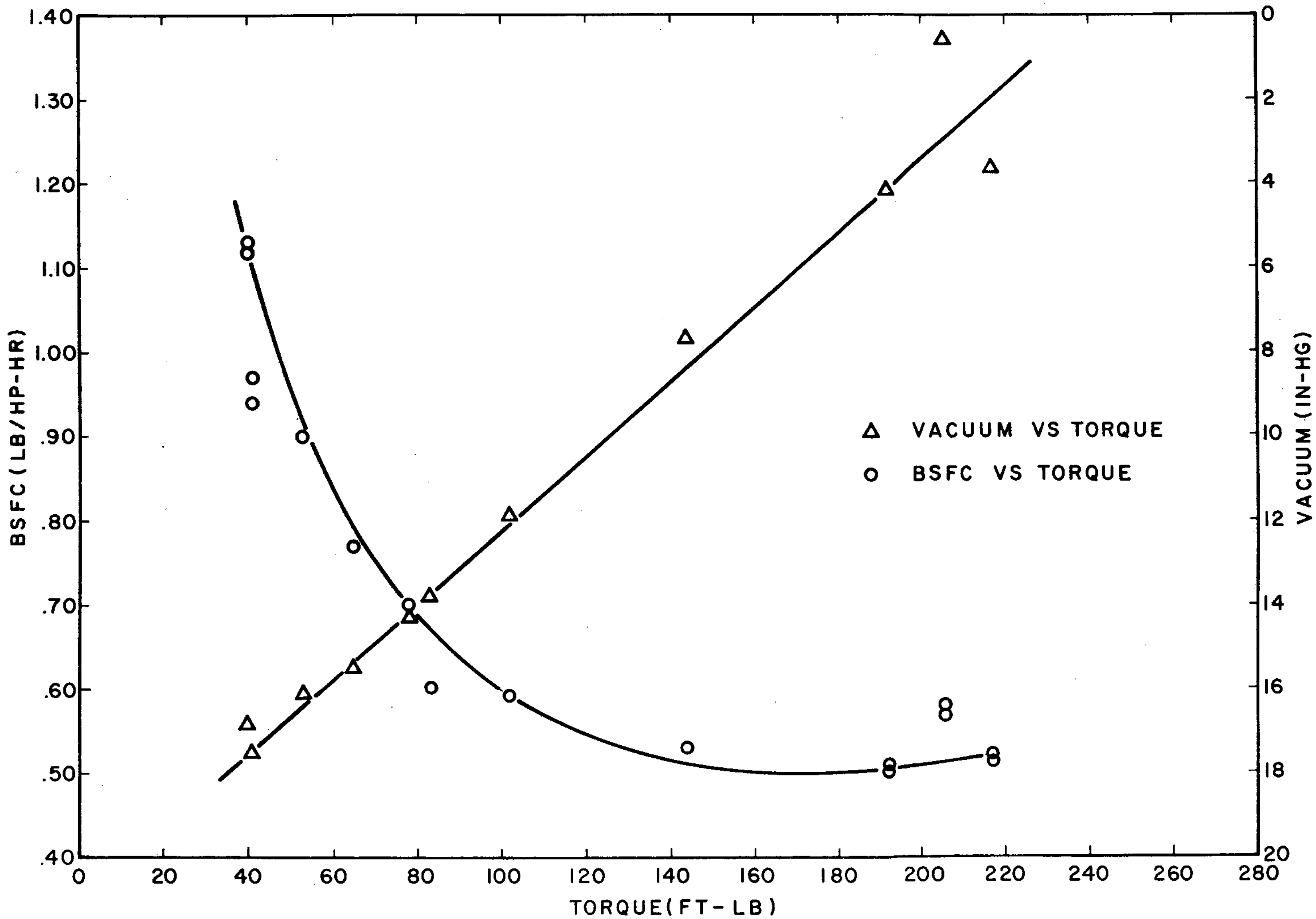

140
130
120
110
100
90
80
70
60
50
40
30
BHP
1000
2000
3000
4000
ENGINE RPM


BSFC (LB/HP-HR)
VACUUM (IN-HG)
TORQUE (FT-LB)
VACUUM VS TORQUE
BSFC VS TORQUE
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
0
2
4
6
8
10
12
14
16
18
20
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280

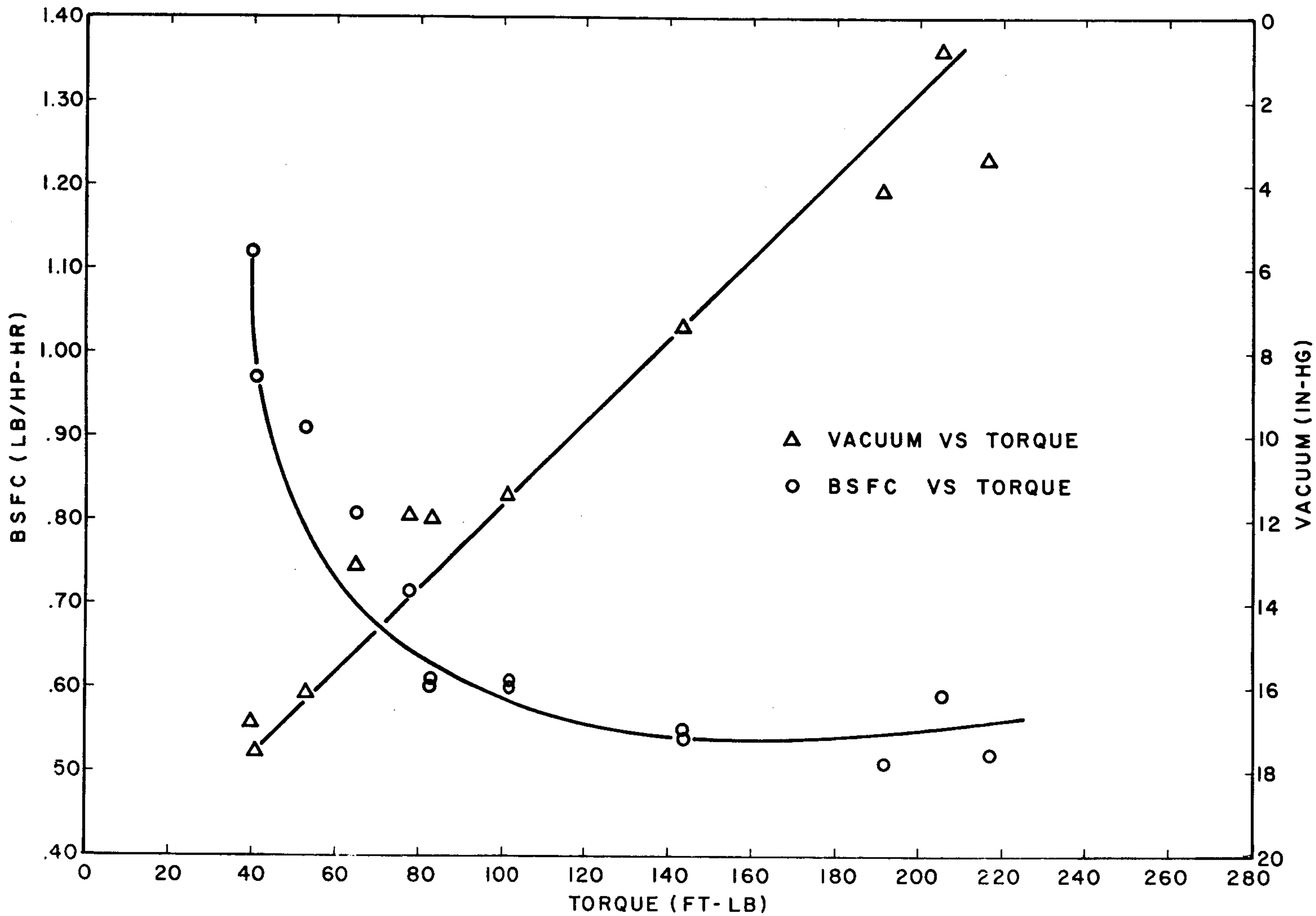

1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
40
BSFC (LB/HP-HR)
0
2
4
6
8
10
12
14
16
18
20
VACUUM (IN-HG)
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280
TORQUE (FT-LB)
VACUUM VS TORQUE
BSFC VS TORQUE



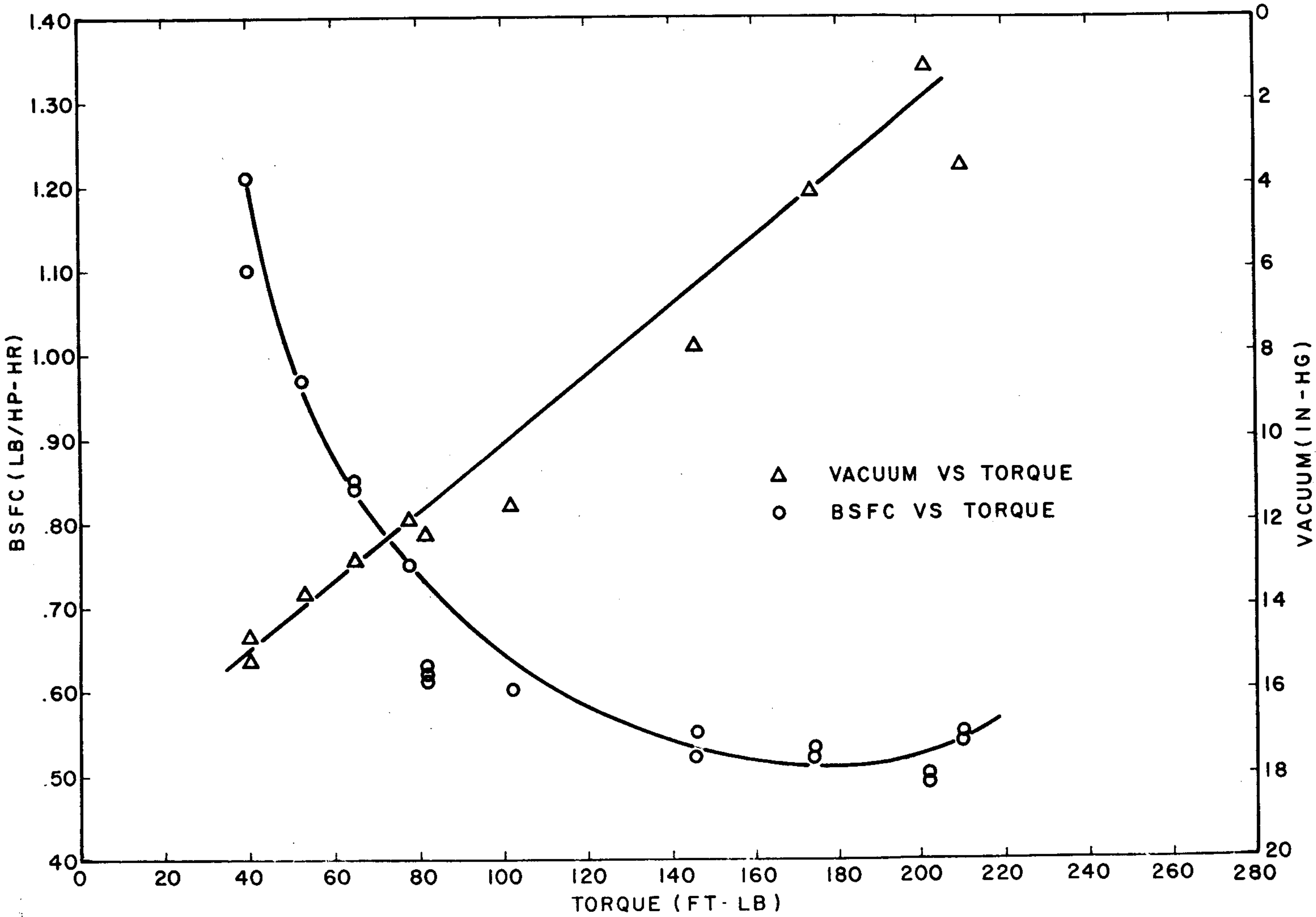
BSFC (LB/HP-HR)
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
VACUUM (IN-HG)
0
2
4
6
8
10
12
14
16
18
20
TORQUE (LB- LB)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
VACUUM VS TORQUE
BSFC VS TORQUE

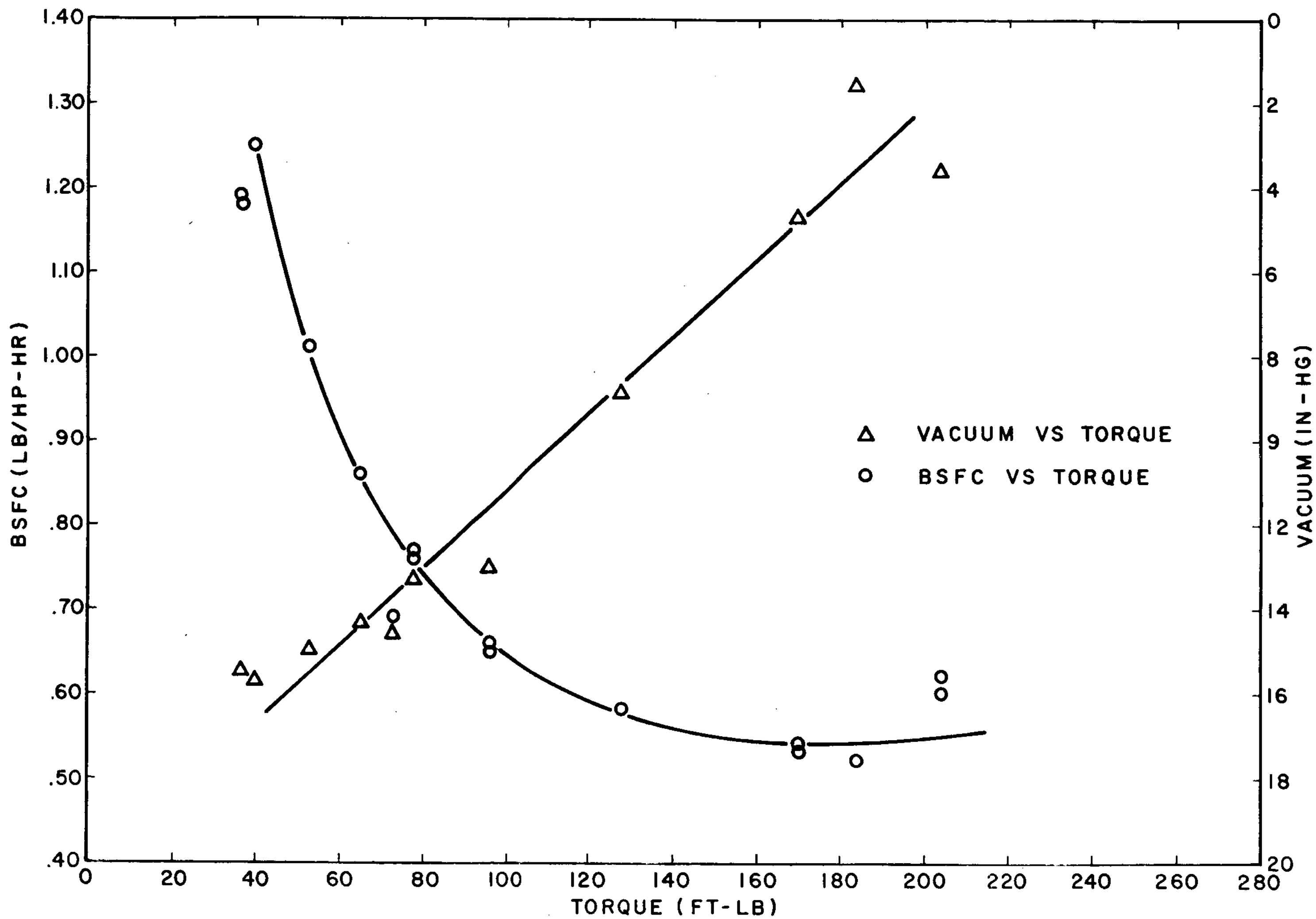


BSFC (LB/HP-HR)
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
VACUUM (IN-HG)
0
2
4
6
8
10
12
14
16
18
20
TORQUE (FT-LB)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
VACUUM VS TORQUE
BSFC VS TORQUE

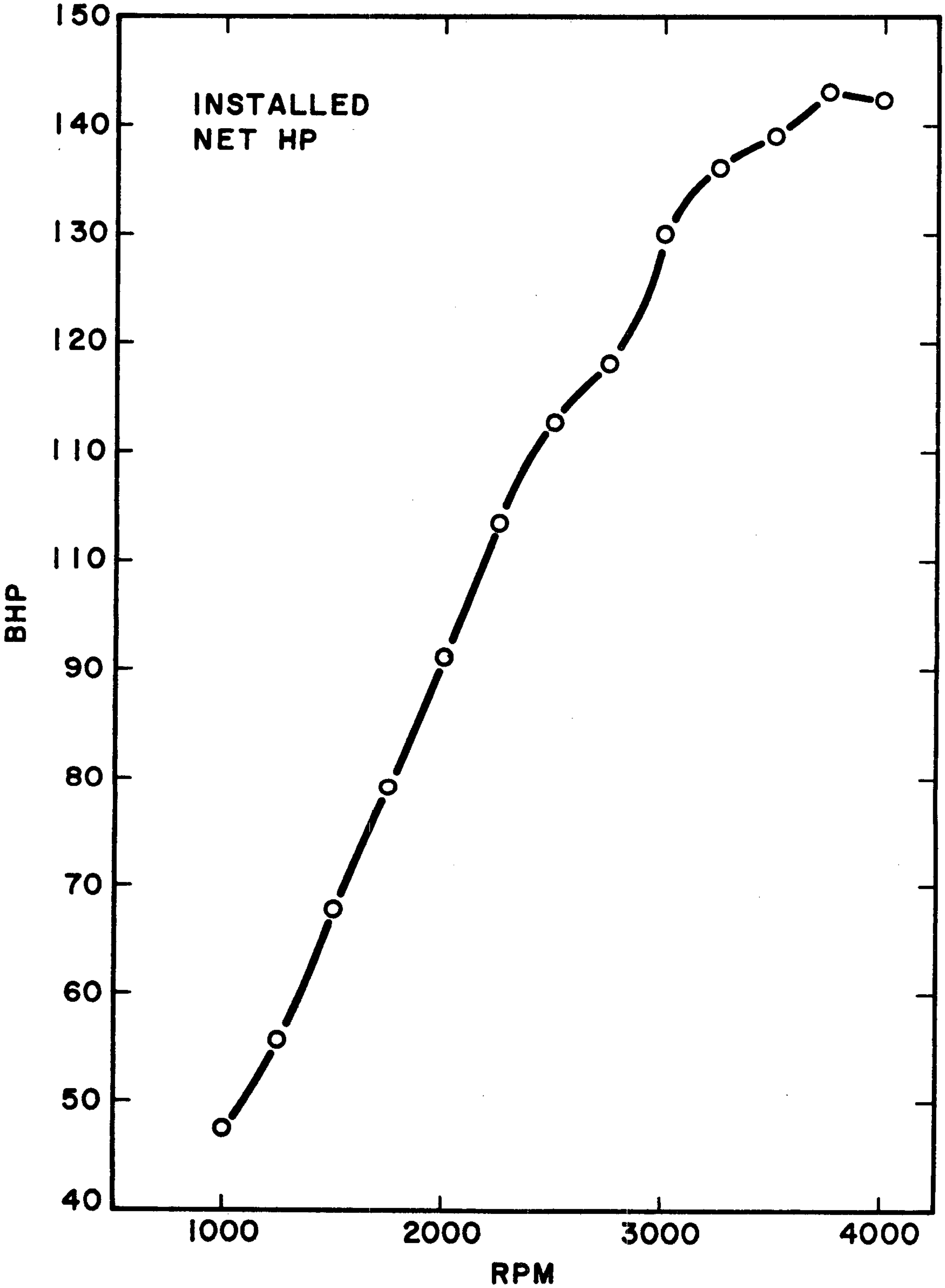


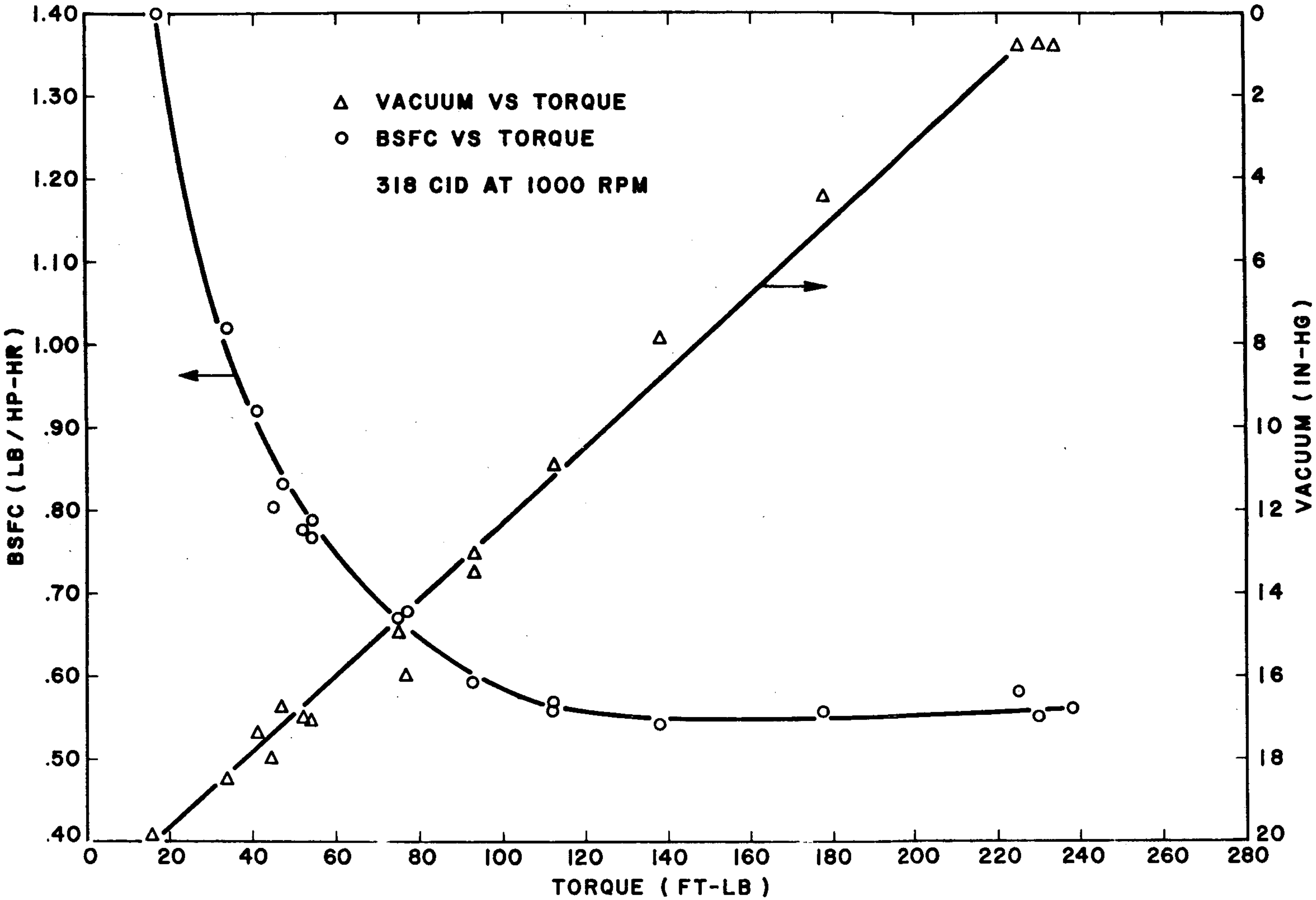
BSFC (LB/HP-HR)
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
TORQUE (FT-LB)
VACUUM (IN-HG)
0
2
4
6
8
10
12
14
16
18
20
VACUUM VS TORQUE
BSFC VS TORQUE


BSFC (LB/HP-HR)
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
40
VACUUM (IN-HG)
0
2
4
6
8
10
12
14
16
18
20
TORQUE (FT-LB)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
VACUUM VS TORQUE
BSFC VS TORQUE

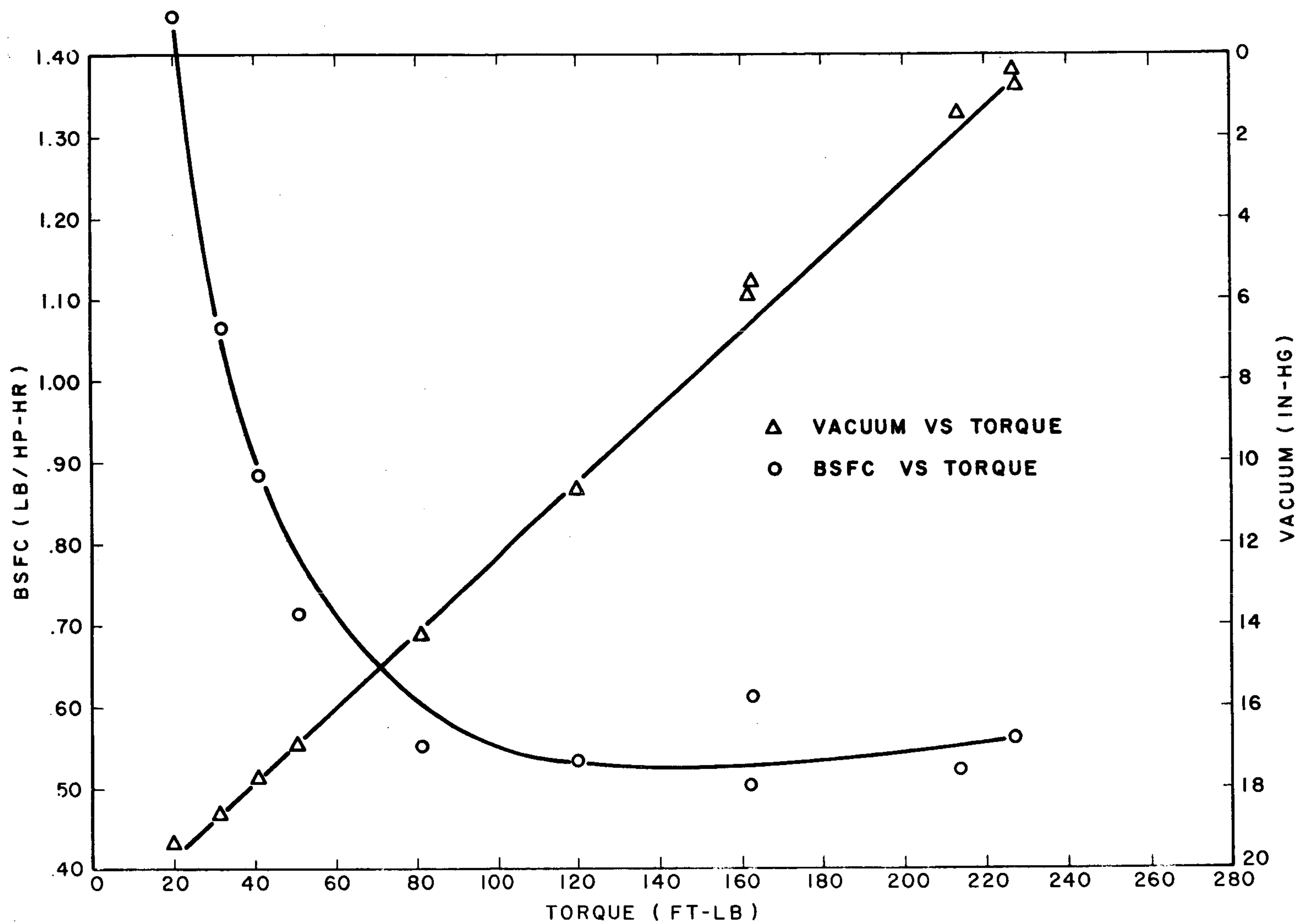

BSFC (LB/HP-HR)
VACUUM (IN-HG)
TORQUE (FT-LB)
VACUUM VS TORQUE
BSFC VS TORQUE
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
0
2
4
6
8
9
12
14
16
18
20
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280

TEST DATA FOR THE ENGINE FROM VEHICLE D

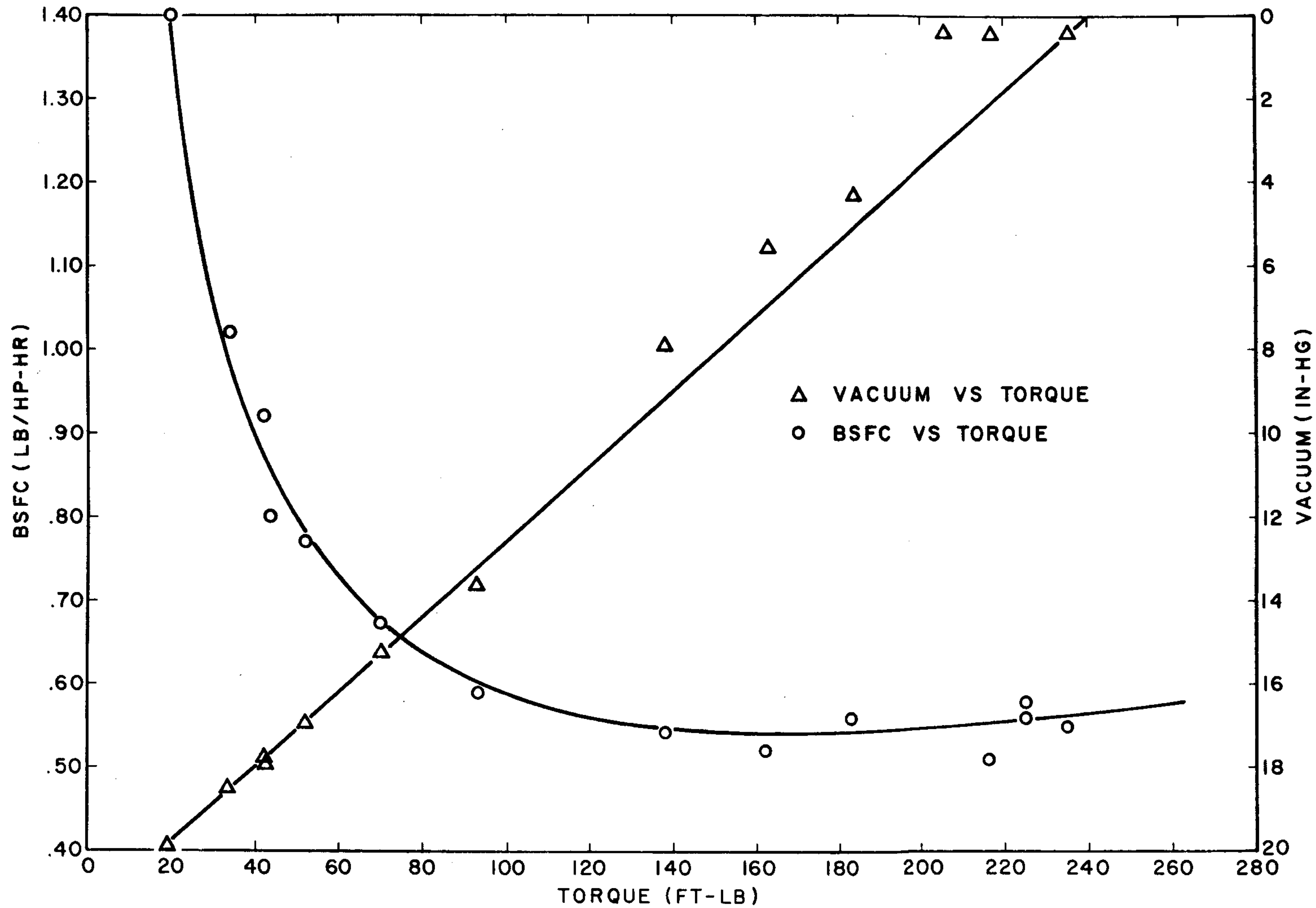

INSTALLED
NET HP
150
140
130
120
110
110
90
80
70
60
50
40
BHP
1000
2000
3000
4000
RPM

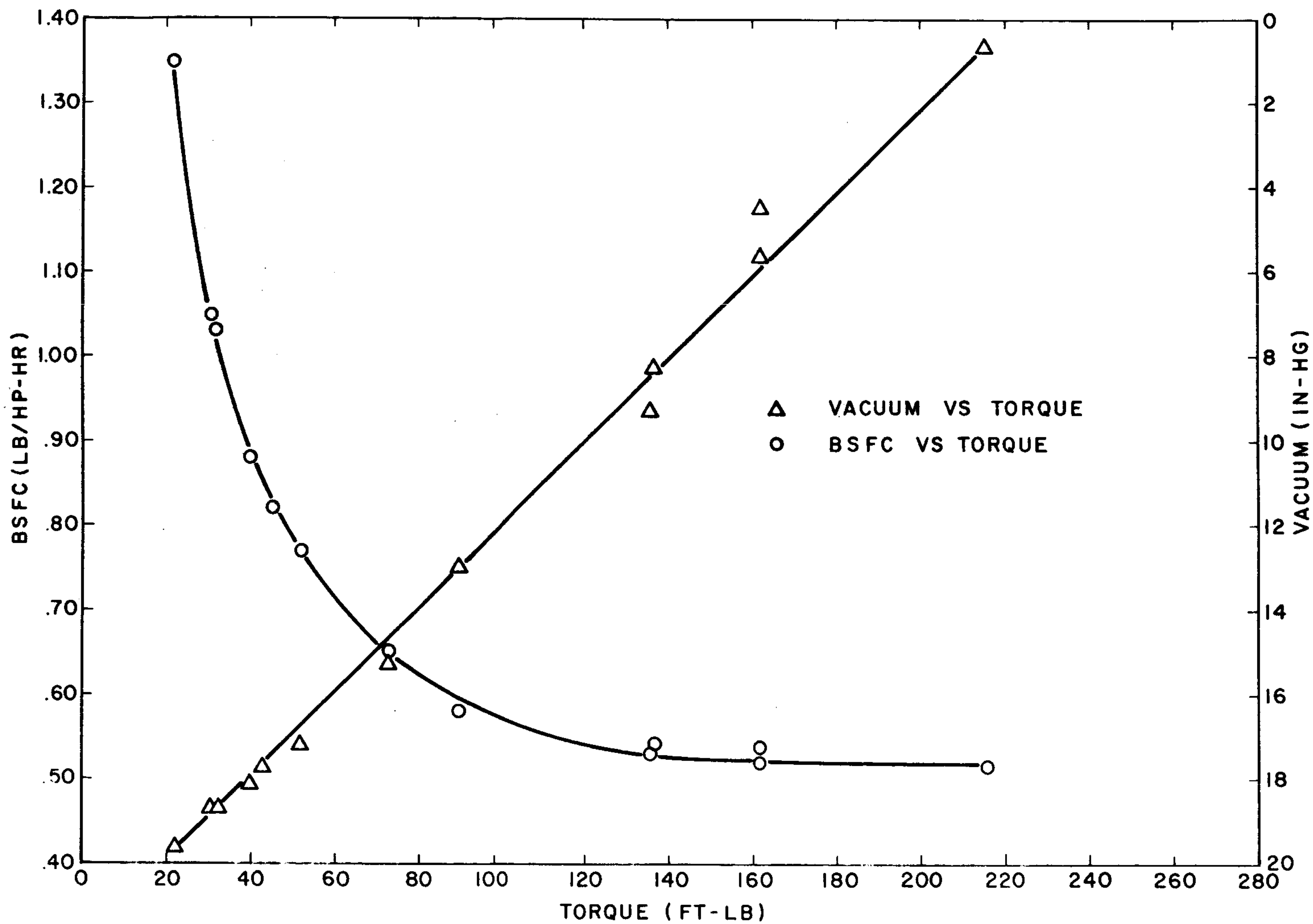


VACUUM VS TORQUE
BSFC VS TORQUE
318 CID AT 1000 RPM
BSFC (LB / HP-HR)
VACUUM (IN-HG)
TORQUE (FT-LB)
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
0
2
4
6
8
10
12
14
16
18
20
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280

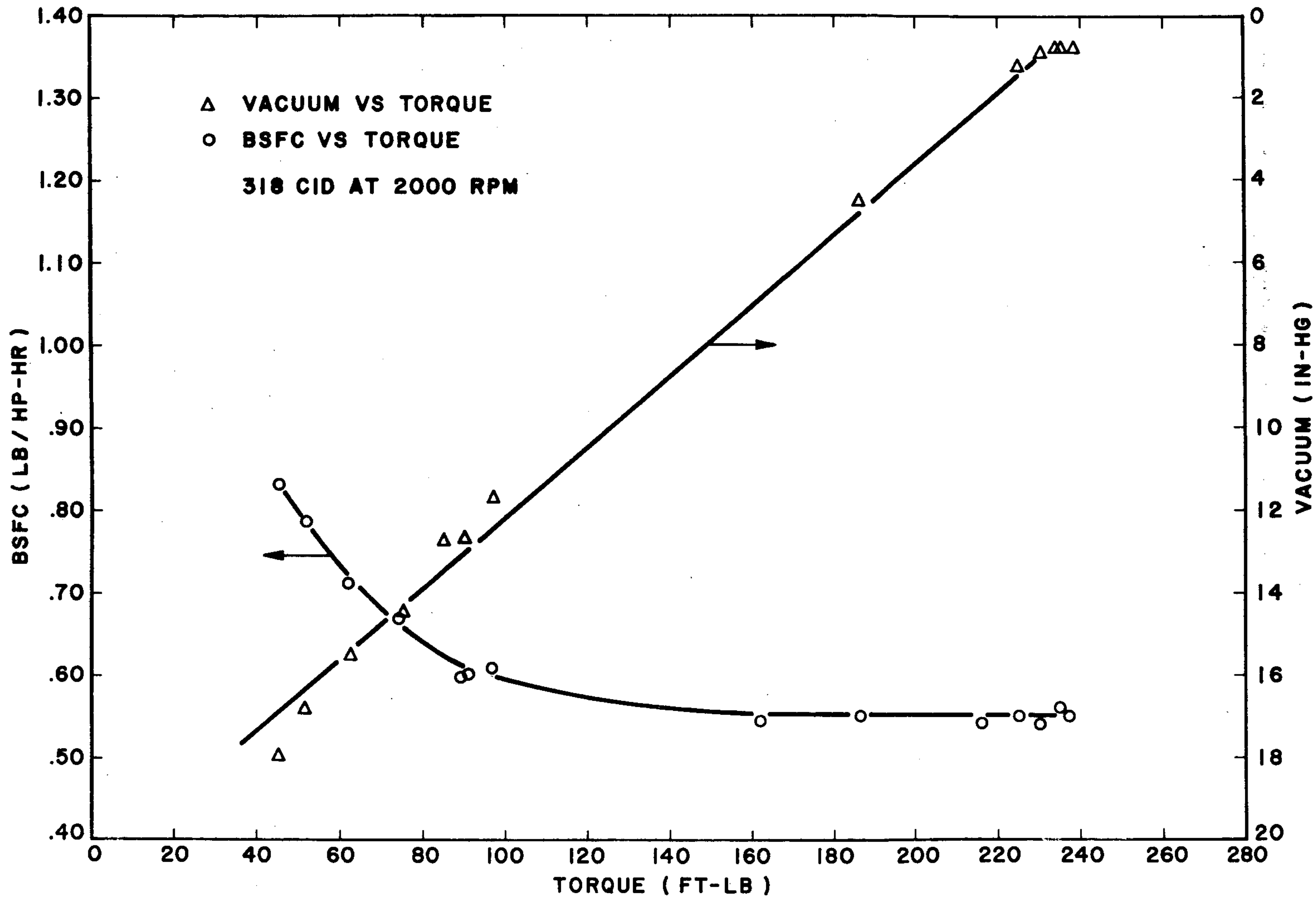


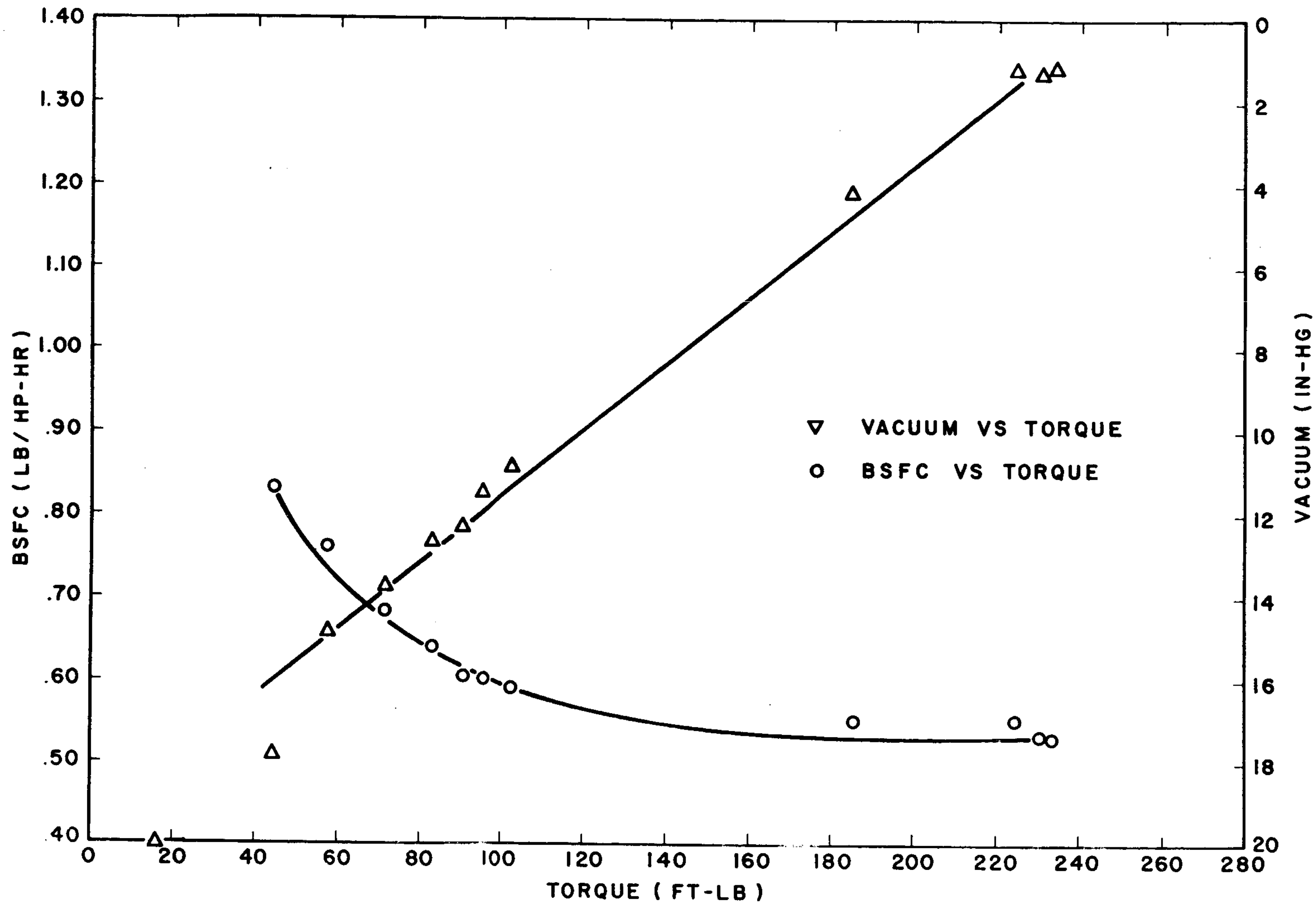
VACUUM VS TORQUE
BSFC VS TORQUE
BSFC (LB/ HP-HR)
VACUUM (IN-HG)
TORQUE (FT-LB)
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
0
2
4
6
8
10
12
14
16
18
20
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280


BSFC (LB/HP-HR)
VACUUM (IN-HG)
TORQUE (FT-LB)
△ VACUUM VS TORQUE
○ BSFC VS TORQUE
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
0
2
4
6
8
10
12
14
16
18
20
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280



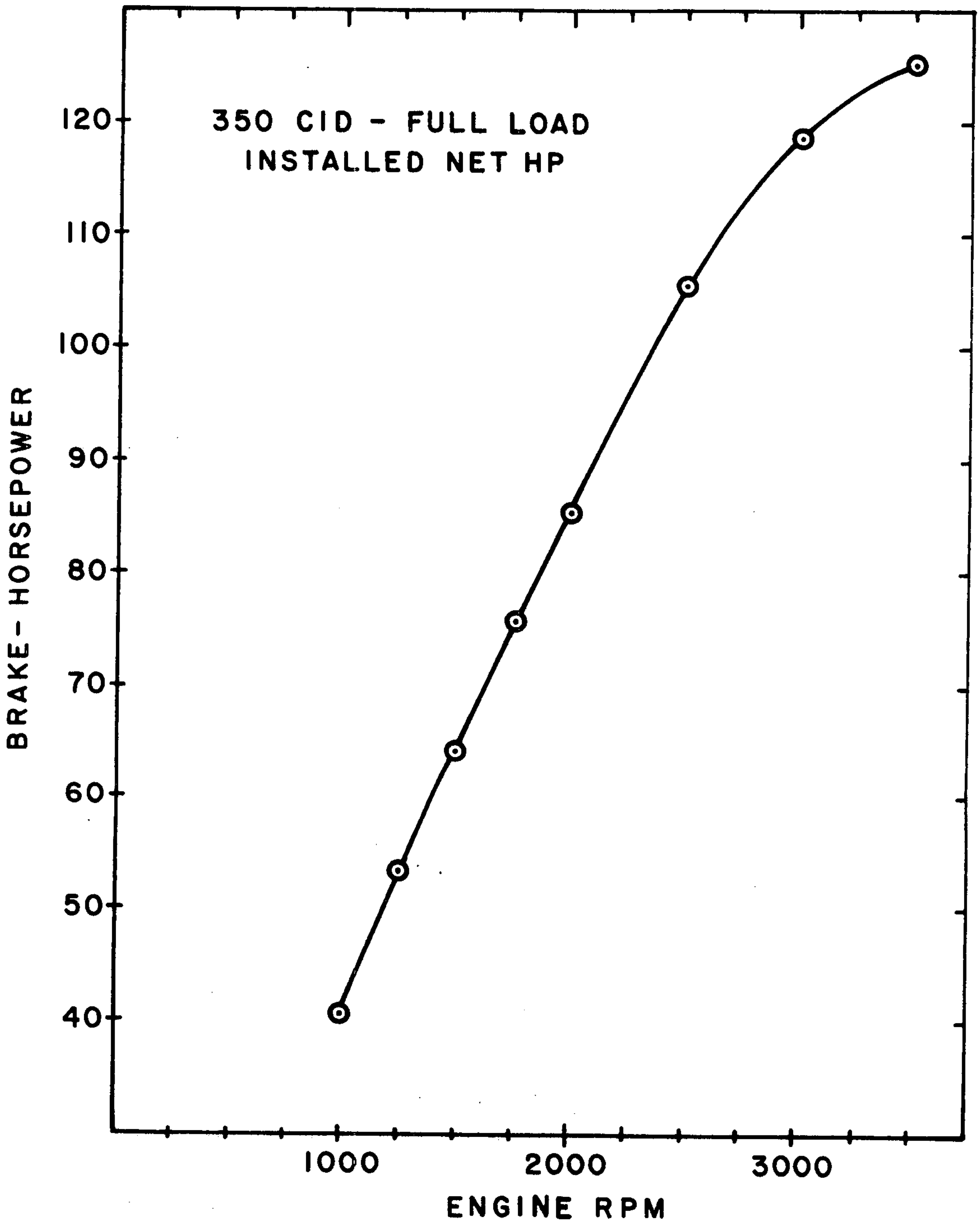
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
BSFC (LB/HP-HR)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
TORQUE (FT-LB)
0
2
4
6
8
10
12
14
16
18
20
VACUUM (IN-HG)
VACUUM VS TORQUE
BSFC VS TORQUE

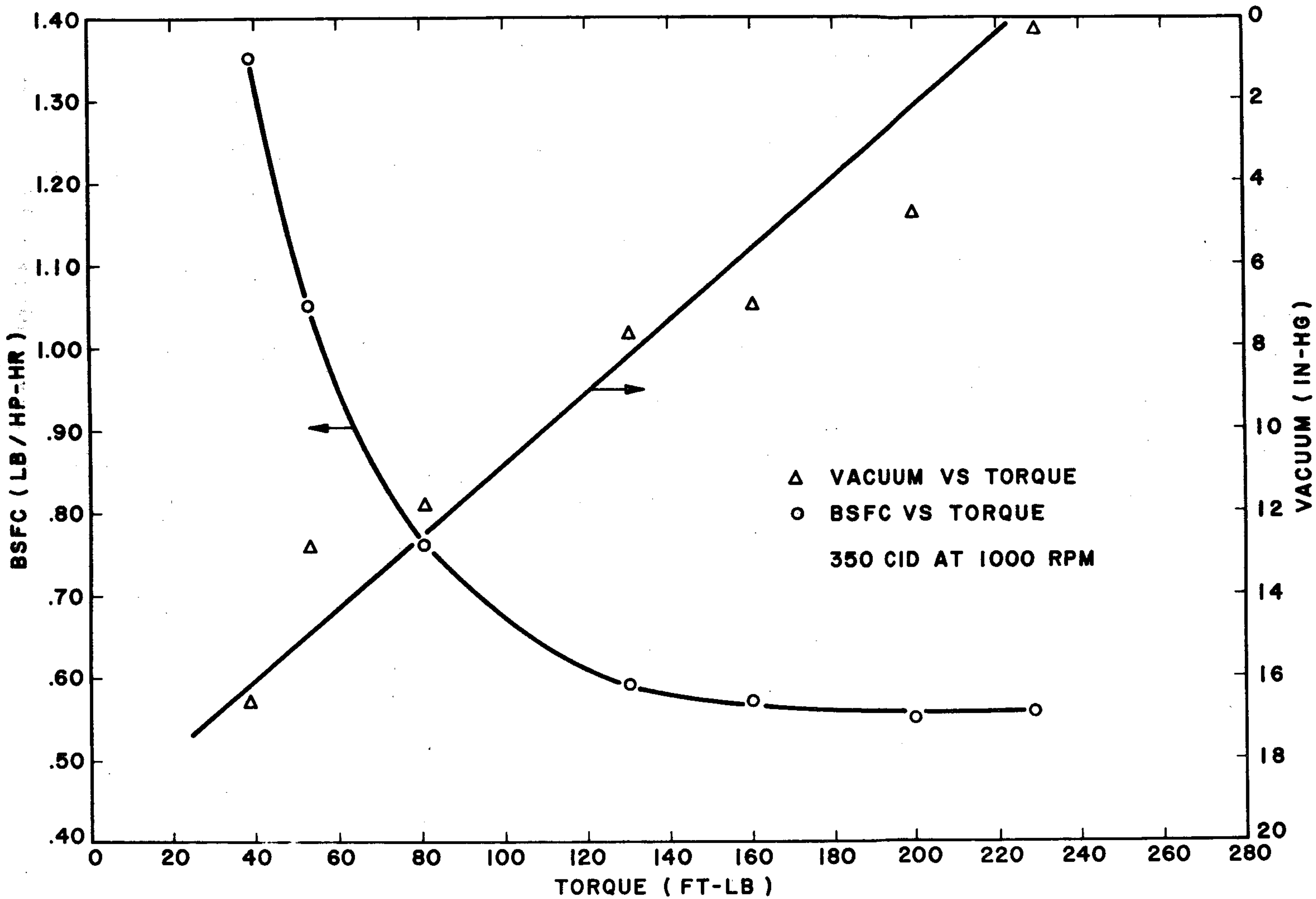

VACUUM VS TORQUE
BSFC VS TORQUE
318 CID AT 2000 RPM
BSFC (LB / HP-HR)
VACUUM (IN-HG)
TORQUE (FT-LB)
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
0
2
4
6
8
10
12
14
16
18
20
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280



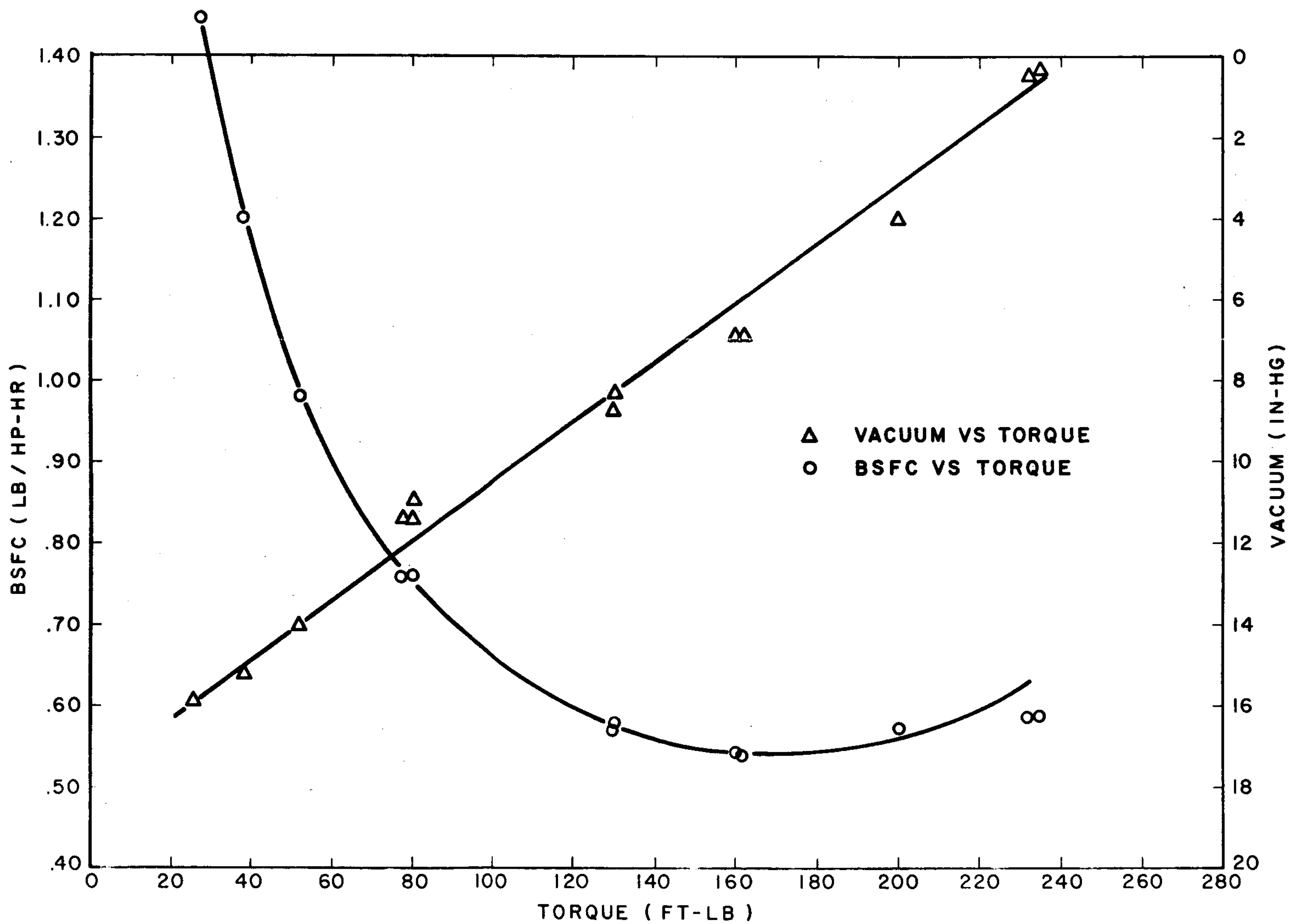
BSFC (LB/ HP-HR)
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
VACUUM (IN-HG)
0
2
4
6
8
10
12
14
16
18
20
TORQUE (FT-LB)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
▽ VACUUM VS TORQUE
o BSFC VS TORQUE

TEST DATA FOR THE ENGINE FROM VEHICLE E

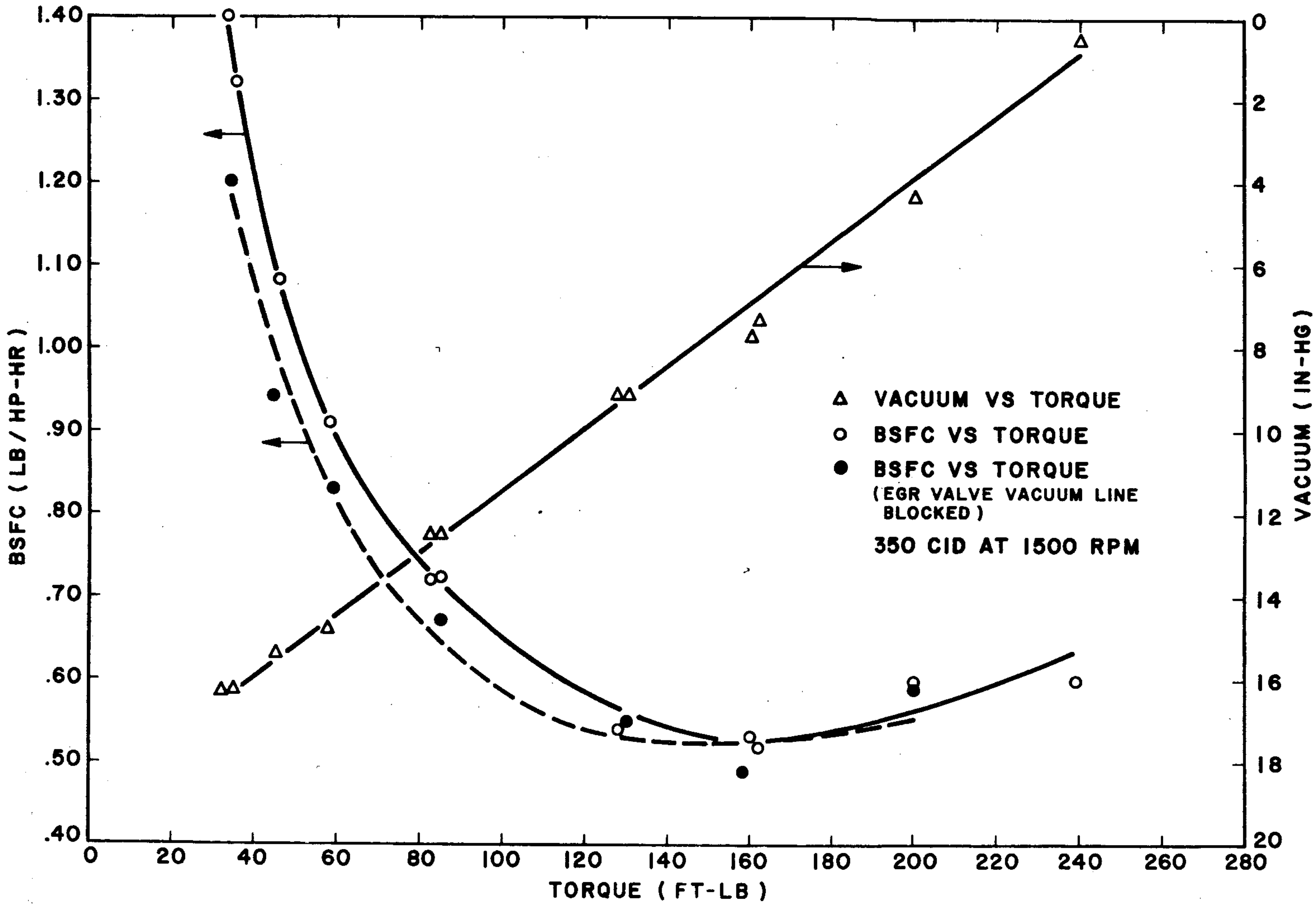

350 CID - FULL LOAD
INSTALLED NET HP
BRAKE - HORSEPOWER
120
110
100
90
80
70
60
50
40
1000
2000
3000
ENGINE RPM



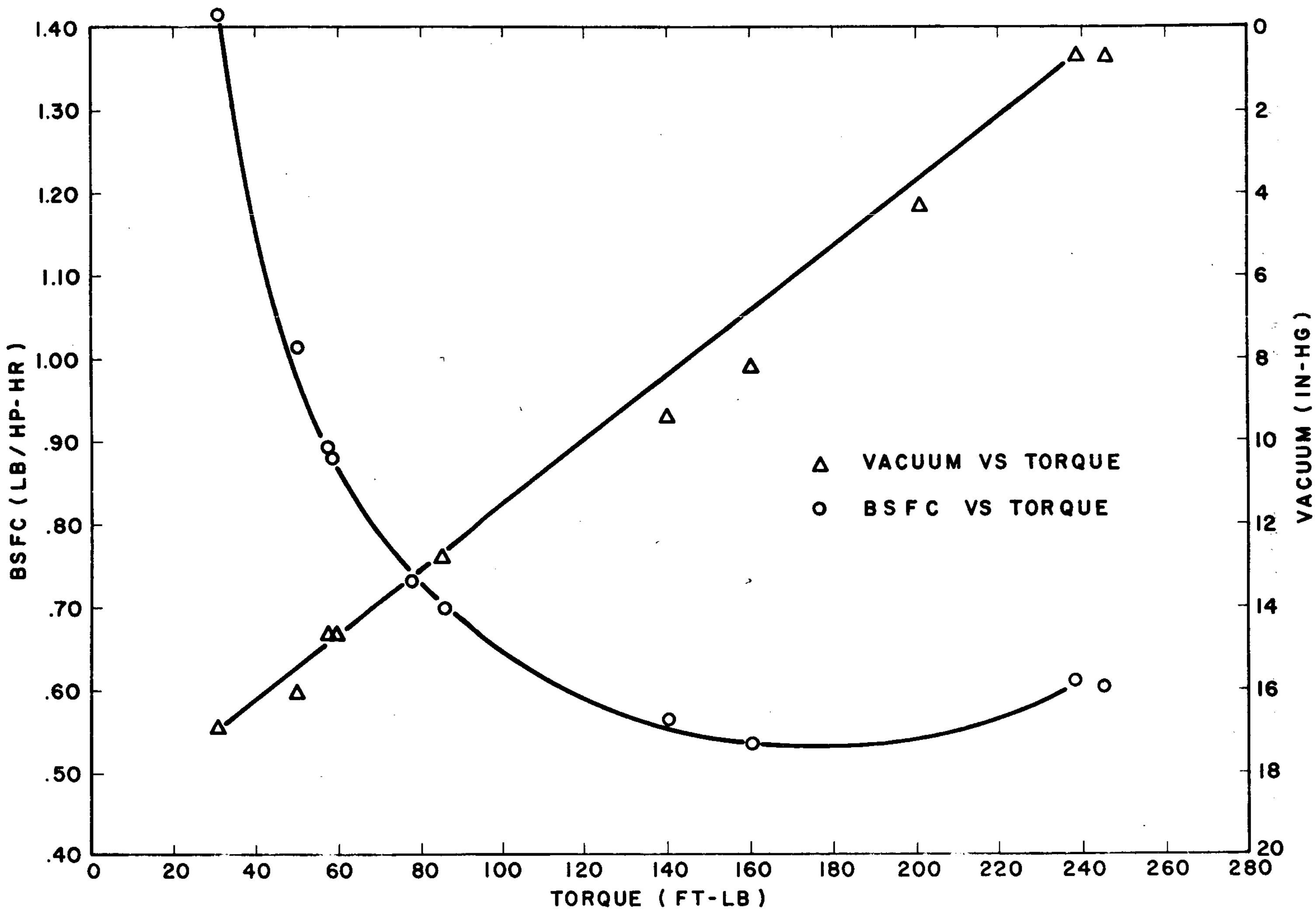
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
BSFC (LB / HP-HR)
0
2
4
6
8
10
12
14
16
18
20
VACUUM (IN-HG)
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280
TORQUE (FT-LB)
Δ VACUUM VS TORQUE
o BSFC VS TORQUE
350 CID AT 1000 RPM



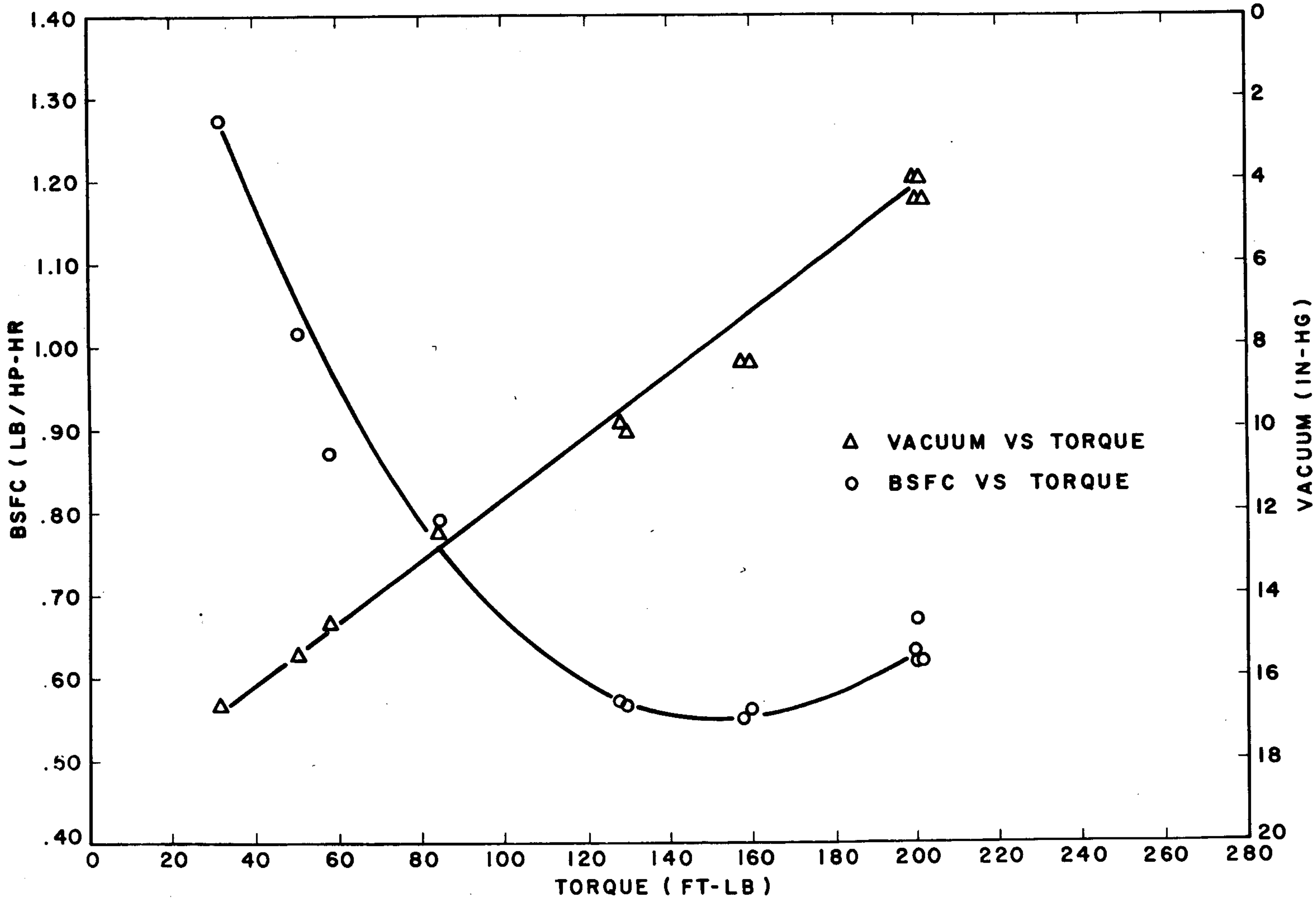
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
BSFC (LB / HP-HR)
0
2
4
6
8
10
12
14
16
18
20
VACUUM (IN-HG)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
TORQUE (FT-LB)
VACUUM VS TORQUE
BSFC VS TORQUE



BSFC (LB / HP-HR)
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
VACUUM (IN-HG)
0
2
4
6
8
10
12
14
16
18
20
TORQUE (FT-LB)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
VACUUM VS TORQUE
BSFC VS TORQUE
BSFC VS TORQUE
(EGR VALVE VACUUM LINE BLOCKED)
350 CID AT 1500 RPM

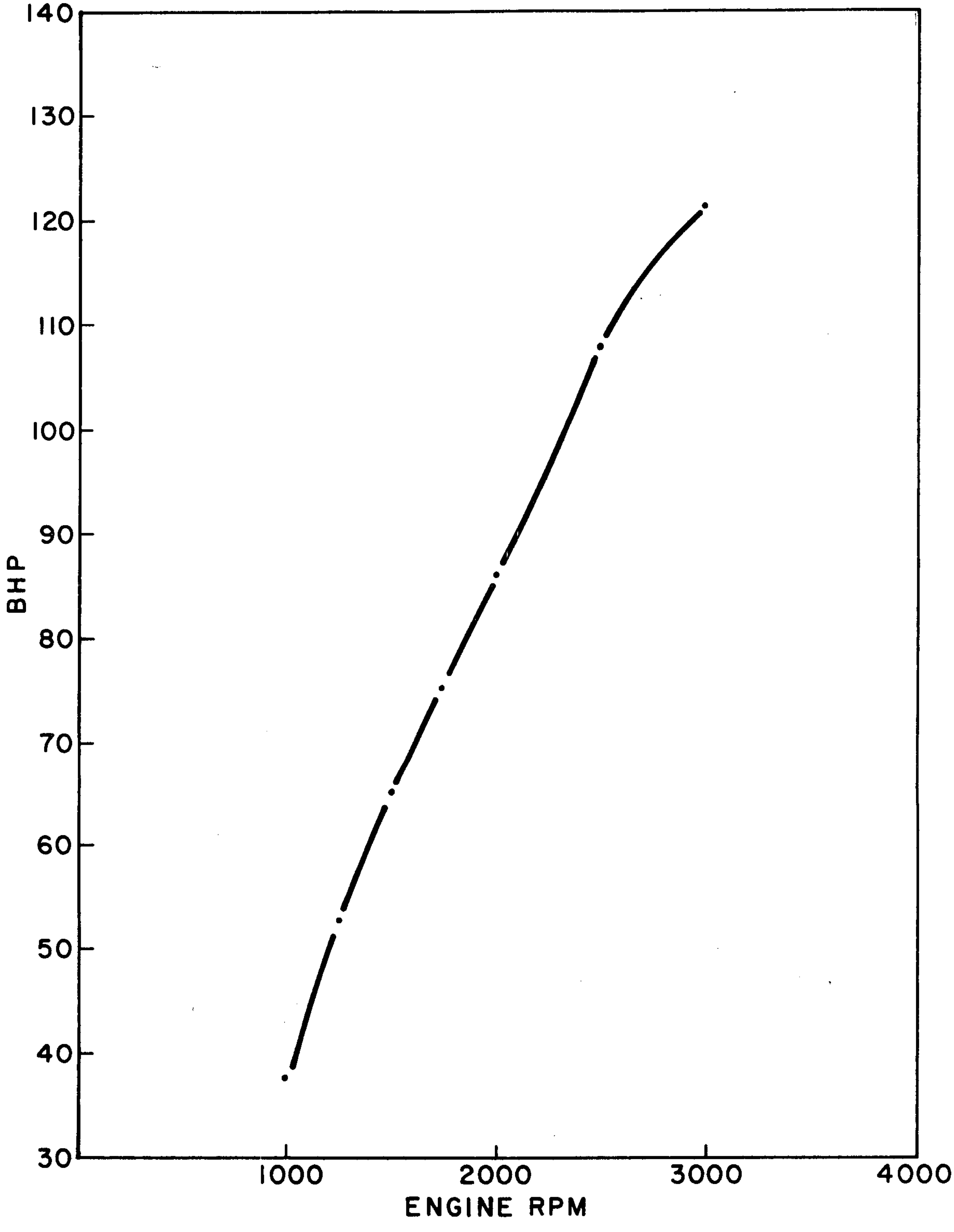


BSFC (LB / HP-HR)
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
VACUUM (IN-HG)
0
2
4
6
8
10
12
14
16
18
20
TORQUE (FT-LB)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
VACUUM VS TORQUE
BSFC VS TORQUE

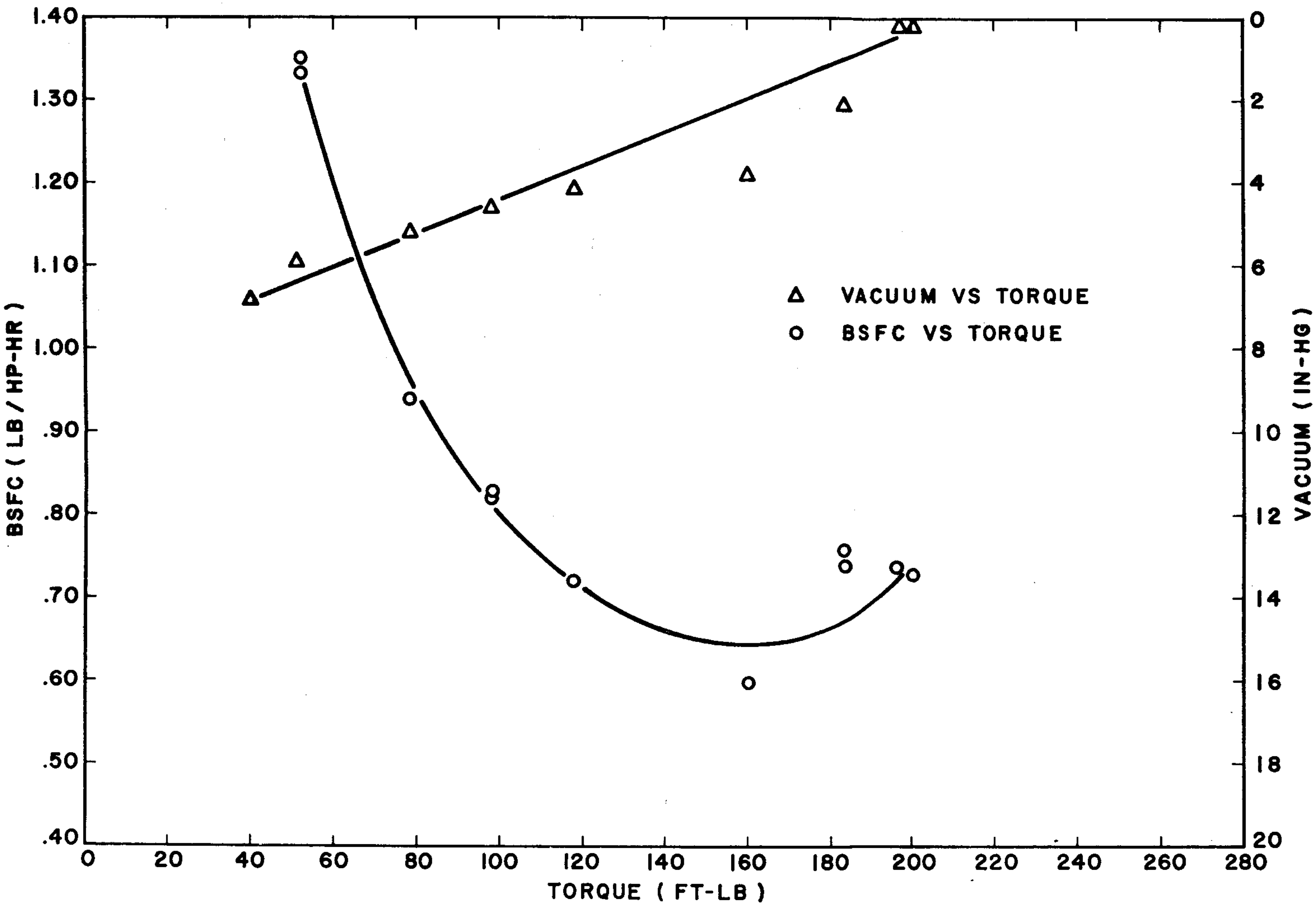


BSFC (LB / HP-HR)
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
VACUUM (IN-HG)
0
2
4
6
8
10
12
14
16
18
20
TORQUE (FT-LB)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
△ VACUUM VS TORQUE
○ BSFC VS TORQUE

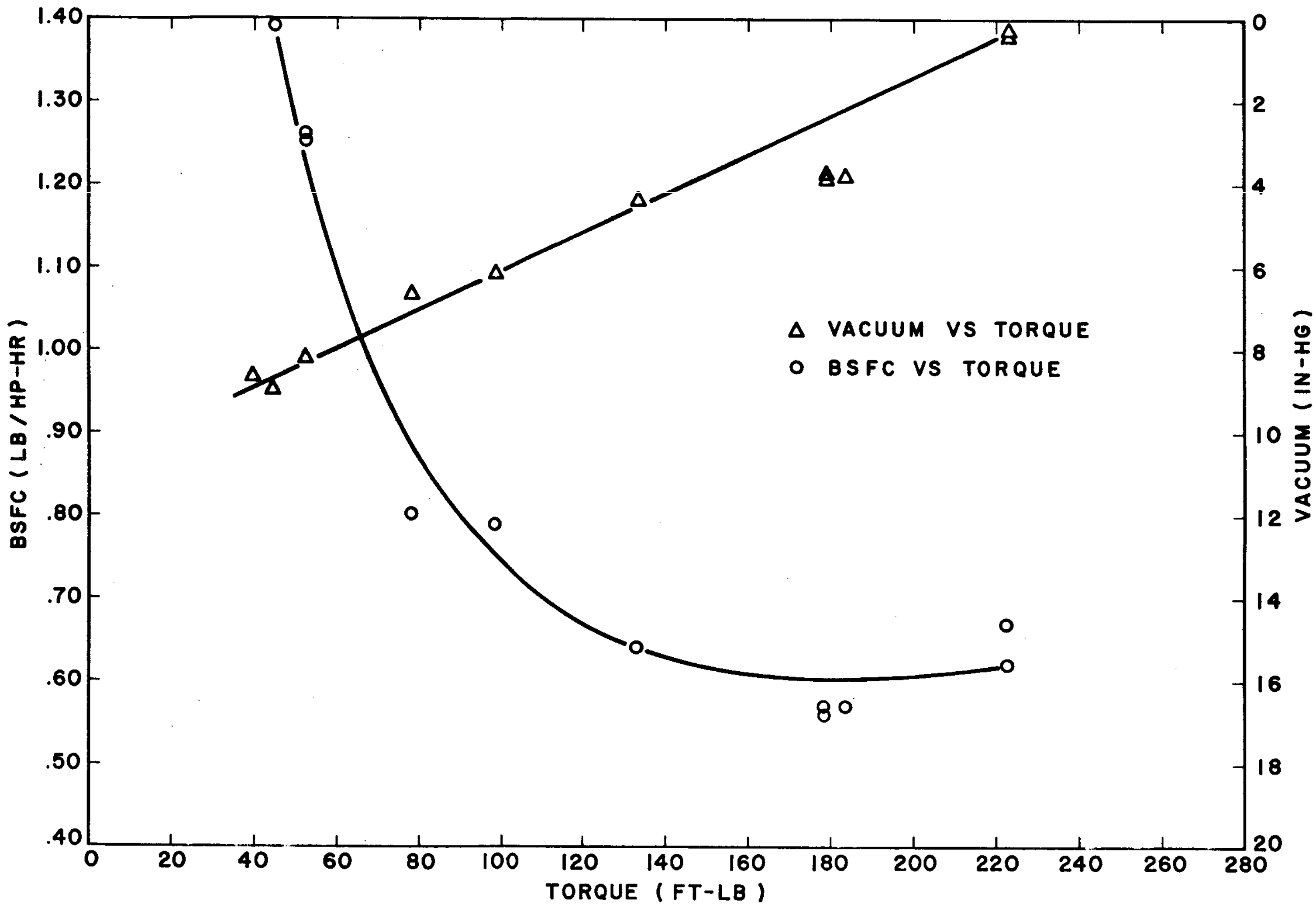
TEST DATA FOR THE ENGINE FROM VEHICLE F



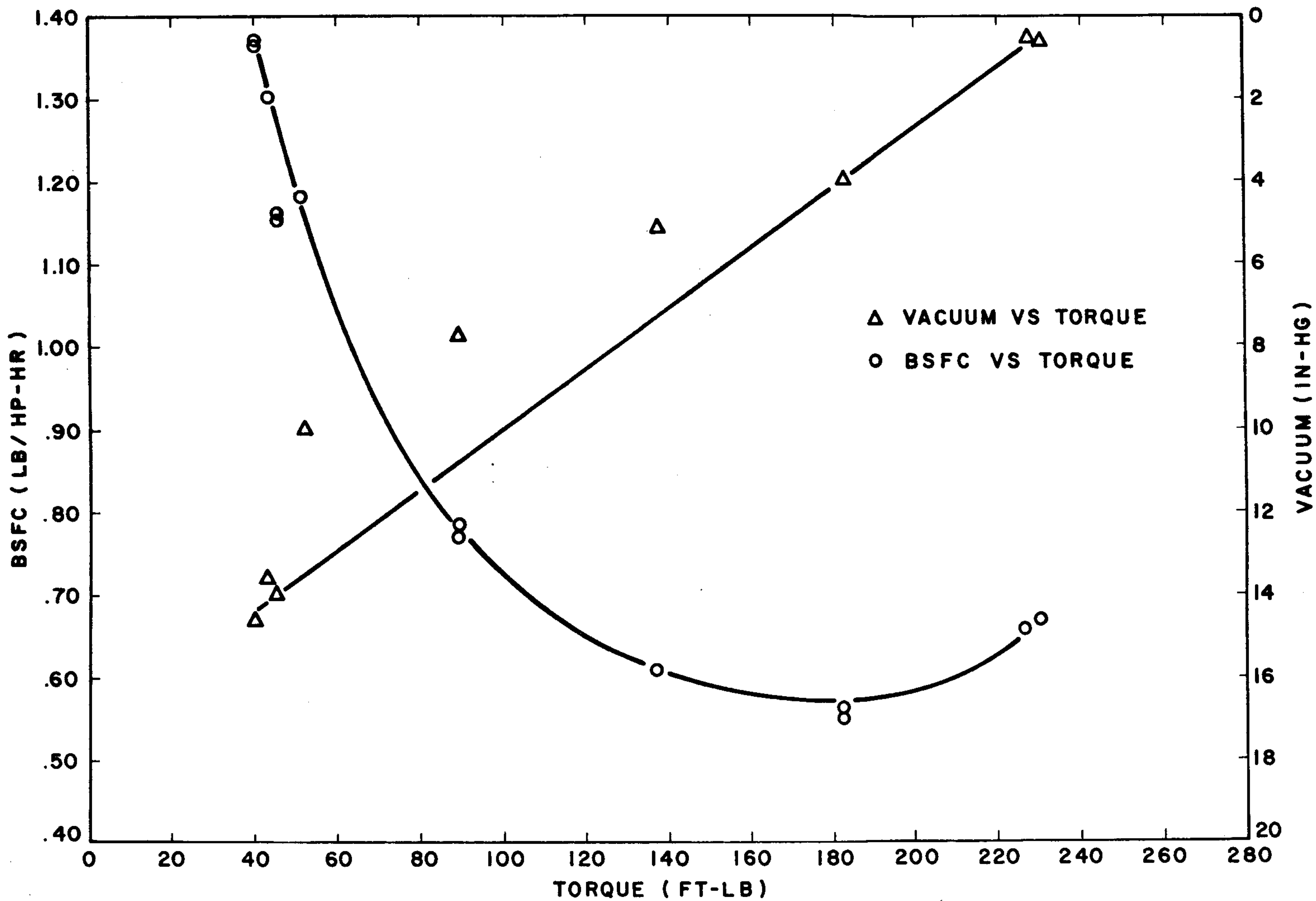
140
130
120
110
100
90
80
70
60
50
40
30
BHP
1000
2000
3000
4000
ENGINE RPM

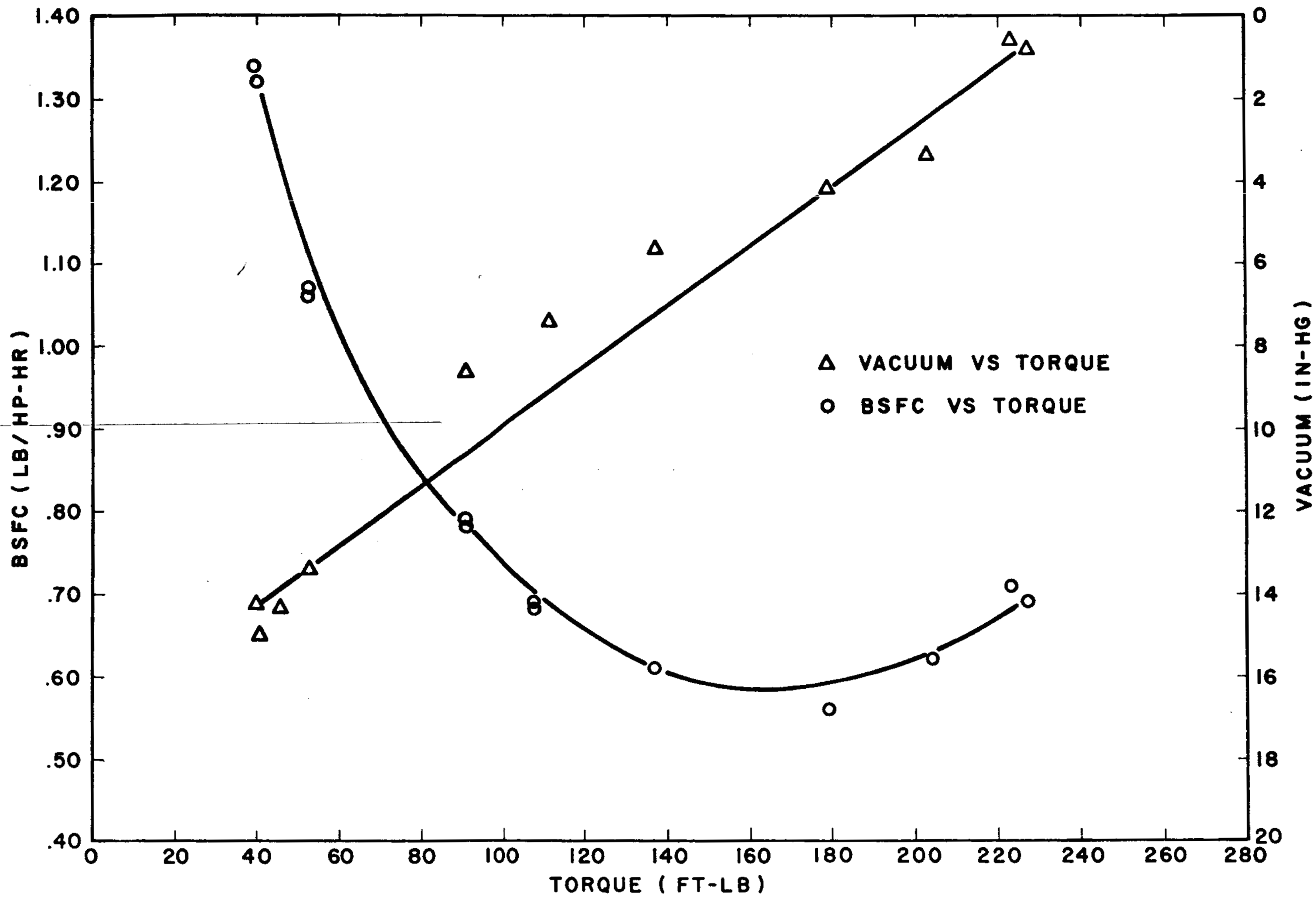


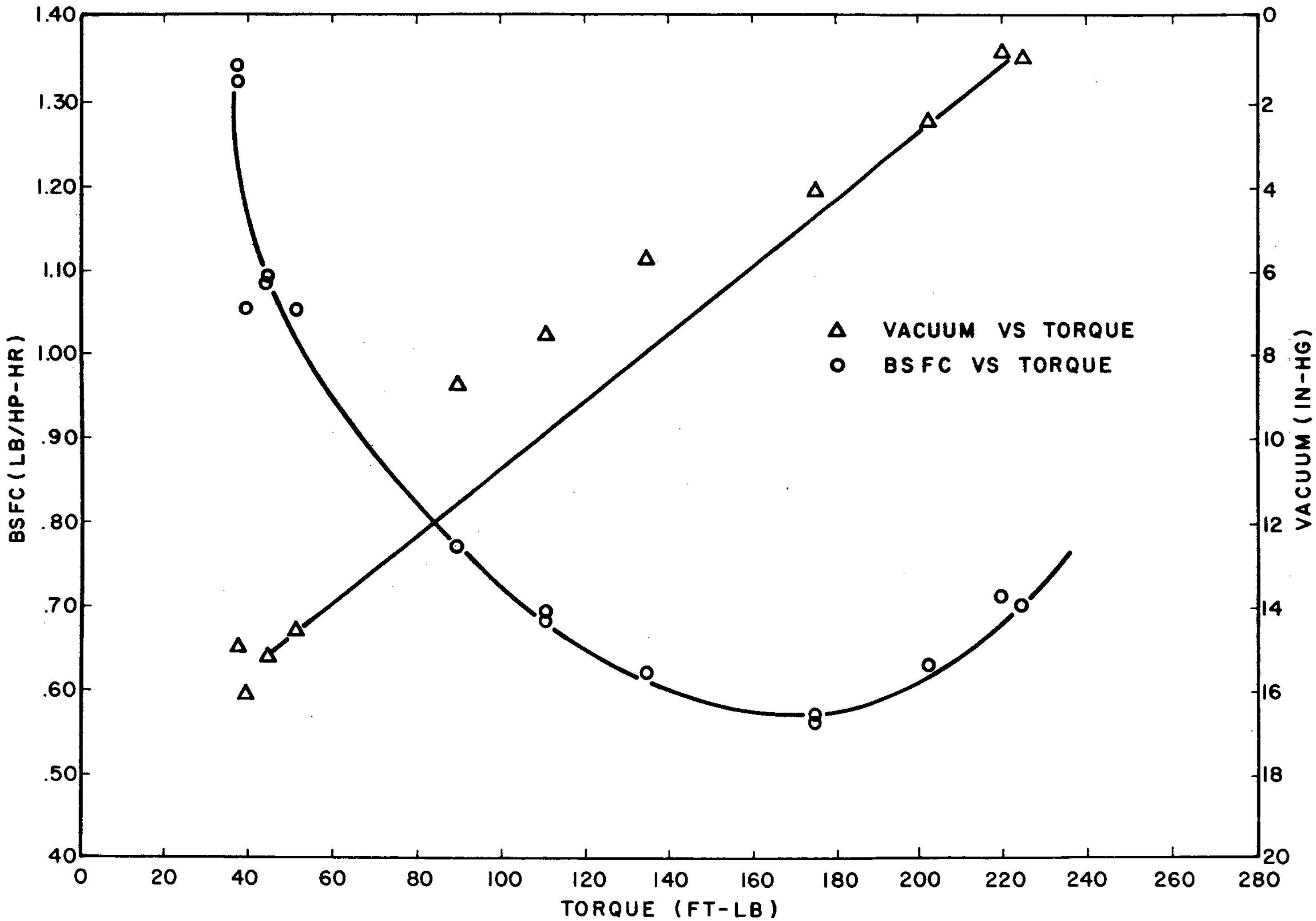
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
BSFC (LB / HP-HR)
0
2
4
6
8
10
12
14
16
18
20
VACUUM (IN-HG)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
TORQUE (FT-LB)
VACUUM VS TORQUE
BSFC VS TORQUE

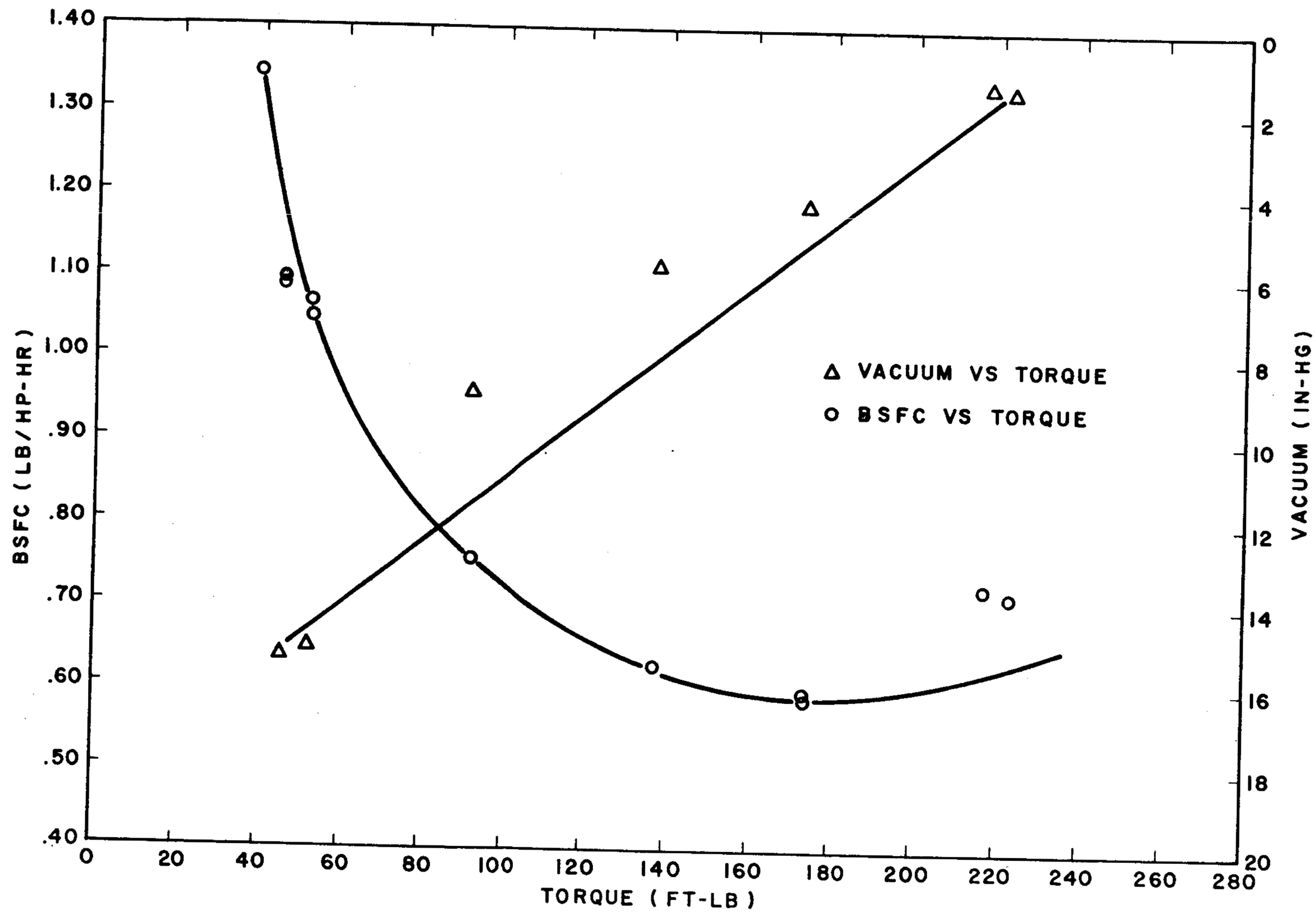


BSFC (LB / HP-HR)
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
VACUUM (IN-HG)
0
2
4
6
8
10
12
14
16
18
20
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
TORQUE (FT-LB)
△ VACUUM VS TORQUE
○ BSFC VS TORQUE

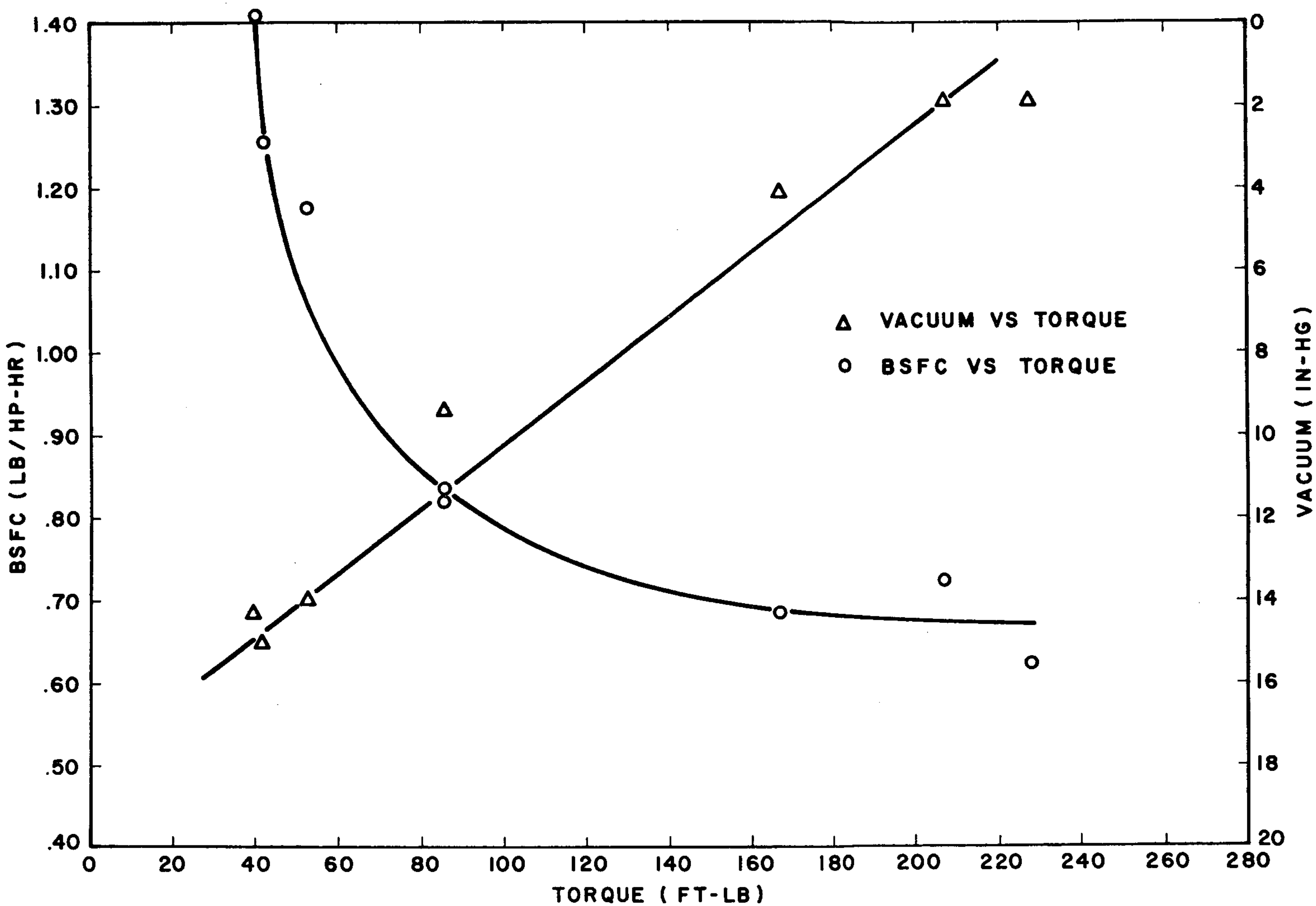

VACUUM VS TORQUE
BSFC VS TORQUE
BSFC (LB/HP-HR)
VACUUM (IN-HG)
TORQUE (FT-LB)
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
0
2
4
6
8
10
12
14
16
18
20
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280


BSFC (LB/ HP-HR)
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
VACUUM (IN-HG)
0
2
4
6
8
10
12
14
16
18
20
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
TORQUE (FT-LB)
△ VACUUM VS TORQUE
○ BSFC VS TORQUE


BSFC (LB/HP-HR)
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
40
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
TORQUE (FT-LB)
VACUUM (IN-HG)
0
2
4
6
8
10
12
14
16
18
20
VACUUM VS TORQUE
BSFC VS TORQUE



BSFC (LB/HP-HR)
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
VACUUM (IN-HG)
0
2
4
6
8
10
12
14
16
18
20
TORQUE (FT-LB)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
△ VACUUM VS TORQUE
○ BSFC VS TORQUE



BSFC (LB / HP-HR)
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
VACUUM (IN-HG)
0
2
4
6
8
10
12
14
16
18
20
TORQUE (FT-LB)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
VACUUM VS TORQUE
BSFC VS TORQUE

APPENDIX F

CALCULATIONS OF FUEL ECONOMY

APPENDIX F

In an attempt to compare various distributions of urban and highway driving in a composite cycle, several of the individual improvements were considered with respect to three different averaging techniques. Calculations of average fuel economy were performed according to the following cycle definitions:

Cycle 1: 50 percent urban, 50 percent evenly divided between 20, 30, 40, 50, 60, 70

$$(MPG)^{-1}_{avg} = \frac{1}{2(mpg)_{LA\text{-}4}} + \frac{1}{12}\left[\frac{1}{(mpg)_{20mph}} + \ldots + \frac{1}{(mph)_{70mph}}\right]$$

Cycle 2: 50 percent urban, 5 percent at 40, 13 percent at 50, 19 percent at 60, 13 percent at 70

$$(MPG)^{-1}_{avg} = \frac{1}{2(mpg)_{LA\text{-}4}} + \frac{1}{20(mpg)_{40\ mph}} + \frac{1}{7.69(mpg)_{50\ mph}} + \frac{1}{5.26(mpg)_{60\ mph}} + \frac{1}{7.69(mpg)_{70\ mph}}$$

Cycle 3: 50 percent urban, 5 percent at 40, 13 percent at 50, 32 percent at 55

$$(MPG^{-1}_{avg} = \frac{1}{2(mpg)_{LA\text{-}4}} + \frac{1}{20(mpg)_{40\ mph}} + \frac{1}{7.69(mpg)_{50\ mph}} + \frac{1}{3.125(mpg)_{55\ mph}}$$

For each individual improvement, the percentage increase in fuel economy was calculated on a mile per gallon basis; the reference vehicle (4600 lb LVW, 350 CID) was used for comparison in each case. No correction for emission control was applied.

The results of the cycle comparisons are shown in Table F-1.

TABLE F-1. MILES PER GALLON; VARIOUS CYCLE MODES

Mode	Reference vehicle	Turbo, S.I., water alcohol	Turbo, S.I., aftercool	Turbo diesel	Naturally aspirated diesel	Variable displace.	Lean burn	Strat. charge
Urban	13.6	15.9	15.1	21.8	18.9	17.5	14.5	17.2
20 mph	17.9	23.8	22.3	29.8	26.3	32.5	22.3	30.3
30 mph	22.4	26.6	24.4	32.7	27.8	31.6	24.1	30.5
40 mph	20.9	24.6	22.6	28.2	24.4	25.3	24.0	27.1
50 mph	19.7	22.2	21.1	27.0	23.2	22.4	21.6	24.7
55 mph	18.8	20.8	19.7	26.1	22.4	20.7	20.3	23.2
60 mph	17.8	19.3	18.2	25.1	21.6	19.0	19.0	21.6
70 mph	16.1	16.9	16.0	22.6	19.2	16.6	16.6	19.0
Avg 1	15.8	18.4	17.3	24.2	20.9	19.9	17.1	20.3
% Imp.		16.5	9.5	53.2	32.3	25.9	8.2	28.5
Avg 2	15.5	17.6	16.7	23.3	20.1	18.5	16.6	19.3
% Imp.		13.5	7.7	50.3	29.7	19.4	7.1	24.5
Avg 3	15.9	18.3	17.3	23.9	20.7	19.3	17.1	20.0
% Imp.		15.1	8.8	50.3	30.2	21.4	7.5	25.8

APPENDIX G

AMBIENT EFFECTS ON ECONOMY

The fuel economy of a vehicle is influenced by a large number of parameters such as the complete technical design details, driver habits, warmup condition, engine state of tune and age, tire condition, road surface characteristics, etc. In this Appendix, partial data are presented illustrating the influence of two ambient conditions (temperature and altitude) on the fuel economy of *a particular vehicle.*[171] Figures G-1 and G-2 illustrate, respectively, the influence of ambient temperature and altitude on the fuel economy of this vehicle. In general, it can be concluded that operation at the higher ambient temperatures (80°F) consumes less fuel than operation at low ambient temperatures (0°F) even under fully warmed-up conditions. Altitudes above 2000 feet will also cause a loss in mileage.

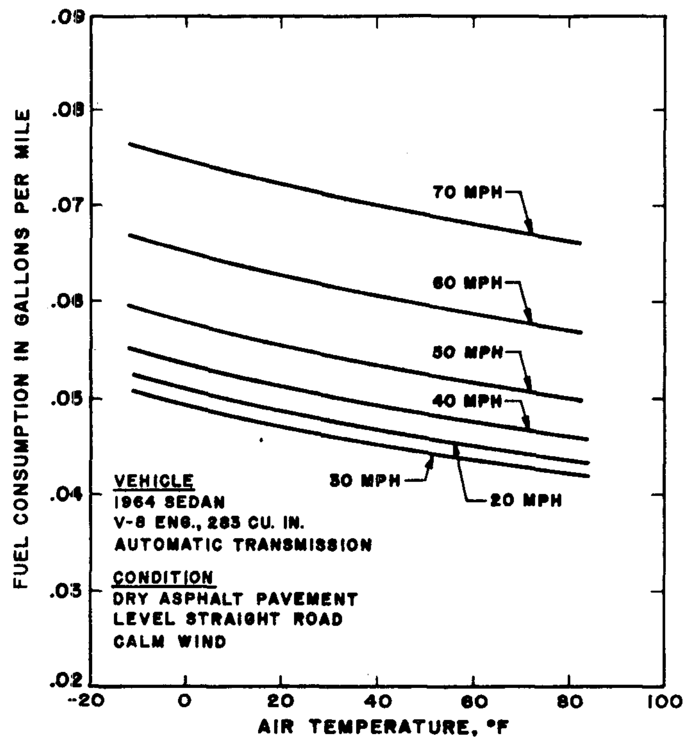


FIGURE G-1

There are many interacting factors that influence these results. First, the fuel consumption of a carbureted engine is dependent on the inlet air density. Lowering the inlet air temperature will produce *more* power output capability for a given engine, thus in the extreme case, a given motive load could be met at a smaller throttle opening (higher pumping losses) and lower economy. At higher elevations fuel distribution in multicylinder engines can *reduce* power output due to the lower potential for evaporation of fuel into the cooler airstream, thus requiring a larger throttle opening to meet a given power demand (due to a leaner fuel/air mixture). Fuel consumption, then, will also increase with increasing altitude.

Spark timing and fuel air ratio aren't continuously optimized for all ambient conditions; consequently, economy and/or performance will be better or worse depending on the deviation of ambient operating temperature from the ambient temperature (~86°F) for which most engine development is conducted. For a detailed discussion of most of the effects on engine fuel consumption see

[171]"Running Costs of Motor Vehicles as Affected by Road Design and Traffic," Highway Research Board, Program Report 111, Appendix B, p 63.

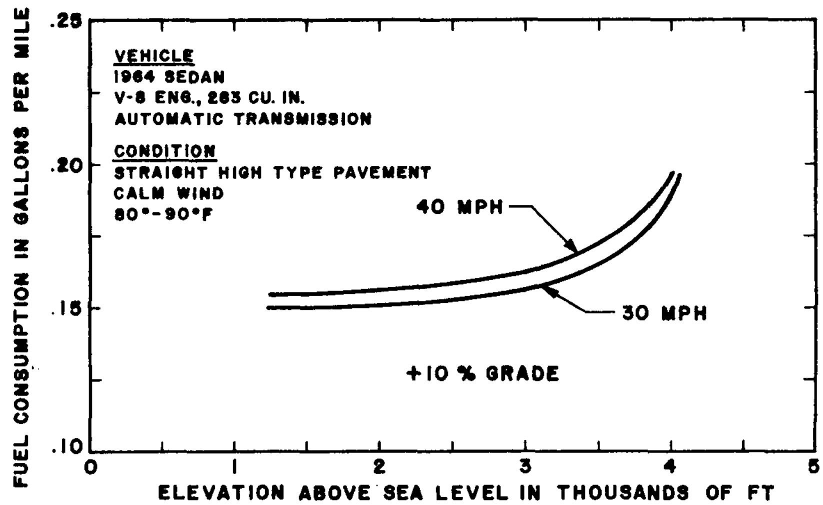


FIGURE G-2

Reference 21. It should be noted that recently produced vehicles may have significantly different mileage (fuel use) levels and the characteristic shapes of Figures G-1 and G-2 may not remain constant due to such changes as heated air from exhaust manifold air diverter valves and other carburetion and manifolding changes incorporated in modern vehicles.

Two other influences are also worthy of note here. First decreasing ambient temperature increases the aerodynamic drag due to increased air density. Increasing altitude can decrease air density, thus lowering drag, but ambient temperature is also lowered at higher elevations. Second, the rolling resistance of tires decreases with increasing temperature due to two effects; (1) less hysteretic flexural losses and (2) increased internal tire pressure due to the higher internal air temperature. (See Reference 172).

The test data presented here reflect the extremes encountered by the operation of one vehicle over a wide range of conditions. Tailoring of a specific vehicle to its most likely operating condition could minimize the variation.

[172] Walter, J. D., "Energy Losses in Tires," Presented at Caltech Seminar Series on Energy Consumption in Private Transportation, December 4, 1973.

APPENDIX H

COMMENT BY REVIEWERS

COMMENT BY REVIEWERS

Following the preparation of the draft of this report, the Government requested a review of the manuscript by individuals and organizations acquainted with the subject of automotive fuel economy. Several helpful and constructive suggestions were received as a result of this evaluation, and the Southwest Research Institute greatly appreciates the contributions of the reviewers.

The comments made by reviewers in response to the formal Government request are reproduced in this appendix. In several cases, changes in the text were made as a result of the suggestions, therefore the comments may not be applicable to the present structure of the report. The areas in which changes were made are identified in the following discussion for the sole purpose of clarifying differences between the original manuscript and the present form.

No attempt at rebuttal of the comments by the reviewers has been made; this appendix to the report is not regarded as a suitable forum for debate. The absence of a response, however, does not necessarily imply agreement with the comments. Many of the points raised involve issues about which there are differences of opinion, and in some cases the data necessary for adequate resolution is not available. On some points, even an adequate presentation of both sides of the issue would require the addition of an extensive discussion. Furthermore, as a matter of interest, it may be observed that there exist differences of opinion between the various reviewers on some points.

It should be noted that the page numbers mentioned in the comments refer to an early manuscript; there is no direct correspondence with page numbers in this edition. However, the general area to which the comments are applicable should be readily identifiable.

Comments by Chrysler Corporation

The section of the report dealing with lock-up clutches has been revised to include the possibility of clutch engagement in more than one gear. In addition, numerical values have been altered to clarify differences between torque converter efficiency and total driveline efficiency.

Comments by Garrett Corporation

The use of retarded spark and the use of fuel as an antidetonant were added to the list of available techniques for preventing knock in turbocharged engines.

Comments by General Motors Corporation

The section of the report dealing with exhaust gas recirculation was revised.

Comments from Texaco, Inc.

The change from TCP to TCCS was made, and the implication that all stratified charge engines exhibit multifuel capability was removed. In the Figure noted, those points not applicable to stratified charge engines were deleted. The statement concerning loss in fuel economy as a result of emission control was clarified.

Comments from Tracor, Inc.

The change from "friction" to "traction" was made as suggested. The implication that major engine design changes would be required for vehicle operation with a continuously variable transmission was removed.

G. J. HUEBNER, JR.
DIRECTOR OF RESEARCH
PRODUCT PLANNING & DEVELOPMENT OFFICE

CHRYSLER
CORPORATION

June 7, 1974

Mr. Herbert H. Gould
TMP
U.S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Massachusetts 02142

Subject: January 1974, Southwest Research Institute, <u>A Study of Technological Improvements to Automobile Fuel Consumption</u>, Contract DOT-TSC-628

Dear Mr. Gould:

At Mr. Cline W. Frasier's request of April 3, 1974, the subject draft report was reviewed in my office and found to be quite complete. The following brief comments are submitted for your information and use:

In our opinion, the study has over-estimated the knock problem as related to supercharged engines. In particular, we do not agree that supercharging to a pressure ratio of 1.45 would require a reduction in compression ratio from 8 to 5. In computing the end-gas temperature, we believe that proper account has not been made of the heat transfer effects that influence the end-gas temperature and thus the knock limited operation. The required reduction in compression ratio will be less than this amount, but will, of course, vary from engine to engine.

In discussing the use of fuel shut-off during deceleration with a fuel injection system, it appears that the authors have not been aware that Volkswagen has used such a system with reasonable success. Some recognition of the Volkswagen system would seem to be in order.

Other than these two comments, we find nothing in the summary that suggests serious disagreement.

Very truly yours,

GJH/Eh

P. O. BOX 1118, DETROIT, MICHIGAN 48231

ENGINEERING AND RESEARCH OFFICE

CHRYSLER CORPORATION

May 22, 1974

Mr. Herbert H. Gould
DOT/Transportation Systems Center
Kendall Square
Cambridge, Mass. 02142

Dear Mr. Gould:

The report developed by the Southwest Research Institute titled "A Study of Technological Improvements to Automobile Fuel Consumption", which was sent to Mr. Sinclair by Mr. C. W. Frasier, has now been reviewed by us. We regret the delay in acknowledging formal receipt of this report, however, we did indicate to you on the telephone that a study was being made and we would report our findings to you when this study was complete. We found the report to be comprehensive and put together in a logical, understandable manner - our compliments to the Southwest Research Institute.

The analysis of the report was conducted by our Vehicle Development Group under Mr. R. R. Love, whom I believe you met at our Chrysler Proving Grounds. Some discrepancies in various sections of the report regarding the fuel economy gains were found - some of these were plus and some were minus. However, when using Chrysler parameters, the end result in total fuel economy gain was approximately the same as the conclusion in your report. I should point out that our analysis was conducted only on the fuel injection engine and did not cover the stratified charge or diesel engine versions. If you desire to discuss the details of our analysis, this could be arranged with our Vehicle Development Group.

You had specifically requested in our telephone conversation our opinion regarding automatic transmission lockup clutches in various gears. Our figures are more favorable than those in your report by approximately 6% in both the urban and highway cycles. Lockup in the one-two upshift shows an additional 3% in the urban cycle.

Enclosed is a paper "General Factors Affecting Vehicle Fuel Consumption" which was presented by Messrs. Huebner and Gasser of Chrysler Corporation last May. You may find this of interest if you have not already seen it.

P. O. BOX 1118, DETROIT, MICHIGAN 48231

Chrysler Corporation is continually active in the area of improved fuel economy and has taken many definite steps which, in general, are in line with your report findings. These include smaller engine sizes in some of our models, extensive effort in the area of weight reduction, increased availability of radial-ply tires, programs to reduce aerodynamic drag, lower numerical axle ratios, overdrive manual transmissions for future models and consideration of a lockup clutch in automatic transmission direct drive.

We appreciate the opportunity to review the report and again let me reiterate that we would be pleased to personally discuss with you details of our analysis.

Very truly yours,

E. D. Heins
Chief Engineer
Advance Programs and
Safety Planning

EDH:lm
cc: S. D. Jeffe
R. R. Love
R. M. Sinclair
S. L. Terry

AIRESEARCH INDUSTRIAL DIVISION

A DIVISION OF THE GARRETT CORPORATION

9225 AVIATION BLVD. • LOS ANGELES, CALIFORNIA 90009 • AREA CODE 213 - 670-7111

May 14, 1974

Mr. Herbert H. Gould/TMP
Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Massachusetts 02142

Via: Mr. Mike Rachlin, Garrett Sales, Washington D.C.

Dear Mr. Gould:

I have studied the draft of the Southwest Research report "A Study of Technological Improvements to Automobile Fuel Consumption", paying particular attention to Item X "Turbocharged, Spark Ignited, Carbureted Engine".

I am concerned that this report shows the small turbocharged spark-ignition engine as a negative or only marginal candidate, for improved fuel consumption; whereas, AID's (AiResearch Industrial Division) test data shows the opposite to be true. This may be due to the fact that the author of the report limited the variables used in his calculation of knock limits; whereas AID has actually tested using a broad range of variables including compression ratio, spark advance, fuel mixture ratio, etc. to search for near maximum obtainable power increases.

Possibly, the difference between our test results and the predictions by Southwest Research lies in spark timing. I have not yet been able to obtain the reports referenced in the Southwest Research paper, but I suspect that the calculated detonation limits are based on constant spark timing.

Test work at AID has shown that power can be increased when spark is retarded and intake manifold pressure is increased to borderline knock. Figure 1, attached, illustrates torque, spark timing, and bsfc vs. intake manifold pressure to show the amount of spark retard and boost which can be utilized until torque ceases to increase.

Fuel can also be used as an antidetonant. One source, "Water Injection for Aircraft Engines", by M. R. Rowe and G. T. Ladd (SAE Transactions, Vol. 54, No. 1, January 1946, Page 28) indicates that by enrichment of the mixture from 12.5:1 to 9:1 A/F, power can be increased approximately 25% by supercharging to the detonation limit. AID tests show that the output from an 8.5:1 compression ratio engine can be increased to 337 ft-lb at 2000 rpm by turbocharging to 39 inHgA intake manifold pressure and operating at an air/fuel ratio of 11:1 while utilizing suitable spark retard. This is a 22% torque increase above naturally-aspirated output. Fuel was the only antidetonant used in conjunction with spark retard.

The experience, as noted in the report, of race cars and aircraft needing alcohol fuel or antidetonant injection is true in some cases. Indianapolis cars which use alcohol fuel naturally-aspirated still do when turbocharged, and World War II aircraft did use water alcohol injection for high power. Today the very successful Porsche Can-Am race cars are turbocharged and burn pump gasoline, and private aircraft (Cessna, Beechcraft, etc.) are turbocharged without antidetonant injection. Although antidetonant does allow extra power, it is not necessary for worthwhile benefits from turbocharging. (Note: Since exhaust gas recirculation is a known method of reducing peak cylinder temperatures for NO_x control, it is possible that exhaust gas could be used for detonation control.)

AID test data substantiates that emissions are not increased by turbocharging. Actually, we have observed slight reductions in HC and NO_x on vehicles we have turbocharged for increased power.

Contrary to the statement onPage 164, I know of no experience or experimental data which indicate that turbocharging a spark-ignition engine does not improve engine performance without the use of aftercooling and/or an antidetonant. Compression ratio reduction, spark retard, and/or rich mixtures are used to control detonation. Turbocharged racing vehicles have recently far outdone their naturally-aspirated counterparts with both using the same fuel and with the non-aftercooled, non-ADI (antidetonant injection) equipped turbocharged engine frequently required to suffer a displacement penalty. For example, a 255 cid naturally-aspirated Offenhauser engine produces 430 hp with 13:1 compression ratio. The turbocharged 159 cid Offenhauser, which has now replaced it, produces more than 900 hp using the same type of fuel.

Although some turbochargers do emit a high frequency whine, these are the units with vaned diffuser compressors. Modern designs of small turbochargers almost exclusively have vaneless compressors. The turbochargers on the Oldsmobile Jetfire and the Corvair Spyder were inaudible.

The reliability of turbochargers is well known in the trucking and construction industry where many turbocharged diesel engines are used successfully. In the antidetonant system used on the Oldsmobile Jetfire, a safety system was incorporated to limit boost if the ADI system ran out of fluid or failed to function.

Although our dynamometer work has been with one size engine only, and included no car testing, we feel sufficient merit has been shown to initiate a car test phase for demonstrating the benefits.

Very truly yours,

AIRESEARCH INDUSTRIAL DIVISION

C. E. McInerney

Charles E. McInerney
Automotive Engineering Specialist

CEM/mfs

cc: Mr. Cline Frasier, DOT
Mr. Mike Rachlin, Garrett Sales, Washington D.C.
Mr. Parker Bartlett, Garrett Corporation

Attach.

Environmental Activities Staff
General Motors Corporation
General Motors Technical Center
Warren, Michigan 48090

May 6, 1974

Cline W. Frasier
Manager, Special Project
Office for Energy and Environmental Projects
Transportation Systems Center
Kendall Square
Cambridge, Massachusetts 02142

Dear Cline:

Pursuant to our discussion, we have examined in some detail the SwRI draft report entitled "A Study of Technological Improvements to Automobile Fuel Consumption". I had asked two different Staffs to examine the document for their comments and I am including their comments as I received them as the easiest way to handle them.

From one of the Staff activities I received the following comments:

> Our major comments in the area of engines are as follows:
>
> Lean Engines (homogeneous and stratified) - They seem to have an inadequate grasp of pollutant formation and control in lean combustion. They do not appear to understand EGR. They place the open-chamber stratified charge engine in a much more favorable light than we think it deserves from published information, but they admittedly have more experience with the open-chamber SCE than GM has.
>
> Turbocharging - Our reviewer's ratings of the SwRI assessment of fuel economy prospects in turbocharged engines (both gasoline and diesel) range from "reasonable" to "optimistic", with the majority holding the latter opinion. Up-to-date experience with turbocharging is not extensive at GMR (although probably greater than at SwRI). Our judgments here will be more definitive as additional experience is accumulated. Certainly their concern about knock in the turbocharged gasoline engine is appropriate.

Diesel - SwRI realistically cites potential problems with particulates and odor, then forges ahead with no sure cures in sight. Their fuel economy projections seem unrealistically optimistic.

Their whole approach to estimating vehicle fuel economy seems overly simplistic and leads to extremely optimistic expectations. In many instances we think their attitudes on the constraints imposed by emissions fall into the same category. Economy estimates can be no more realistic than the guesses they made to provide input data, of course. Although we doubt that their projected gains in fuel economy will be realized in practice, I see little to gain from additional discussions with SwRI on this topic. The only consequences I foresee from such a meeting are arguments about appropriate input assumptions.

The comments I received from the other Staff activity are as follows:

1. Fuel economy improvements should be expressed as percent decrease in fuel consumption.
2. Present technology does not permit construction of a diesel engine powered car with performance equal to a present-day reference car but lighter in weight.
3. Present technology does not permit construction of a cylinder injected stratified charge engine powered car with performance equal to the reference car but lighter in weight.
4. Present technology does not permit achieving low levels of HC emission with the cylinder injected stratified charge engine while still maintaining a sizable fuel economy advantage.
5. Present fuel economy analysis techniques will not provide reliable fuel economy penalty for emission controls, either by applying a fixed percentage loss, or by synthesizing a brake specific fuel consumption engine map.

Comments 2, 3, 4, and 5 are not of a constructive nature. For these comments I can only recommend that the authors point out the "programmed inventions" required to accomplish those goals that are outside of present technology.

Also, the hazards should be noted regarding estimates of fuel economy penalties assigned for emission controls. The following offers some elaboration on the above comments:

On page one of the Introduction the authors state that their primary objective was to reduce fuel consumption by at least 30%. However, through the report they used the larger numbers resulting from comparisons based on percent increase in miles per gallon. In view of the objective, it would be more appropriate to make all comparisons based on percent decrease in fuel consumption.

In the report Summary the following potential individual improvements were discussed:

- Turbocharging
- Variable displacement
- Reduction in engine friction
- Lean mixture engine
- Intake port fuel injection
- Stratified charge cylinder injected engine
- Diesel engine
- Drive trains
  - Lock-up clutch
  - Manual transmission
  - Overdrive
  - Continuously variable
- Tires
- Aerodynamics
- Weight
- Air conditioning
- Cooling system

The most promising of these individual improvements were combined in three different synthesized vehicle designs:

- Conventional spark ignition engine
- Stratified charge cylinder injected engine
- Turbocharged diesel engine

It was specified that these synthesized vehicles must meet the 1976 interim grams/mile emission standards of 0.41 HC, 3.4 CO, and 2.0 NO_x. Fuel economy was calculated using an arbitrary mix of one acceleration rate, cruise speeds in 10 mph increments from 20 through 70 mph, and one fuel rate for idle and deceleration. Fuel consumption values were determined from a map of engine brake specific consumption plotted on torque and speed coordinates.

The synthesized vehicle designs involve some design goals and fuel economy analysis techniques that are outside of present technology. A summary of these synthesized vehicles is shown on the attached chart.

First among the design goals that would require very significant breakthroughs is the construction of a diesel engine powered car that would meet reference car performance levels and be lighter in weight. The authors recognize this problem as a "primary development risk", but there is no presently known solution. This same problem applies to the direct cylinder injection stratified charge engine.

An additional design problem with the cylinder injection stratified charge engine is achieving low HC emission without a substantial reduction in the fuel economy advantage. The authors touch on this problem by suggesting a 5% loss in the fuel economy advantage if EGR is required for control of NO_x.

The fuel economy analysis technique problem involves estimating the fuel economy penalty resulting from the addition of emission controls. In our experience it has been necessary to develop the required engine hardware first. Then an engine test produces the required bsfc map from which to calculate fuel economy. Assuming that emission controls can be developed without an economy penalty, or assuming an arbitrary economy penalty is not realistic.

As I'm certain you appreciate, the draft is quite a tome and we have not attempted to make many of the minor changes which might be appropriate.

Thank you for giving us an opportunity to examine the draft before final publication.

Very truly yours,

Fred W. Bowditch
Executive Assistant
to the Vice President
Vehicle Emission Matters

FWB:rf
att.

TEXACO

PETROLEUM PRODUCTS

AUTOMOTIVE ENGINE DEVELOPMENTS

WILLIAM T. TIERNEY
PROJECT MANAGER

TEXACO INC.
P. O. BOX 509
BEACON, NEW YORK 12508
TEL. (AREA 914) 831-3400

April 22, 1974

Mr. Herbert H. Gould/TMP
DOT/Transportation Systems Center
Kendall Square,
Cambridge, Massachusetts 02142

Dear Mr. Gould:

As requested in Mr. C. W. Frasier's letter to me of April 3, we have reviewed the report "A Study of Technological Improvements to Automobile Fuel Consumption" with particular reference to the statements concerning stratified charge engines, and wish to offer the following comments.

Page 219, last paragraph - Change reference TCP to Texaco Controlled-Combustion System (TCCS). ((The name change from Texaco Combustion Process (TCP) was made in 1970 and has been used in all of the work discussed in this report.))

Page 222, last paragraph - On the basis of our information, the TCCS is the only stratified charge engine having a true multifuel capability. In any event this attribute cannot be assigned to all engines discussed in the report.

Page 228 - Figure 76 was based on a curve provided by Texaco*, copy attached. You will note that the hexagonal points are not stratified charge engine data but are those presented by INOUE et al of Toyota based on their pre-mixed charge engine studies.

Page 234, first paragraph, last sentence - "---stratified charge engine could satisfy the most stringent emission requirements, but the fuel economy benefits of stratified charge operation were lost in the process---." The "benefit" is not defined and it must be recognized that some stratified charge engines exhibit better basic fuel economy than their pre-mixed charge prototypes. The "loss" in fuel economy in achieving emission controls must be related to the "loss" associated with emission control of the pre-mixed charge engine. His statement as made

*Page 18, Figure D, Supporting Information to Statement by John K. McKinley, President of Texaco Inc., to the Air and Water Pollution Subcommittee of the Senate Public Works Committee, June 26, 1973.

in the report implies that the fuel economy of stratified charge engines is lost in emission control such that it has no advantage over the pre-mixed charge engine when both are adjusted to meet the same emission standards.

Your letter did not request that the report draft be returned to you. We will retain it in our file pending further advice. It will not be distributed or discussed outside of the group of those who have contributed to the foregoing editorial comments. We appreciate your having made this report available to us. If you wish to discuss any of our comments, please do not hesitate to contact me.

Very truly yours,

W. T. Tierney

W. T. TIERNEY

WTT-lmm
Attach.

Tracor Sciences & Systems

Tracor, Inc.
6500 Tracor Lane
Austin, Texas 78721
Telephone 512 926 2800

30 April 1974

Mr. Herbert H. Gould
Department of Transportation
Transportation Systems Center
55 Broadway
Cambridge, Massachusetts 02142

Dear Mr. Gould:

On the attached sheets are listed our comments to Section XVII, "Drive Trains," from the report by Southwest Research Institute, "A Study of Technological Improvements to Automotive Fuel Consumption," as requested by Mr. Cline Frasier in his letter of 3 April.

In reference to the last item on this listing, an article which was printed in the SAE Transactions, Volume 61, dated 1953, it should be noted that this was written over 20 years ago and nothing has been done to date. The enclosed graphs show data that were originally taken from test cars at Curtiss-Wright in 1961. These demonstrated a traction CVT was practical; but again, nothing has been done by the automobile makers to date.

Sincerely,

James H. Kraus
Project Engineer

JHK:am

Enclosures

Copy to Mr. Cline W. Frasier

COMMENTS TO SECTION XVII, "DRIVE TRAINS"
FROM THE REPORT BY
SOUTHWEST RESEARCH INSTITUTE

"A Study of Technological Improvements to Automotive Fuel Consumption"

Page 275 - bottom of page: The word friction should be changed to traction. Friction refers to sliding where traction refers to power transfer through rolling contacts as in the wheels of a car.

Page 276 - second line: The word friction should be traction, as above.

Page 278: The graph is fine but does not show the power curve of a continuously variable transmission (CVT). Such a curve would come up the full reduction ratio curve to maximum power, then go straight across to the point where maximum power intersects the road load curve. The available power for acceleration with a CVT is always greater than or equal to the power available from a shifted transmission.

Page 279: Same as above.

Page 282 - end of first paragraph: Add: A CVT can adjust to provide the optimum drive train ratio under all conditions and, consequently, can provide equal performance from the smallest sized engine. Fuel economy is increased by both the reduced engine size and the increased loading of that engine during normal operations.

Page 284: The graph shows curves 6, 7, and 8 for a CVD transmission straddling an optimum fuel economy curve (not shown). The CVT can indeed follow the plotted curves, but with proper controls, it can also follow the optimum curve.

Page 285 - Table 26: The author shows an "optimum drive train" with a smaller engine but does not show a smaller engine for the CVT. He has provided no performance comparison. The CVT-equipped vehicle would show equal performance and significantly greater fuel economy compared to the "optimum drive train" with an even smaller engine. Each transmission should have an engine sized for equal performance. Typical ratio range for a traction CVT runs from about 5:1 to 0.65:1 for an overall of about 7.6:1. While this overall could be extended to about 9:1, little, if any, additional performance or fuel economy is gained.

Page 286 - Table 27: Same as above. Real fuel economy improvements are not shown for the CVT because no performance criteria were set. With the same engine, the CVT-equipped car will greatly outperform its counterpart.

Page 286 - second line from end: Delete the words "relatively major." The changes required to harden an engine sufficiently for the loading from a CVT are not considered major. Most small European engines are capable of this type of loading. The VW engine, even though air cooled, can be run at full throttle virtually continuously.

Page 291 - The author should consider automatically modulated clutches. These are presently used successfully in industrial applications and in some trucks. The primary problem with all fluid couplings and torque converters is the required 2:1 speed ratio to go from stall to lockup. This prevents the engine from being operated at below 16-1800 rpm for low-to-medium speed highway cruise even though maximum fuel economy is obtained there.

Page 293 - line 6: Change the word friction to traction as discussed previously.

Page 294 - Table 28: Change the words friction CVD to traction CVT.

Page 295 - Paragraph 5. Safety: A CVT can provide equal or better 50-70 mph passing ability with a smaller engine than with the present conventional transmission. This would both reduce top speed for safety and improve fuel economy. From the graph on Page 278, a 125 hp engine with a CVT would provide better 50-70 mph acceleration than the 160 hp engine with a 3:1 drive train ratio; top speed is cut from 110 mph to about 102 mph.

Page 298A - Calculations: The author has not entered performance into his equation nor has he adjusted the relative engine sizes to equal performance. It is not realistic to compare fuel economy for muscle cars and normal family sedans. If a potential buyer is satisfied with the performance of a standard sedan, he should be shown the added fuel economy of a different drive train in the same car with the same performance.

Page 298A - Table 27: The author has failed to adjust his baseline vehicle to the latest emission standards. Therefore, all comparisons are low and even the simple lock-up clutch which does improve fuel economy with no effect on emissions shows a negative effect.

Page 299 - Paragraph 7. Noise: A traction CVT by itself is extremely quiet and can significantly lower engine noise at highway speeds by allowing the engine to operate at greatly reduced speed. The Tracor Pinto test car runs the engine at about 1800 rpm at 60 mph.

Page 299 - Paragraph 8. Performance: The engine must operate at maximum power for maximum performance, not at maximum torque. The transmission must accept that power, provide the correct torque multiplication, and deliver that power to the drive shaft at the correct instantaneous speed. Maximum thrust is generated by maximum wheel torque at the correct wheel speed (i.e., at maximum power).

Page 302 - References: The author should reference an article entitled "Engine-Transmission Relationship for Higher Efficiency" by D. F. Caris and R. A. Richardson which was printed in the SAE Transactions, Volume 61, dated 1953. This article concludes:

"High-Compression--Ideal Transmission System

"A summary of the gains in economy which are possible with a combination of high-compression engines and ideal transmissions, shows the incentive for further intensive work. This paper has shown how a gain of from 25 to 35% is easily possible with an ideal transmission. It has also been shown that large gains of 25 to 35% are possible with engines of 12/1 compression ratio. By obtaining the advantage of gains from both high-compression engine and ideal transmission developments through further research, a total saving of 45 to 60% could be made.

"It seems entirely possible, therefore, to reduce gasoline consumption by half without a sacrifice in car size, performance, or roominess. To obtain a 50% increase in the present miles per gallon with normal driving is indeed an incentive for automotive engineers to take advantage of the potentials in the high-compression engine and the ideal transmission.

"Progressive industry has always had a goal in the future, set by the research of today. This study presents such a goal as a challenge for future development.

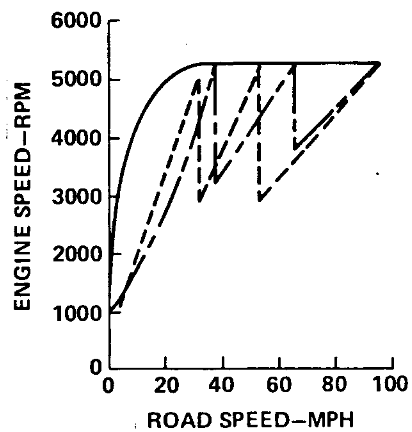
"When the goal is reached, motorists will go half again as far on a tank of gasoline. This will permit valuable oil resources to be used more effectively and more efficiently. If oil wells are considered sources of miles of transportation, each well will produce 50% more than the present mileage. Where 20 mpg in the family car is now considered, 30 will be obtained in the future. The savings, made up of the total of each motorist, will reach into billions of dollars per year.

"Automotive engineers will have performed one of the basic jobs of engineering--to make the most efficient use of natural resources."

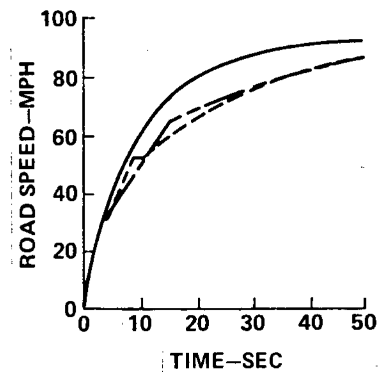
comparative application...

• Standard Personal Vehicle

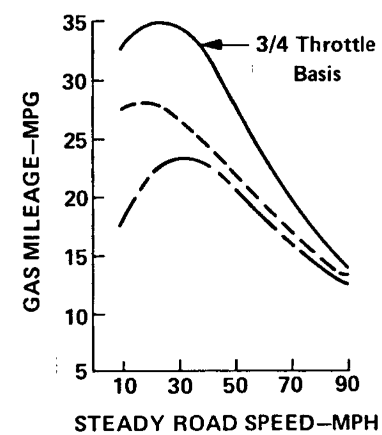
- 3000-Lb. Vehicle
- 100 HP at 5250 RPM Engine



● SMOOTH ACCELERATION



● QUICKER ACCELERATION



● IMPROVED GAS MILEAGE

———— TOROID TRACTION TRANSMISSION 6.25:1 OVERALL RATIO
- - - - - 3 SPEED MANUAL TRANSMISSION 1, 1.75, 3.0:1
—— – —— 3 SPEED AUTOMATIC 1, 1.46, 2.45:1 +2.16 FOR TORQUE CONVERTER

A6-184-92
M 1/14/72

APPENDIX I

Report of Inventions

REPORT OF INVENTIONS

A diligent review of the work performed under this contract has revealed no new innovation, discovery, improvement or invention.